Theme 2. Ecosystem Pressures and Limits

Track 2a. Biodiversity and Ecosystem Challenges

Track 2b. Food Security and Sustainable Agriculture

Track 2c. Resource Exhaustion

Track 2a. Biodiversity and Ecosystem Challenges

Session 2a-02

Session 2a-03

Session 2a-06

Session 2a-08

Private protected areas in Europe: what role for public organizations?

Giulia Iannuzzi (1), Rui Ferreira dos Santos (2), João Mourato (3)

(1) CENSE Center for Environmental and Sustainability Research, Faculty of Sciences and Technology, Universidade NOVA de Lisboa, Portugal, g.iannuzzi@campus.fct.unl.pt

(2) CENSE Center for Environmental and Sustainability Research, Faculty of Sciences and Technology, Universidade NOVA de Lisboa, Portugal, rfs@fct.unl.pt

(3) Instituto de Ciências Sociais, Universidade de Lisboa, Portugal, joao.mourato@ics.ulisboa.pt

Abstract

Private protected areas (PPAs) are seen as a promising approach to enhance nature conservation efforts and extend protected areas networks. Prevailing arguments for their use as a policy tool call upon political constraints and the scarcity of public funds directed to the creation and maintenance of additional state-run natural reserves. Being voluntary instruments, PPAs are expected to reduce social controversies usually caused by top-down approaches due to restrictions on land uses. On the other hand, scholars have pointed out the arising concerns regarding the loss of government authority in preserving public interest in relation to landscapes and biodiversity protection.

In PPAs, public actors do not necessarily impose conservation objectives on private lands; instead, NGOs, private landowners or companies voluntarily limit human activities and resources uses negatively impacting biodiversity, and eventually implement active measures to promote nature conservation. However, public actors involvement, through the removal of constraints and the creation of incentives is a key factor that calls for a more in-depth research, due to its impact on: the geographical distribution of PPAs and their contribution to high value ecosystems and threatened species coverage, PPAs long term financial security and their long term effective protection. Thus, there is a need to investigate their distinct designs, focusing on governance arrangements, in order to improve our understanding on opportunities and challenges in promoting PPAs as a complementary policy tool for nature conservation.

While protected areas owned and managed by private actors are well-established practices in the United States, Australia, Costa Rica and other Latin-American countries, the promotion of private involvement to voluntarily integrate private land into conservation planning is at its embryonic stage in European countries. According to the Common Database on Designated Areas (maintained by the European Environmental Agency), that holds information about protected areas and national legislative instruments in European countries, the countries that both formally recognize PPAs as a distinct governance typology within national protected area networks, and have a list of officially recognized PPAs: Finland, France, the Netherlands and Portugal.

Drawing on existing research and based on the study of national legal and regulatory frameworks, we propose a preliminary mapping of the different existing governance models for PPAs as recognized de jure in those four countries. We especially address the typology of private actors involved, and we draw on two intertwined dimensions of public actors intervention: their role as facilitators of private actors engagement and their role as regulator. The degree of public actors intervention as enablers of private actors involvement deals, for example, with PPAs legal recognition and their inclusion in public financing schemes. While the role of regulator is related to the definition of criteria for PPAs recognition and the implementation of monitoring actions to ensure the protection of environmental values and long-term commitment for conservation.

This is an initial step towards a wider and more systematic categorization of governance models for PPAs that is of critical importance in order to discuss deeply the successful balance between regulatory approaches and voluntary systems in nature conservation strategies.

Using social media to assess cultural ecosystem services

Pedro Clemente, Marta Calvache, Rui Santos, and Paula Antunes

Abstract

The concept of Ecosystem Services (ES) has been increasingly attracting the interest of researchers and policy-makers. The development of spatial models to measure and value their distribution and diversity across the territory, becomes increasingly important to effectively implement and mainstream the ES concept in existing planning and policy tools.

Cultural Ecosystem Services (CES) are nowadays recognized as a main pillar in existing conceptual frameworks for ES classification. CES definitions and classifications vary across different frameworks, but generally CES embrace direct benefits people obtain from ecosystems, such as recreation or aesthetic experience, as well as other benefits resulting from the interaction of natural and human/cultural capital, such as cultural heritage.

In this presentation we explore the use of social media photos to address the spatial distribution of people preferences for CES, using as example a case study in Southwest Alentejo, Portugal. The ultimate goal of this research is to promote the integration of CES into regional planning by identifying the existing CES, mapping their hotspots, and assessing the variables explaining their spatial distribution.

The Sudoeste Alentejano and Costa Vicentina Natural Park (PNSACV) was created in 1995. Located in the Southwestern corner of Portugal, this protected area covers a coastal strip composed of 60.567 ha of land and 28.858 ha of marine waters. 1378 geo-tagged digital images from the Park posted in the Flickr web platform between 2004 and 2015 were analyzed and classified according to land uses and CES represented in the photos. A tailored CES classification system was defined for this purpose.

The aesthetic values were the main CES identified, followed by recreation and cultural heritage. Landscape, a subcategory of aesthetic values, was the most commonly identified CES and Hiking, the main CES within recreational CES. Sea and cliff areas were the most present land uses in the photos. CES spatial distribution can be explained by a set of biophysical and infrastructural descriptors, such as accessibility or the proximity to the ocean.

This methodology has proven useful to map CES at this scale, providing reliable maps of CES hotspots, of their diversity and spatial patterns in the territory. Working with up to date and easily accessible flow of data also makes this method very appealing. However, it also embodies some challenges that need to be considered, such as an overrepresentation of aesthetic values and a classification bias from the analysts classifying the photos.

Keywords: Cultural Ecosystem Services; social media; territorial planning

What does it take to make integrated ecosystem service valuation feasible in urban environmental decisions? Real life impact of value pluralism

Katharina Janja Sevecke
ESCP Europe Business School Berlin, Heubnerweg 8-10, 14059 Berlin, Germany, ksevecke@escpeurope.eu

Abstract

The low use of ecosystem service valuation (ESV) in environmental policy and management calls for a change of ESV research. In order to spread from academia to practice, the development of ESV methodologies and tools should incorporate input from environmental decision-makers (Fisher et al., 2009, Liu et al., 2010). The current research progress on integrated ESV methodologies for decision-making is still at an early stage (Boeraeve et al., 2015) and can thus benefit from this attempt. Acknowledging value pluralism of ecosystem services, integrated ESV does not just independently asses biophysical, socio-cultural and economic values but should also consider associated trade-offs between these value-domains (Gómez-Baggethun et al., 2014, Martín-López et al., 2014). In order to ensure integrated ESV methodologies are likely to be used in practice, it is important to understand the underlying interests, beliefs and potential applications of value pluralism in environmental decision-making. However, a state-of-the-art analysis in an urban context is missing. Given the complexity of urban ecosystems and associated stakeholders in limited space, integrated ESV promises to be particularly appropriate to reflect the benefits of urban ecosystem services that contribute to urban resilience and human-wellbeing (Gómez-Baggethun and Barton, 2013, McPhearson et al., 2015). Based on semi-structured interviews of urban environmental decision-makers in Germany, this paper investigates the practical perspective on value pluralism and integrated ESV. One aim of this study is to shed light on decision-makers knowledge and acceptance of different ecosystem values. A further step assesses the practice of independent inclusion of different valuation metrics into decisions to date. The scope is finally broadened to a *truly* integrated ESV to learn if the potential of the approach for urban ecosystem policy is recognized by and relevant for environmental decision-makers. On the basis of our results we identify potential implementation drawbacks of integrated ESV in practice as well as drivers to increase its application in urban environmental decision-making. The results mark an important starting point for the ongoing research of the construction of integrated ESV frameworks for urban ecosystem services.

Keywords: value pluralism, integrated valuation, urban ecosystem services, environmental decision-making

References

BOERAEVE, F., DENDONCKER, N., JACOBS, S., GÓMEZ-BAGGETHUN, E. & DUFRÊNE, M. 2015. Erratum to: How (not) to perform ecosystem service valuations: pricing gorillas in the mist. Biodiversity and Conservation, 24, 427-427.

FISHER, B., TURNER, R. K. & MORLING, P. 2009. Defining and classifying ecosystem services for decision making. Ecological Economics, 68, 643-653.

GÓMEZ-BAGGETHUN, E. & BARTON, D. N. 2013. Classifying and valuing ecosystem services for urban planning. Ecological Economics, 86, 235-245.

GÓMEZ-BAGGETHUN, E., MARTÍN-LÓPEZ, B., BARTON, D., BRAAT, L., KELEMEN, E., GARCÍA-LLORENTE, M., SAARIKOSKI, H., VAN DEN BERGH, J., ARIAS, P. & BERRY, P. 2014. State-of-the-art report on integrated valuation of ecosystem services. European Commission, EU FP7 OpenNESS Project Deliverable, 4.

LIU, S., COSTANZA, R., FARBER, S. & TROY, A. 2010. Valuing ecosystem services: theory, practice, and the need for a transdisciplinary synthesis. Annals of the New York Academy of Sciences, 1185, 54-78.

MARTÍN-LÓPEZ, B., GÓMEZ-BAGGETHUN, E., GARCÍA-LLORENTE, M. & MONTES, C. 2014. Trade-offs across value-domains in ecosystem services assessment. Ecological Indicators, 37, Part A, 220-228.

MCPHEARSON, T., ANDERSSON, E., ELMQVIST, T. & FRANTZESKAKI, N. 2015. Resilience of and through urban ecosystem services. Ecosystem Services, 12, 152-156.

How are ecosystem services integrated in strategic environmental assessment? The case of small islands

Alexandra Polido[1], André Mascarenhas[1,2], Tomás B. Ramos[1], Elsa João[3]

[1] CENSE – Center for Environmental and Sustainability Research, Departamento de Ciências e Engenharia do Ambiente, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Portugal

[2] Lab of Landscape Ecology, Department of Geography, Humboldt-Universität zu Berlin, Germany

[3] Department of Civil and Environmental Engineering, University of Strathclyde, Level 5, James Weir Building, 75 Montrose Street, Glasgow G1 1XJ, Scotland, UK

Abstract

Strategic Environmental Assessment is a systematic process for evaluating the environmental consequences of proposed policies, plans or programmes, alongside economic and social considerations. Therefore it can support sustainable decision making. Additionally, ecosystem services (ES) – the benefits people obtain from nature – can be regarded as sustainability boundary objects. Hence, integrating ES in SEA may bring additional benefits to SEA practice. On the other hand, SEA is context-specific. In the case of small islands, due to the specific characteristics of these territories (*e.g.* specificities of insular ecosystems, unique biodiversity, limited resources), there are several challenges to tackle related to the SEA process, including how to consider biodiversity and ES. However, there is a lack of research on the integration of biodiversity and ES in SEA, specifically for small islands. This research explores how biodiversity and ES have been integrated into SEA in small islands' planning processes. It covers aspects like which ES are addressed and existing relations, for example between ES and SEA sustainability issues (topics such as biodiversity, soil or water). This was achieved through a multi-method approach comprised of case study research, grounded theory and content analysis, targeting a selected set of SEA reports from the Azores (Portugal) and Orkney (Scotland) islands. Through this approach the main sustainability issues (aggregated themes, including biodiversity) for each archipelago were identified and related to ES, which were structured according to the Common International Classification of Ecosystem Services – CICES. Differences in these relationships were observed between the Azores and Orkney islands. Some evidence of a transition towards ES-driven SEA was found, although accompanied by the need for improved knowledge, skills and data to conduct comprehensive assessments of effects on ES. The profile of the team conducting SEA also seems to play a role on ES integration. This research provides insights that support an enhanced consideration of biodiversity and ES in SEA practice. It also contributes to the aim of the track of investigating how threats to ecological integrity, biodiversity conservation and healthy ecosystems can be managed to simultaneously support sustainable development in a variety of contexts, looking at the specific context of small islands.

Keywords: Ecosystem Services; Strategic Environmental Assessment; small islands; Azores; Orkney

Integrating Adaptive Governance and Ecosystem Services Evaluation Methods: A Methodology for Steering Regional Development towards Sustainability

Xiaohui Ding[1], Chen Zhou[2], Xiaoling Zhang[3], Volker Mauerhofer[4], Weizhou Zhong[5], Jinfeng Wang[6], Yilan Liao[7]

[1] Northwest Institute of Historical Environmental and Socio-Economic Development, Shaanxi Normal University, 199, Changannan Road, Xi'an, China, xhding@snnu.edu.cn

[2,5] School of Finance and Economics, Xi'an Jiaotong University, 74, Yantaxi Road, Xi'an, China, young5206@stu.xjtu.edu.cn, weizhou@xjtu.edu.cn

[3] Department of Public Policy, City University of Hong Kong, Tat Chee Avenue, Kowloon, xiaoling.zhang@cityu.edu.hk

[4] Department of Conservation Biology, Vegetation and Landscape Ecology, Faculty Centre for Biodiversity, Faculty of Life Sciences, University of Vienna, Rennweg 14, 1030 Vienna, Austria, volker.mauerhofer@gmx.at

[6,7] State Key Laboratory of Resources and Environmental Information System, Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing, China, liaoyl@lreis.ac.cn, wangjf@lreis.ac.cn

Abstract

Endowed with distinctive ecosystems and abundant biodiversity, the aim of regional governance in developing countries, particularly in environmental sensitive areas (ESAs), is to divert regional development towards regenerative and sustainable fashion. Given the context of under-developed economies, unsound political regimes and poor governance capacity in these regions, achieving this task is without a doubt a daunting task. In order to settle the incompatibility between economic development and ecosystem conservation, and reveal the complex and interlocked nature of regional governance regime, we introduced an ecosystem services value (ESV) based adaptive governance model (AGM), to identify deficiencies and failures of the existing institutional systems and establish innovative arenas and transition agendas for facilitating regional governance regime reframing. According to the ESV based AGM, tailored approaches for diverting regional governance regime can be formulated in a circular process. A case study was conducted in a typical ESA – the Water Source Area (WSA) of the Middle Route (MR) Project of the South-North Water Diversion (SNWD) Project in China, for demonstrating the implementation of the ESV based AGM. Compared with traditional proposals for administrative transition, the methodology proposed in this study is neither prescriptive nor directive, but an approach through influencing the direction and speed of transition through a series of steering and coordination mechanism. Therefore, the ESV based AGM as well as approaches for implementing this model is suitable for regions, with the same environmental endowment, or encountering the similar daunting tasks as ESAs in developing countries, to innovate and upgrade their regional governance regimes and divert regional development path towards sustainability.

Keywords: ecosystem services value, the Water Source Area of the Middle Route Project of the South-North Water Diversion Project, adaptive governance model, sustainable development

1. Introduction

Endowed with distinctive natural ecosystems and abundant biodiversity, such regions in developing countries are often termed as Environmentally Sensitive Areas (ESAs), sanctioned by regional or national authorities (Haigh, 1990; Grodzinska-Jurczak & Cent, 2011). Compared with developed countries, ESAs in developing countries are often facing the "regional governance dilemma", that on one hand, local governments of these regions are often expected to maintain the functionality and integrity of local ecosystems, on the other hand, they are demanded by the local communities as well as their superior administrative hierarchies to revitalize the local economy and improves people's welfare level. Such dilemma is intrinsically rooted in the less developed status of these regions, for instance under-developed economies, unsound political regimes, and poor governance capacity (UN, 2012; Puppim de Oliveira *et al*., 2013).

With the degradation of ecosystem services increasing at an alarming rate (Millennium Ecosystem Assessment, 2005), there is an urgent need for ESAs in developing countries to divert their regional development pattern from purely environmental retaining towards comprehensively sustainable development. That is, the growth of regional economy and improvement of social welfare in developing countries, especially ESAs, are necessarily decoupled from environmental degradation, and retaining the quality and quantity of ecosystem services through gradually shifting regional socio-ecological system (SES) towards a self-restraint and sustainable fashion.

Attempts are made to nudge or "push" such regions towards more sustainable futures - for instance, the United Nation's "Millennium Development Goals (MDGs) of 2000" (UN, 2014), succeeded by "Sustainable Development Goals (SDGs)" (Loewe & Rippin, 2015), pledge governments at national and sub-national levels in developing countries to formulate policies and frameworks to "eradicate extreme poverty and hunger" and to "ensure environmental sustainability". Meanwhile, measurements, for "pulling" regions in developing countries, especially ESAs, are also established to deorbiting the regional development from former low orbit – sacrifice environment for economic development, towards sustainable development through innovating and reframing their governance regime, pledged by local communities as well as superior administrative hierarchies. After decades of endeavours on improving regional sustainability worldwide, a series of methods were developed for assessing and therefore improving reconciliation of triple-bottom-line of regional development (Rees & Wackernagel, 1996; Hammond, 2004; Sciubba & Ulgiati, 2005; Munda, 2006; Gasparatos et al., 2008).

Among which the method of ecosystem services value (ESV) evaluation (Costanza et al., 1997; Daily, 1997; MA, 2003; Curtis, 2004; Peng et al., 2005; Nuñez et al., 2006) and theory of adaptive governance (Folke et al., 2005; Brunner et al., 2006; Armitage et al., 2007; Huitema et al., 2009) provide promising instruments for resolving the "regional governance dilemma" and diverting regional development pattern towards sustainability of ESAs in developing countries. In this research, we introduced an integrated governance model for guiding innovation and reframing of the regional governance regime, through combining the principle of adaptive governance and the method of ecosystem services value (ESV) evaluation, and performed a case study in the Water Source Area (WSA) of the Middle Route (MR) Project of the South-North Water Diversion (SNWD) Project in China (in the following "WSA of the MR project" or "the research area"), for demonstrating the implementation of this model.

2. Methods

2.1 Research area

The WSA of the MR project (31°31′N to 34°25′N, 105°31′E to 112°2′E) corresponds to the upstream region of the Han River (a tributary of the Yangtze River) and the Dangjiangkou Reservoir, and comprises 40 counties (Fig.1). Dominantly located in the Hanjiang and Danjiang river basins, this region received a per capita water supply of 3,741 m^3 in 2010, which was approximately 170% of the national average level (2,200 m^3 water per capital).

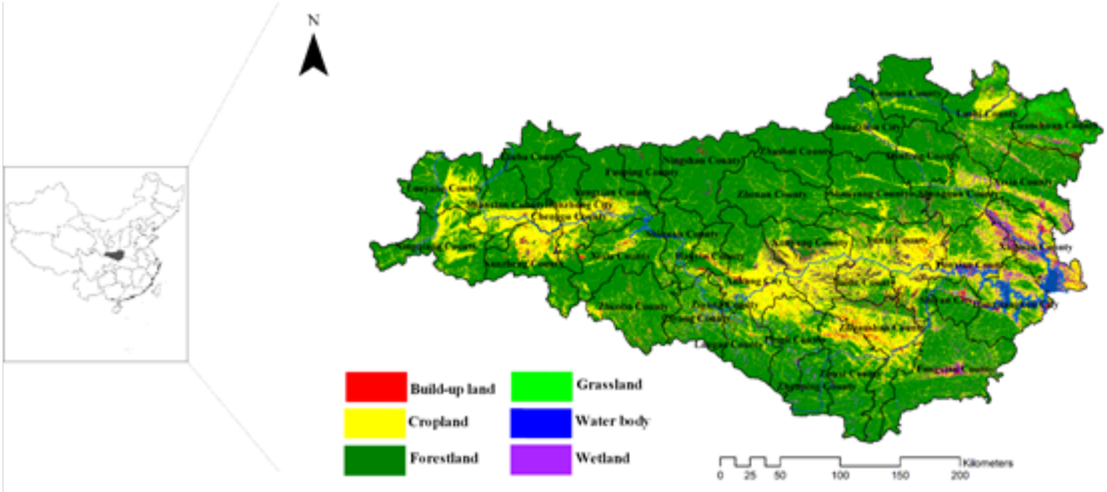


Figure 1. Location of the research area.

Located between the North Temperate Zone and the Subtropical Climate Zone, the research area enjoys four distinct seasons, a wet climate, and a long frost-free period (Table 1). In the research area, mountainous terrain accounts for 79%, hilly terrain for 18%, and river valleys for only 3%. Given such unique geographical and climatic conditions, the ecosystems here are extremely fragile (53.8% of the research area has undergone severe soil erosion according to the results of the 2nd National Land Resource Investigation in China) (Kong, 2014).

Table 1. Environmental conditions in the research area.

Province	Municipality/County (County-level City, District)	Climate	Annual Mean Sunshine (hours)	Annual Mean Temperature (°C)	Annual Precipitation (mm)
	Hanzhong	Transition Zone between North Temperate Zone and Subtropical Zone	1591	14	800~1000
Shaanxi	Ankang	Subtropical-Continental Monsoon Climate	1496~1836	15 (except Ningshan and Zhenping County with a temperature of 12°C)	750~1100
	Shangluo	Transition Zone between North Temperate Zone and Subtropical Zone	1860~2130	14	710~930
Hubei	Shiyan	North Subtropical-Continental Monsoon Climate	1655~1958	16	More than 800
	Lushi County (Sanmenxia)	Transition Zone between North Temperate Zone and Subtropical Zone	1860~2130	14	710~930
	Luanchuan County (Luoyang)	Transition Zone between North Temperate Zone and Subtropical Zone	1860~2130	14	710~930
Henan	Xixia County, (Nanyang) Zhechuan County (Nanyang)	Transition Zone between North Temperate Zone and Subtropical Zone North Subtropical-Continental Monsoon Climate	1860~2130 1655~1958	14 16	710~930 More than 800

The socio-economic foundation of the research area is weak. The population in the research area was 14 million, while its per capita GDP was approximately 20% of Beijing (75,943 CNY per capital) and 21% of Tianjin (72,994 CNY per capita) (Du & Dong, 2011; Yu, 2011) in 2010. The total investment of the fixed assets of the research area was less than 35% of the amounts of Tianjin (651.14 billion CNY) or Beijing (549 billion CNY) in 2010, and the structure of local economy was locked in the low value-added, energy-extensive, and low-tech industrialized pattern.

2.2 Ecosystem service value (ESV) based adaptive governance model (AGM) for the regional institution innovation and reframing

Played an irreplaceable role in regional ecosystem services conservation, ESAs are deemed to be the demonstrating zone for tackling the "regional development dilemma" in developing countries. An integrated model – entitled the Ecosystem Service Value (ESV) based Adaptive Governance Model (AGM) (Fig. 2) was introduced for innovating and reframing regional governance system.

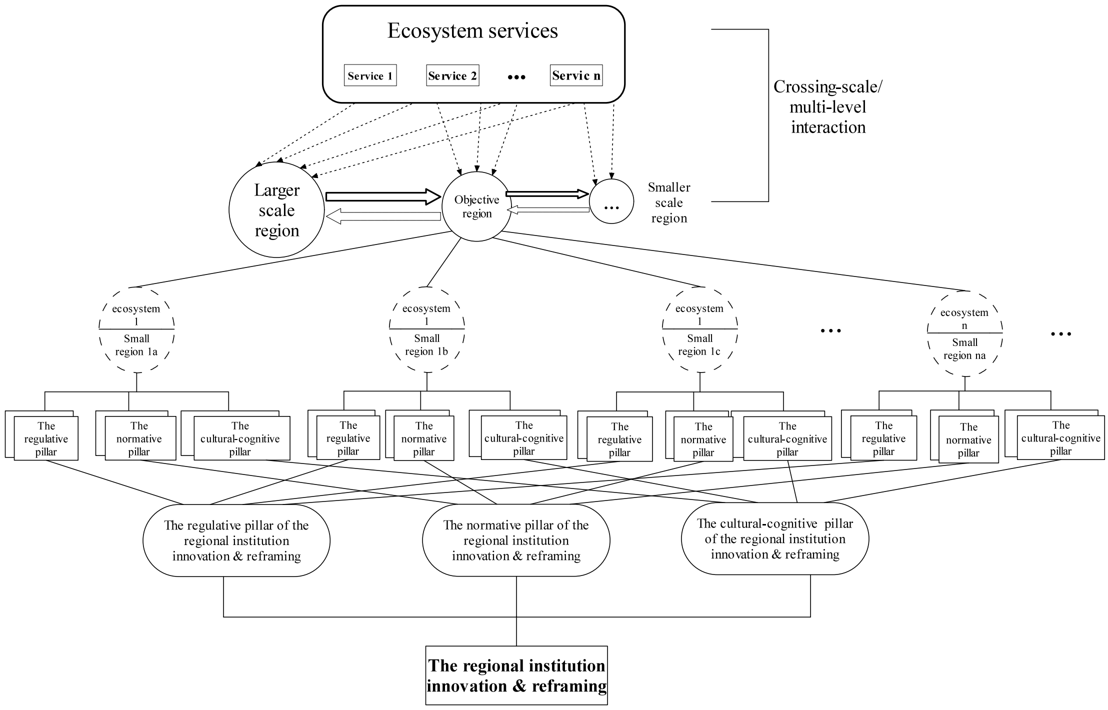


Figure 2. Ecosystem service-value (ESV) based adaptive governance model (AGM).

According to the ESV based AGM, a spectrum of regions, from larger scales – superior to the "objective region" in administrative hierarchy and with immediate concerns on ecosystem retaining and conservation, to sub-regional scales – under the juridical hierarchy of the "object region" and with the responsibility to maintain the quantity and quality of ecosystem services, are identified in the first place. Based thereon, crossing-scale/multi-level interaction analysis is performed for defining regional accountabilities at much larger scale and identifying responsibilities undertaken by sub-regions of the "object region" for performing ecosystem conservation.

Since administrative boundaries and the border of ecosystems are normally not perfectly matched, the "niche ecosystems" are thereby determined in accordance with categories as well as spatial distribution pattern of each ecosystem service function provided by the "object region". Based on the ESV changes, challenges on regional governance of each "niche ecosystems" are identified from regulative, normative, and cultural-cognitive dimensions, and the innovation arenas of regional governance regime are generated thereafter. Then, the portfolio of regional governance innovation and reframing of the "objective region" are formulated through integrating and synthesizing the innovation arenas of each "niche ecosystems".

2.3 Ecosystem services value (ESV) variation and spatial distribution pattern

The ESV variation of the research area between 2002 and 2010 was detected through integrated application of remote sensing and equivalent weighting factors of ecosystem services per hectare for the terrestrial ecosystems in China by Xie et al. (2003). Six land-use categories (forestland, cropland, wetland, water body, grassland and built-up land) were detected, among which the ESV of the built-up land set as 0. The ESV of one unit of each land-use category was assigned based on the nearest equivalent ecosystem (Table 2), and one unit of the coefficient in the scheme (Table 3) is equal to the average value of the natural food produced by one hectare of cropland per year (Xie et al., 2003). According to Wang (2011), the ESV of one equivalent weight factor in the research area is 1114.28 Yuan.

Table 2. Equivalent weighting factors of ecosystem services per hectare of China's entire terrestrial ecosystem (adopted from Xie et al., 2003).

Ecosystem Function	Forestland	Grassland	Cropland	Wetland	Water Body	Built-up Land
Gas Regulation	3.5	0.8	0.5	1.8	0	0
Climate Regulation	2.7	0.9	0.89	17.1	0.46	0
Water Supply	3.2	0.8	0.6	15.5	20.38	0.03
Soil Formation and Retention	3.9	1.95	1.46	1.71	0.01	0.02
Waste Treatment	1.31	1.31	1.64	18.18	18.18	0.01
Biodiversity Protection	3.26	1.09	0.71	2.5	2.49	0.34
Food	0.1	0.3	1	0.3	0.1	0.01
Raw Material	2.6	0.05	0.1	0.07	0.01	0
Recreation and Culture	1.28	0.04	0.01	5.55	4.34	0.01
Total	21.85	7.24	6.91	62.71	46.01	0.42

Table 3. Annual ecosystem service value per unit area of each land-use category in the research area* (CNY·ha-1·yr-1).

Ecosystem Function	Forestland	Grassland	Cropland	Wetland	Water Body	Built-up land
Gas regulation	3,900	891	557	2,006	0	0
Climate regulation	3,009	1,003	992	19,054	513	0
Water supply	3,566	891	669	17,271	22,709	0
Soil formation and retention	4,346	2,173	1,627	1,905	11	0
Waste treatment	1,460	1,460	1,827	20,258	20,258	0
Biodiversity protection	3,633	1,215	791	2,786	2,775	0
Food	111	334	1,114	334	111	0
Raw material	2,897	56	111	78	11,143	0
Recreation and culture	1,426	45	11	6,184	4,836	0
Total	2,4347	8,067	7,700	69,877	62,356	0

The ESV of each ecosystem was estimated based on their equivalent land-use categories by Eqs. (1), and the ESV of each corresponding ecosystem service function, and the total ESV of the research area were also calculated by Eqs. (2) and (3).

(1)

(2)

$$ESV = \sum_{k}\sum_{f} A_k VC_{kf} \quad (3)$$

where , and refer to the ESV of LULC category "*k*", the value of ecosystem function type "*f*" and the total ESV of the research area respectively. A_k is the area occupied by the LULC category "*k*", and VC_{kf} is the value coefficient (CNY·ha^{-1}·a^{-1}) for the LULC category "*k*" and the ecosystem service function type "*f*".

2.4 Challenges and innovation & reframing of regional governance

Along with the completion of the construction of the MR project of the SNWD project, the major challenges on the regional governance in the research area has shift to regional development transformation towards more sustainable and inclusive fashion.

To identify failures of regional governance, the prerequisite is to comprehend the status quo of the regional institution system. The spectrum of the regional governance of the research area can be grouped into three administrative levels: the supra-regional, regional, and sub-regional levels. The first two levels correspond to the central government and regional governments in the beneficiary regions (BR) of the MR project (Hebei and Henan provinces, and Beijing and Tianjin), while the sub-regional level denotes the local governments (at municipal and county-level) from the research area.

Through the crossing-scale analysis, flaws and challenges on regional governance regime can be identified from two different perspectives, namely "upward" accountability to the supra-regional level governmental hierarchies, as well as through the lens of the ESV variation in the sub-regional levels areas. Based thereon, the portfolio of regional institution innovation and reframing were identified through cross-checking the innovation arenas of the regional institution with the existing institutions issued by sub-regional level administrative authorities in the research area.

To divert regional development towards sustainable development, institutional innovation on macro-vision as well as bottom-up (micro) initiatives are necessarily involved into a practical and operational methodological framework - a meso-regime. Therefore, an adaptive institution transition model in terms of a transition circle was introduced in this research, based on the notion of the transition management (Loorbach, 2010b). As a cyclical and interactive process, this theoretical framework consists of four independent but interconnected components (Loorbach, 2004a): (1) structure the problem in question, develop a long-term vision for regional sustainability governance, and establish and organize the transition arena; (2) develop future images, from a transition agenda and derive the necessary transition paths; (3) establish and initiate transition experiments and mobilize the resulting transition networks; (4) monitor, evaluate, and learn lessons from the transition experiments and, based on these, make adjustments in the vision, agenda, and coalitions.

3. Results

3.1 Ecosystem services value (ESV) variation

The ESV in the research area has decreased from 228 billion CNY in 2002 to 222 billion CNY in 2010 (Table 4). During 2002 to 2010, the ESV of cropland, wetland and water bodies have increased significantly, with a net increase of 4, 7 and 4 billion CNY respectively. However, such increments were offset by the decrement of ESV of the forestland in the meantime by roughly 21 billion CNY. Additionally, the expansion of the built-up land also has negative contribution to the overall ESV of the research area during the same time frame.

Table 4. ESV variation ecosystems proxied by different land-use categories in the research area.

		Forestland	Grassland	Cropland	Wetland	Water Body	Build-up Land	Total
ESV 2002-2010 (10^4Yuan·yr^{-1})	2002	19,445,514	78,198	1,628,627	1,228,541	418,481	0	22,799,361
	2010	17,376,338	66,338	2,064,497	1,889,985	775,584	0	22,172,743
	(10^4 Yuan)	-2,069,176	-11,860	435,871	661,444	357,103	0	-626,619

	(%)[a]	-10.64	-15.17	26.76	53.84	85.33	0	-2.75
	(%·yr^{-1})	-1.33	-1.90	3.35	6.73	10.67	0	-0.34

From the perspective of each ecosystem, five ecosystems with positive ESV (proxied by LULC categories of forestland, grassland, wetland, cropland and waterbody) can be grouped into three types: (i) High-contribution ecosystem – wetland and water body. The areas of wetland and water bodies accounted for 2.6% and 1.4% of the total area, while ESV of these ecosystems accounted for about 8.5% and 3.5% of the overall ESV in 2010 respectively; (ii) Medium-contribution ecosystem – forestland. The proportion of the area classified as forestland (67.3%) is smaller than its contribution (78.4%) to the overall ESV in 2010; (iii) Low-contribution ecosystem – cropland and grassland. Cropland and grassland, occupied by 25.3% and 0.8% of the whole area, only contributed 9.3% and 0.3% of the overall ESV in 2010.

The rank of each ESVf based on their contributions to the overall ESV were relatively steady between 2002 to 2010 (Table 5). The overall rank of ESVf in decreasing order was soil formation and retention, water supply, gas regulation, climate regulation, biodiversity protection, waste treatment, raw material, recreation and culture, and food. The top two ESVf were crucial for retaining the quality and quantity of water resources in the research area. The top six ESVf in ranking were jointly accounted for more than 80% of the overall ESV, while ESVf of food, at the button of rank, contributed no more than 2% to the overall ESV.

Table 5. ESV of each ecosystem service functions of the research area between 2002 and 2010*.

Ecosystem Function	2002			2010			Overall Rank [b]	Tendency [c]
	ESV_f (10^4 Yuan·yr^{-1})	%[a]	Rank	ESV_f (10^4 Yuan·yr^{-1})	%	Rank		
Gas regulation	3,276,592	14.37	3	2,994,359	13.50	3	3	↓
Climate regulation	2,961,555	12.99	5	2,944,471	13.28	4	4	↓
Water supply	3,487,095	15.29	2	3,542,399	15.98	2	2	↑
Soil formation and retention	3,869,586	16.97	1	3,607,274	16.27	1	1	↓
Waste treatment	2,088,184	9.16	7	2,398,412	10.82	6	6	↑
Biodiversity protection	3,152,011	13.82	4	2,932,004	13.22	5	5	↓
Food	334,715	1.47	9	391,773	1.77	9	9	↑
Raw material	2,339,454	10.26	6	2,100,278	9.47	7	7	↓
Recreation and culture	1,290,168	5.66	8	1,261,772	5.69	8	8	↓
Total	22,799,361	100.00		22,172,743	100.00	–	–	–

*The water source area of the Middle-Route project of South-North Water Diversion project.

[a] The proportion of ESV of certain ecosystem function in the total ESV in the same year.

[b] Overall rank refers to the order of the averaging ESV of each ecosystem services function in 2002 and 2010.

[c] An upward arrow "↑" denotes an increasing contribution, a downward arrow "↓" denotes a decreasing contribution, and a dash "−" indicates no changes.

3.2 Spatial distribution pattern of ecosystem services values (ESV)

Apart from the southeast-central regions, ESV in the rest part of the research area has increased between 2002 and 2010 (Fig. 3). Regions with the highest ESV (over 40,000 Yuan) were generally located in the southeastern part of the research area, including the Danjiangkou Water Reservoir and some river basins in its adjacent regions. Dominantly distributed in the northern part of the research area (along the Qinling Mountain and in the southern part of the Bashan Mountain), regions covered by forestland possessed the second-highest ESV (between 20,000 and 40,000 Yuan). While regions covered by crop and the grass lands, with an ESV between 5,000 and 20,000 Yuan, were generally distributed in regions adherent to the urbanized area, on the plateaus of mountainous terrain, and in the mountain valleys. Between 2002 and 2010, the spatial distribution pattern of the urbanized regions, with the lowest ESV contribution (less than 5,000 Yuan), has transformed from concentrated in several major cities (i.e., Hanzhong, Ankang, Shiyan, etc) to scattered in several urbanized agglomerations located in the western (Hanzhong and its adjacent urbanized area), central (Ankang and its adjacent urbanized area) and eastern part (Shiyan and Dangjiangkou and their adjacent urbanized areas) of the research area.

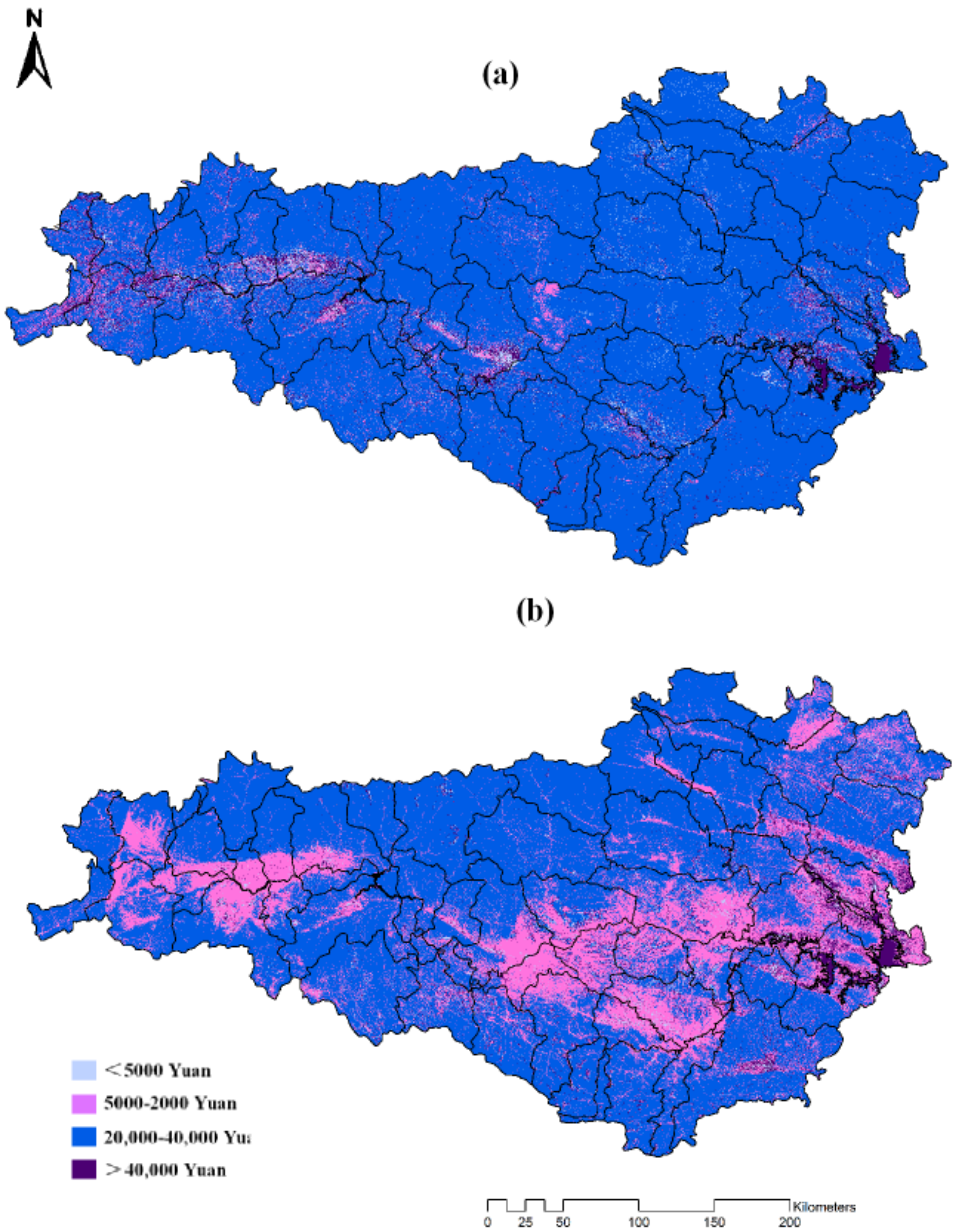


Figure 3. Spatial distribution pattern of ecosystems services value (ESV) of the research area between 2002 and 2010.

Increment of the built-up land was dominantly converted from the forestland (69.1%), which were scattered distributed and can hardly be identified in Fig. 4a. Built-up lands that converted from wetland were distributed in the eastern and western parts of the research area, among which the two largest concentrations were situated at Zhechuan County and Zhushan County. While built-up lands that converted from the cropland were concentrated in Ankang City, Hanyin County, Xixiang County and Yangxian County along the Hanjiang River. While the largest region with built-up land that converted from grassland was located in Xunyang County.

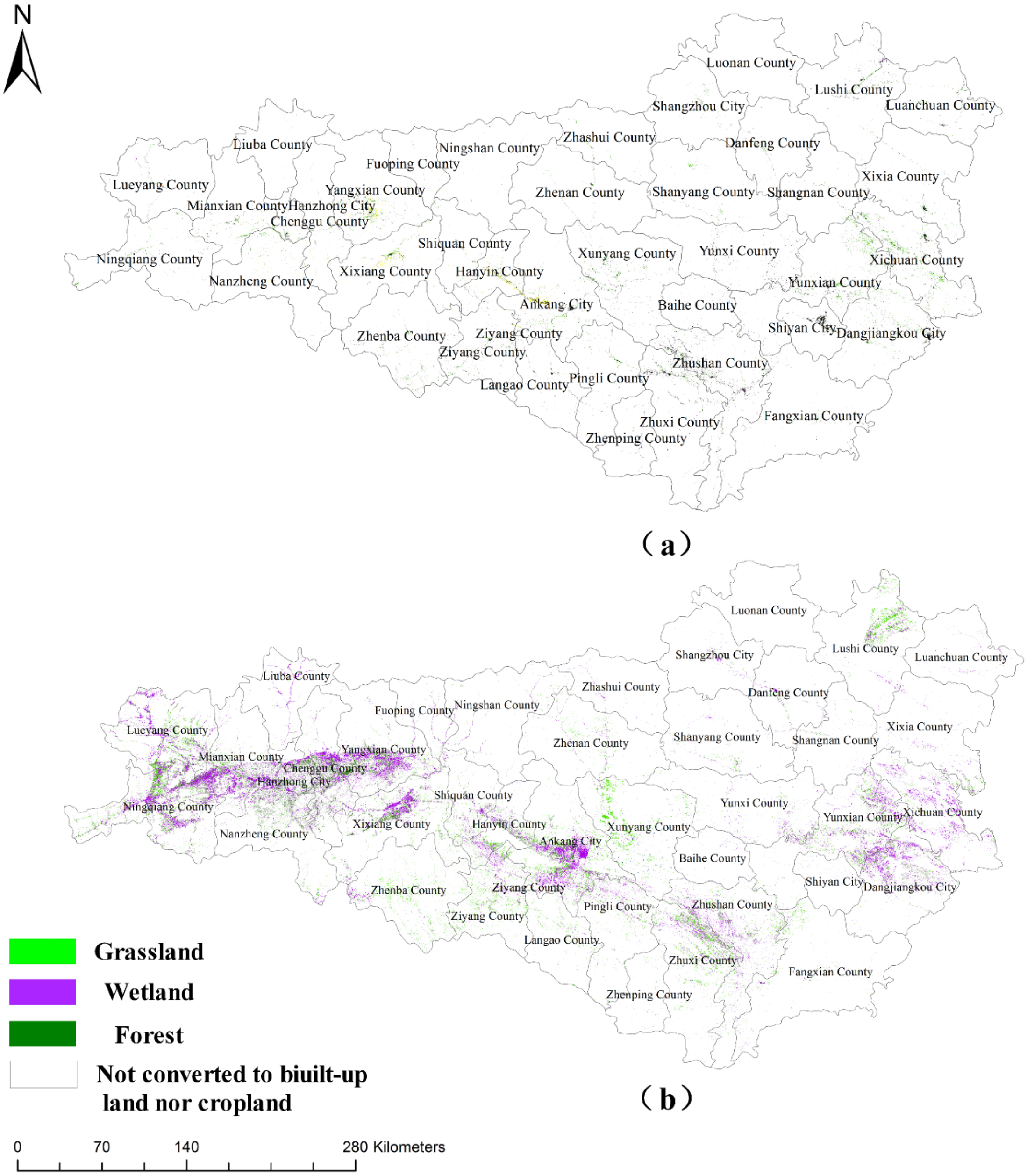


Figure 4. Spatial distribution of regions with land-ues categories converted to built-up land and cropland in the research area between 2002 and 2010.

Croplands that converted from other land-use categories between 2002 and 2010 were shown in Fig. 4b. Main LULC categories that converted to cropland were wetland, forestland and grassland. Croplands that converted from wetland were dominantly located in the western (Hanzhong city and its adjacent regions), east-central (Dangjiangkou city and two adjacent counties to its north), and west-central part (Ankang city and its adjacent regions) along the Hanjiang River basin. Regions with croplands converted from forestland were also along the Hanjiang River basin as well as regions along the Danjiang River basin in Lushi County.

3.3 Challenges and institutional innovation arenas of regional governance

Formal institution that linked to the official channels of governmental bureaucracy (North, 1990; Scott, 2001) can be grouped into three types: (i) regulations (regulatory documents), drafted and enacted by the State Council or departments of the State Council, for regulating and administrating issues corresponding to construction and operation of the MR project of the SNWD project at national or crossing-region scale. Such institutions addressed Issues are including investment and planning (the investment management, the project tendering, the engineering design and bidding, etc.), financing and accounting (the financing arrangement, the contract management, the investment control, etc.), construction management, environmental protection (specially focused on the regional water-soil conservation and water pollution prevention in the research area), land requisition and resettlement (land requisition and resettlement, heritage preservation, etc.), and supervision and administration; (ii) laws. These institutions are with regard to the complex context of regional governance in the research area and covered at least 20 different topics; (iii) local regulations (regulatory documents) drafted and enacted by local governments at provincial or prefecture level. These institutions address a series of issues related to regional governance during the construction and operation of the MR project.

Enforced outside legally sanctioned channels, the informal institutions, such as social or cultural norms, that relevant to regional governance in the research area were folk custom and religious belief. Local folk customs in research area were dominantly demonstrating the reverence and honour of the wilderness, while religious belief were more involved in normal life of local residents (e.g. house building, travelling, funeral, wedding, family formation) and had great influence on cultural-cognitive issues of local communities (Atran & Norenzayan, 2004; Barrett, 2000; Boyer, 2003), but paid little attentions to ecosystem conservation.

Through crossing-scale analysis, major challenges on regional governance at different hierarchical levels were including: (i) balancing water resources distribution in BR of MRP, organizing negotiation on ecosystem service compensation (ESC) between BR and WSA of MRP, and facilitating regional governance innovation at the central-governmental level; (ii) how to determine the amount of the ESC paid to WSA, the share of the ESC paid by sub-regions of BR, and the payment mode of the ESC (on what form and through which channels may the ESC to be delivered to the WSA) at the BR level; (iii) the incompatibility of local institution system on ecosystem conservation, stemming from fragmented (hierarchical) regional governmental regime at the sub-regional level of the WSA.

To more precisely pinpoint the regional institutional innovation and reframing arenas in the research area, the multi-level interactive analysis was performed through the lens of two types of “niche ecosystems” (NE) – namely LULC based NE and ecosystem service function (ESf) based NE.

From the perspective of land-use based NE, the increment of NE of the built-up land, as the key reason for ESV decreasing, was dominantly converted from the forestland, arable land, and with small port from the wetland. Since the amount of the population in the research area was relative steady (Table 2), urban sprawl was the main driver of such land-use conversion between 2002 and 2010. The newly converted urban area were dominantly concentrated in Hanzhong City, Ankang City, Shangluo City, Shiyan City, and Zhechuan and Zhushan Counties. Such urbanization process in these regions was failed in urbanized land-use control and stimulating local residents’ income growth, therefore institutional innovation arenas should lie on the following issues: regional economic development pattern transformation, industrial structure adjustment, rigid control of urban sprawl, comprehensive upgrading of public services.

As for NE of cropland, two major challenges are necessarily highlighted, namely undesirable land structure (i.e. high proportion of low-yielding dryland but low proportion of high-yielding paddy fields), and inefficient distribution of land. More specifically, paddy fields are concentrated in hilly and low mountainous areas, while drylands are distributed in dry, hypothermal, and sloped areas. Whereby, institutional innovation arenas regarding NE of cropland should focus on the establishment of the Rural Land Circulation Mechanism, prevention of soil erosion and promotion of land-use efficiency in rural area, and upgrading the agricultural industry towards technology-intensive and eco-friendly fashion.

Since NEs of wetland and water body are vital for ecosystem conservation, the functionality and integrity of these two NEs are guarantee of the quantity and quality of the water resources retention in the research area. However, the adjacent area of NEs of the wetland and water body are largely transformed from the Medium-contribution ecosystem – proxied by forestland, to the Low-contribution ecosystem – proxied by cropland and grassland, and some even into urbanized area in the downstream area of the Danjing River and Hanjiang River basins. Given such pressing scenario, arenas of regional governance innovation and reframing should highlight the point and non-point source pollution control and the sewage treatment, ad hoc countermeasures for forest conservation and recovery, eco-compensation and transfer payment for water body and wetland conservation, and environmental education and decision-making with local communities' involvement.

There are nine types of ESf based NE, namely soil formation and retention, water supply, gas regulation, climate regulation, biodiversity protection, waste treatment, raw material, recreation and culture, and food.

NEs of soil formation and retention and water supply, which are crucial for retaining the quality and quantity of water resources, were slightly decreased between 2002 and 2010. Whereby, institutional innovation arenas should bring the whole spectrum of regional governance into consideration and include: at the central-government level - establishing plans for soil and water conservation, supervising the implementation of the plan, and formulating more detailed and operational guidance on the scheme of payment transformation from the central government to the WSA; at the BR level - forming the mechanism of eco-compensation allocation to sub-regions of the research area; at the sub-regional level of the research area - formulating strict rules/regulations to guarantee the water and soil conservation.

With a much larger beneficial area at national and global scales, NEs of gas emissions regulations, climate regulation, and biodiversity protection demonstrated a decreasing trend. Therefore, institutional innovation arenas on these NEs should highlight financial support and favorable polices on ecosystem conservation and reforestation of natural forest and water conservation forest, and ad hoc transfer payment mechanisms and policies to facilitate regional social-economic development transformation towards sustainable development, from the central-government level.

As for the remaining four NEs, namely waste treatment, raw material, recreation and culture, and food, these NEs are with a beneficial area at local scale and revealed distinct trends during the construction and operation of the MR project. With direct relationship with local environment daintiness and comfortability of living, ESV of NE of water treatment increased between 2002 and 2010, and institutional innovation arenas with regard to this NE should emphasize the maintenance of local waste emission control and treatment, initiation of the pollution rights trading, and guidance on the assignment and usage of the eco-compensation and transfer payment for water pollution treatment. The NE of recreation and culture, as vital for regional development path transformation, however demonstrated a decreasing trend in its ESV. Therefore, institutional innovation arenas should enforce providing preferential policies and financial support for evoking eco-tourism, and executing strict rules and regulations for pollution detection and control.

Through cross-checking the institutional innovation arenas with the existing institution system, innovation arenas that are not covered by the regional governance were identified (Table 6), and the portfolio for regional governance innovation and reframing can be formulated and concluded as follows: at the central-government level - future governance innovation should focus on the transfer payment scheme on gas emissions regulating, climate change adaption, biodiversity conservation, pollution rights trading market establishment, and regional development mode transformation in the research area; at the BR level - governance innovation should focus on not only the quality control of water resources conserved by the WSA, but also the share of the ESC assigned to each sub-regions of the BR of the MR project, as well as the form of each ESC (monetary or in kind); at the sub-region level - governance innovation should focus on formulating phased targets for regional development mode transformation, supervising the performance of rules/regulations on urban expansion control, advancing the public services facilities, monitoring ad hoc regulations on waste treatment, facilitating fiscal and policy support on the agro-industry advancement towards technology-intensive and eco-friendly fashion, publicizing and educating local communities on regional environmental protection and ecosystem conservation, and involving local communities in the process of decision-making.

Table 6. Mismatches between current institutions and arenas of innovation and reframing of regional governance in the research area.

LULC based and ecosystem services function (ESV_f) based "Niche ecosystem" regions		Beyond/Parallel to WSA of MRP		Sub-region of WSA of MRP	Coverage of current institutions		
		Central-government	Benefiting area (BA) of MRP				
Land-use based NESV	NESV of forestland			• Regional economy form transformation and industrial structure advancing • Strict control of urban sprawl and comprehensively upgrading of urban public services • *Ad hoc* measurements for forestland conservation and recovery			■
	NESV of cropland			• Establishing and perfecting the agro-land transfer mechanisms • Controlling soil erosion and increasing land utilization rate • Encouraging and supporting local agro-industries advancement toward technology-intensive and eco-friendly			■ ■
	NESV of wetland and water body			• Regulations on point source and non-point source pollution control (liquid and solid waste) • Policies on facilities construction of industrial and living sewage discharge and treatment • Rules and regulations on industrial and living sewage discharge norms and monitoring system • Mechanism of capital allocation and utilization of transfer payment and eco-compensation scheme for advancing ecosystems of water body and wetland • Mechanism of wetland and water body ecosystems management by regional governments • Mechanisms of publicity, education and participation in decision making process on ecosystem management of wetland and water body by local communities			■ ■
ESF based NESV	NESV of soil formation and retention, and water supply	• Mechanism on planning, implementation and monitoring of water and soil conservation in WSA of MRP • Mechanism on transfer payments from central government to WSA of MRP on water and soil conservation • Policies on advocating and promoting trade market of pollution emission rights in WSA of MRP • Mechanism on eco-compensation negotiation between BA and WSA of MRP	• Mechanism on the share of eco-compensation on water and soil conservation among regions in BA of MRP • Mechanism on the form of eco-compensation of water and soil conservation from BA of MRP	• Rules and regulations on strictly application of supervision policies on water and soil conservation	■ ■		■

	NESV of gas regulation, climate regulation, and biodiversity protection	• Planning and financial support on protection of natural forest and construction of water conservation forest in WSA of MRP • Transfer payment scheme to WSA of MRP on gas regulation, climate regulation, biodiversity protection from the central government • System on facilitating local economy transformation towards low-carbon emission fashion			■		
	NESV of waste treatment, raw material, recreation and culture, and food			• Rules and regulations on waste emission monitoring and control • Mechanism on regional pollution rights trading • Principles and payment method for funds of eco-compensation and transfer payment on water treatment • Preferential policies and financial supports on industries relied on or beneficial from these ES_f; • Rule and regulation on control and supervision of industries may harm to these ES_f			■ ■ ■

3.4 Adaptive transformation model for regional governance innovation and reframing

With the portfolio of regional governance innovation and reframing, an adaptive institution transition model in terms of cyclical and iterative process was introduced for guiding the adaptive transformation of regional governance system in the research area (Fig.5). Through this model, the relatively vague, intangible and scattered regional institution transition goals are converted into more precise, tangible and staged targets and diverted towards the desired end-state (Kemp & Rotmans, 2004).

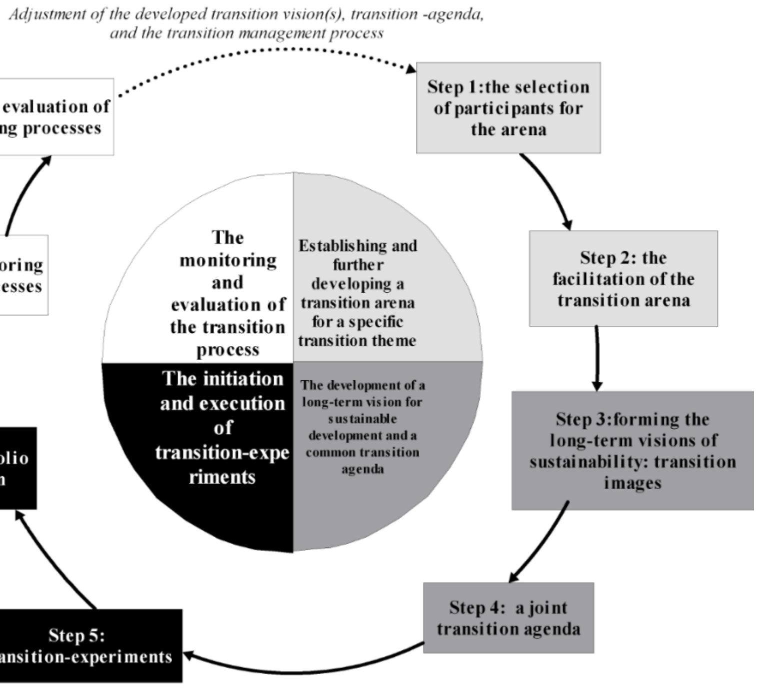


Figure 5. Adaptive institution transition model.

In the 1st stage (Fig. 5), two steps are applied to detect and frame challenges of regional governance system in light of the long-term vision of regional development transformation. First, the regional development vision is articulated, and then status of regional governance system is analysed from the regulative, normative, and cultural-cognitive perspectives.

In the 2nd stage, two steps are taken to generate the new ESV based agenda for regional governance innovation and reframing. In step 3, ESV assessment and regional governance system analysis are performed for identifying the innovating arenas. Thereafter, a joint transition agenda of the regional governance system is sketched out in step 4. In this research, the 1st and 2nd stages were conducted through the application of the ESV based AGM.

In the 3rd stage, measures are proposed to steer the regional institution and plans are proposed to construct the afore-formulated transition portfolio. In step 5, the transition-experiments shall be introduced in the “typical” regions. As for this research, the initiation of the policy of “Demonstration Zone for Building Ecological Civilization” (DZBEC) by the State Council in Shiyan City can be taken as such transition-experiments, which aims to establish the ESC mechanism, built the national forest park system, and innovate the regional coordination mechanisms. Through the performance of this experiment, a portfolio of regional governance innovation and reframing can be devised and duplicate to the rest regions of the research area.

In the 4th stage, two steps are necessary for monitoring and evaluating the regional governance system transformation. Steps 6 and 7 are required to monitor the trends of regional social-economic development and ESV variation, in order to navigate such transformation towards the long-term vision and determine readiness to be steered into the next round. In case of the research area, measures on reform of regional statistical caliber, enhancement of the supervisory system of government, establishment of strict standards for local environmental condition control and ecosystem conservation, founding of markets for emission and carbon trading, are fundamental for performing the DZBEC project in Shiyan. Experience achieved from this project can be duplicated to the rest parts of the research area, and shared with other ESAs in developing countries.

4. Discussion

The purposes of diverting regional development of the WSA of MR porject transformation are pluralistic. It is, on one hand, to balance the geographic distribution of water resources and alleviate water scarcity in Northern China, and on the other hand, to shift the regional development mode towards self-restraint and eco-friendly process, which invokes urgent need of regional governance system innovation and reframing. Besides the institutional innovation of regional governance regime, the actor network and goverance mode are also vital compoents for regional governance improvement (Swallow *et al*., 2001, Cash *et al*., 2006, Clark *et al*., 2011).

There are generally two kinds of actor network, namely the state and non-state actors (Princen & Finger 1994, Lipschutz 1996, Humphreys 1996, Raustiala 1997). In the research area, the state actors refer to the governments and affiliated authorities at national, provincial and local levels (municipal or county level), and ad hoc governmental agencies of the MR project of the SNWD project from national to local level. Adjustment on their roles in regional goverance should highlight branching out their conventional jurisdictions horizon, in order to manage and coordinate crossing-region and multi-level governmental issues.

The non-state actors refers to private stakeholders, from economic departments (e.g. companies, banks) and civil societies (e.g. individual, citizen groups). For local enterprises and businesses, they need to become more proactive in the process of regional industrial structure transformation; for democratic parties, universities and research institutions in the resesearch area, they should play more influential roles on regional governance in terms of professional think tanks, third-part participants, etc; for the civil society, their opinions on regional governance through the channel of new media and internet based online communities should be highly valued by local government, and involved in the process of decision-making, in terms of online surveys, online discussion groups as well as online access to government services.

As for the governance mode of the research area, another influencing components of regional governance, refers to the extent and nature of involvement of the state and/or non-state actors in governing activities (Treib *et al*. 2005). The vertical hierarchical government regime situates in the dominating position, while for the lower governance levels, which have much closer connections to local communities and groups, should listen to and involve local communities in the process of regional governance. The advocacy and trial of some other governance modes, such as self-governance or co-governance civil societies, can be a meaningful supplement to the existing governance mode in the research area.

5. Conclusions

For addressing the regional development dilemma encountered by ESAs in developing countries, the ESV based AGM was introduced and applied in the WSA of the MR project in China. Through the adoption of this model, the deficiencies and failures of existing regional governance system were identified, and portfolio for innovating and reframing the regional governance regime were established and performed in a circular diverting process. This model is proved to be a useful tool for apprehending the complex regional institution system and facilitating the regional development mode transformation towards sustainable fashion. Therefore, this model is suitable to be implemented in regions of developing countries, especially ESAs, where encountering the similar regional development challenges.

The innovativeness of this research rests in way that the measurement and assessment of ecosystem services is integrated into a wider framework of institutional innovation. Compared with traditional proposals for administrative change, the methodology proposed in this study is not prescriptive or directive, but rather an approach to influence the direction and speed of transformation through a series of steering and coordination mechanism. Since regional development transformation in developing countries rest fundamentally on the interplay between many different processes (e.g. cultural changes, religious custom, social norms), future efforts for improving the ESV based AGM could focus on more comprehensive incorporation of marketing and planning mechanisms.

References

Armitage, D. R., Berkes, F., Doubleday, N. 2007. Introduction: moving beyond co-management. Pages 1–15 in D. Armitage, F. Berkes, and N. Doubleday, editors. Adaptive comanagement: collaboration, learning, and multi-level governance. University of British Columbia Press, Vancouver, British Columbia, Canada.

Atran, S., A. Norenzayan. 2004. Religion's evolutionary landscape: counterintuition, commitment, compassion, communion. Behavioral and Brain Sciences 27(6): 713-770.

Barrett, J. L. 2000. Exploring the natural foundations of religious belief. Trends in Cognitive Science. 4(1): 29-34.

Boyer, P. 2003. Religious thought and behavior as by-products of brain function. Trends in Cognitive Sciences 7(3): 119-124.

Brunner, R.D., et al. 2006. Adaptive governance: integrating science policy and decision making. Columbia University Press, New York, New York, USA.

Cash. D. W., W.N. Adge, F. Berkes, P. Garden, L. Lebel, P. Olsson, L. Prichard, O. Young. 2006. Scale and cross-scale dynamics: governance and information in a multilevel world. Ecology and Society 11(2): 8.

Clark, W. C., T. P. Tomich, M. van Noordwiik, D. Guston, D. Catacutan, N. M. Dickson, E. Mcnief. 2011. Boundary work for sustainable development: natural resource management at the consultative group on international agricultural research (CGIAR). Proceedings of the National Academies of Sciences Linking Knowledge with Action for Sustainable Development. The

National Academy of Sciences in DC. April 3–4 2008. Washington: The National Academy of Sciences.

Constanza, R., R. et al. 1997. The value of the world's ecosystem services and natural capital. Nature 387(6630): 253–260.

Curtis, I.A. 2004. Valuing ecosystem goods and services: a new approach using a surrogate market and the combination of a multiple criteria analysis and a Delphi panel to assign weights to the attributes. Ecological Economics 50, 163–194.

Daily, G., 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, USA.

Du, X. P., S. R. Dong. (ed.). 2011. Tianjin Statistical Yearbook. Beijing: China Statistical Press. (in Chinese).

Folke, C., Hahn, T., Olsson, P., Norberg, J. 2005. Adaptive Governance of Social Ecological Systems. Annual Review of Environment and Resources 30, 8:1–33.

Gasparatos, A., et al., 2008. A critical review of reductionist approaches for assessing the progress towards sustainability. Environmental Impact Assessment Review. 28(4-5): 286–311.

Grodzinska-Jurczak, M., J. Cent, 2011. Expansion of nature conservation areas: problems with natura 2000 implementation in Poland. Environmental Management 47(1): 11-27. http://dx.doi.org/10.1007/s00267-010-9583-2.

Haigh, V. J. 1990. Environmentally sensitive areas. Landscape and Urban Planning 18(3-4): 235–239. http://dx.doi.org/10.1016/0169-2046(90)90010-Y.

Hammond, G.P. 2004. Engineering sustainability: thermodynamics, energy systems and the environment. Int J Energy Res. 28:613–39.

Huitema, D., et al. 2009. Adaptive water governance: assessing the institutional prescriptions of adaptive (co-) management from a governance perspective and defining a research agenda. Ecology and Society 14(1): 26. [online] URL: http://www.ecologyandsociety.org/vol14/iss1/art26/.

Humphreys, D. 1996. Regime theory and Non-Governmental Organizations: the case of forest conservation. In Potter, D. (ed.). NGOs and Environmental Policies: Asia and Africa. London: Frank Cass.

Kemp, R., Rotmans, J. 2004. Managing the transition to a sustainable mobility, forthcoming, in B. Elzen, F. Geels and K. Green (eds.) System Innovation and the Transition to Sustainability: Theory, Evidence and Policy, Cheltenham: Edgar Elgar.

Kong, X. China must protect high-quality arable land. Nature 2014, 506(7486), 7. doi:10.1038/506007a.

Lipschutz, R. D. 1996. Global civil society and global environmental governance: the politics of nature from place to planet. Albany, NY: State University of New York Press.

Loewe, M., N. Rippin (ed.). 2015. The sustainable development goals of the post-2015 agenda: comments on the OWG and SDSN proposals. German Development Institute, Bonn.

Loorbach, D. national Dimensions of Human Change. 2004a. Governance and Transitions: A Multi-Level Policy-Framework Based on Complex Systems Thinking. Berlin: Conference on Human Dimensions of Global Environmental Change.

Loorbach, D. 2010b. Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework. Governance, 23(1), 161–183. doi:10.1111/j.1468-0491.2009.01471.x.

MA, Millennium Ecosystem Assessment. 2003. Ecosystems and Human Well-being. A Framework for Assessment. Island Press.

MA, Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis

Report. Island Press, Washington, D.C., USA.

Munda, G. 2006. Social multi-criteria evaluation for urban sustainability policies. Land Use Policy. 23:86–94.

North, D. C. 1990. Institutions, Institutional Change, and Economic Performance. Cambridge: Cambridge University Press.

Nuñez, D., Nahuelhual, L., Oyarzún, C. 2006. Forests and water: the value of native temperate forests in supplying water for human consumption. Ecological Economics 58, 606–616.

Peng, et al., 2005. Economic Value of urban ecosystem services: a case study in Shenzhen. ActaScientiarumNaturalium, Universitatis Pekinensis 41, 594–604 (in Chinese).

Princen, T., M. Finger. 1994. Environmental NGOs in world politics: linking the local and the global. London: Routledge.

Puppim de Oliveira J. A., C. N. H. Dolla, T. A. Kurniawan, Y. Geng, M. Kapshe, D. Huisingh. 2013. Promoting win–win situations in climate change mitigation, local environmental quality and development in Asian cities through co-benefits. Journal of Cleaner Production 58(1): 1–6.

Raustiala, K. 1997. The "participatory revolution" in international environmental law. The Harvard Environmental Law Review 21: 537.

Rees, W.E., Wackernagel, M. 1996. Urban ecological footprints: why cities cannot be sustainable and why they are a key to sustainability. Environmental Impact Assessment Review. 16:223–48.

Sciubba, E., Ulgiati, S. 2005. Emergy and exergy analyses: complementary methods or irreducible ideological options? Energy. 30:1953–88.

Scott, R.W. 2001. Institutional and organization. 2nd Ed. Thousand Oaks, CA: Sage Publication.

Swallow, B. M., D. Garrity, M. S. van Noordwijk. 2001. The effects of scales, flows and filters on property rights and collective action in watershed management. Water Policy 3(6): 457-474.

Treib, O., H. Baehr, G. Falkner. 2005. Modes of Governance: A Note Towards Conceptual Clarification. European Governance Papers (EUROGOV) No. N-05-02.

United Nation (UN). 2012. World Urbanization Prospects the 2011 Revision. New York.

United Nations (UN). 2014. The Millennium Development Goals Report 2014. New York.

Xie, G. D., C. X. Lu, Y. F. Leng, D. Zheng, S. C. Li. 2003. Ecological assets valuation of the Tibetan Plateau. Journal of Natural Resources 18: 189–196. (in Chinese).

Yu, X. Q. (ed.). 2011. Beijing Statistical Yearbook. Beijing: China Statistical Press. (in Chinese).

Modelling future scenarios for ecosystem services management

Comín, Francisco A.[1]**, Maria R. Felipe-Lucia**[2]

[1] Instituto Pirenaico de Ecología-CSIC, Zaragoza-Jaca, Spain, comin@ipe.csic.es

[2] Institute of Plant Sciences, University of Bern, Switzerland,maria.felipe@ips.unibe.ch

Abstract

Landscape planning based on ecosystem services requires modelling future trends. Scenario analysis is a useful technique to identify the current status of ecosystem services supply and to investigate the effects of land management decisions. We estimated values of 29 ecosystem services indicators derived from five alternative scenarios based on the combination of two gradients: agricultural intensification and ecological restoration in the River Piedra floodplain, a small agricultural dominated floodplain in Central Spain. In addition, we identified ecosystem services bundles and trade-offs using redundancy analysis. Our results clearly showed how land management affects ecosystem services supply. Scenarios promoting ecological restoration supplied more services than those scenarios focused on specific services. We also found a bundle of services related to the production of material goods and another one related to socio-cultural activities. Interestingly, these bundles were composed of a mix of ecosystem services from different categories. We discuss how different management objectives would benefit from different land planning scenarios but suggest an intermediate scenario based on the conservation of ecosystem integrity and the sustainable use of provisioning services in order to obtain a more balanced provision of a set of ecosystem services from this floodplain.

Keywords: Agroecosystem, Multifunctional, Management, Restoration, Floodplain.

1. Introduction

Alternative land use scenarios can be proposed for the development of a rural society based on agrarian production (Marsden et al., 2011). However, a sustainable development must ensure long term persistence of a balanced provision of food and the services regulating the ecological functioning of the agroecosystem, including cultural services if these are a substantial part of the living characteristics of rural people (Plieninger et al., 2006).

Floodplains in rural areas of advanced countries are submitted to strong pressures to provide food and raw materials as part of their living system. It is also common that these areas are highly depopulated after years of people's migration to urban sites. This is a common fact in most of the world. Alternative scenarios can be foreseen for the development of this type of territories and societies which are mostly based on agrarian production (Altieri et al., 1983, Porter et al., 2009).

The assessment of ecosystem services is a practical tool and approach to evaluate potential scenarios for land use of large territories and different types of agroecosystems (Nelson et al., 2009). Applying the assessment of ecosystem services to agroecosystems makes it evident where to allocate efforts to recover damaged sites and stimulate contrasting use of resources as food production and cultural land uses (Trabucchi et al., 2013, Felipe-Lucia et al., 2015). On the other hand, scenario planning has been quoted as a practical approach and tool to assist decision making with respect to alternative land use and cover changes in a territory (Biggs et al., 2007). In this work setting up alternative land use and land cover scenarios was used through the evaluation of ecosystem services of an agricultural dominated floodplain (River Piedra in Central Spain) in a rural landscape to suggest the best strategy for achieving a sustainable development. Most of this territory is dedicated to agricultural production but in limiting conditions due to the lack of demanding markets and the non-structural population inhabiting the villages which is dominated by elder non-qualified people (1,539 persons living in 12 municipalities, 60% of the persons are older than 60 years old).

2. Methods

Fifteen ecosystem services were evaluated after ecological, cultural and agrarian proxy indicators (Table 1) in the River Piedra floodplain (923 km^2 at between 600 and 1,100 m.a.s.l in the Iberian Range in Central Spain) during late spring 2013 (Scenario 0) and land cover changes were simulated in 4 different scenarios (Scenario 1, conserving natural habitats and restoring degraded riparian zones and abandoned agricultural areas; Scenario 2, agricultural production is increased by growing dry cereal in abandoned crops of the upper lands and by irrigating both abandoned crops and water-fed crops in middle and lower lands; Scenario 3, extending irrigated agriculture in less productive fields and restoring degraded riparian zones in the riparian 5 meters aside the river banks of public domain) taking the present conditions as reference values of the ecosystem services (Felipe-Lucia, 2015); Scenario 4, rural abandonment progresses, so agricultural production is limited to present irrigated agriculture and poplar groves.

Table 1. **Ecosystem services, indicators and units. (Detailed methods are described in Felipe-Lucia et al., 2015).**

Type of Ecosystem Service	Ecosystem Service	Proxy indicator	Unit	Method
Supporting	**Soil stability**	**Organic matter layer**	**cm**	
	Habitat quality	**Riparian Quality Index**	**RQI*-**	
Regulating	**Water quality (water purification)**	**Dissolved organic matter**	**ppm**	
		Dissolved nitrate	**ppm**	
		Dissolved phosphate	**ppm**	
		Suspended solids	**ppm**	
	Soil formation	**Organic matter**	**kg**	
	Nutrient regulation	**Organic nitrogen**	**kg**	
		Soluble reactive phosphorus	**kg**	
	Climate regulation	**Temperature variation**	**°C**	
		Moisture variation	**%**	
	Pest biological control	**Vertical vegetation structure**	**number**	
	Carbon sequestration	**Carbon sequestration**	**CO_2eq**	
Provisioning	**Food production**	**Gross value**	**€**	
		Yield	**kg**	
	Raw materials production	**Biomass increase**	**T**	
Cultural	**Aesthetic value**	**Picture density**	**items/ha**	
	Recreation	**Picnic areas density**	**items/ha**	
	Environmental	**Educative panels**	**items/ha**	

education	**density**	
Sport facilities	**Paths density**	**m/ha**
Nature enjoyment	**Forest cover**	**m^2**

*Gonzalez and Garcia (2011).

3. Results

In the present conditions, a general lack of service provision is observed in the River Piedra floodplain. Low food provision, cultural services accumulated in just one site of the floodplain, and very low regulation capacity of the riparian zones are observed compared to those in alternative scenarios (Fig. 1)

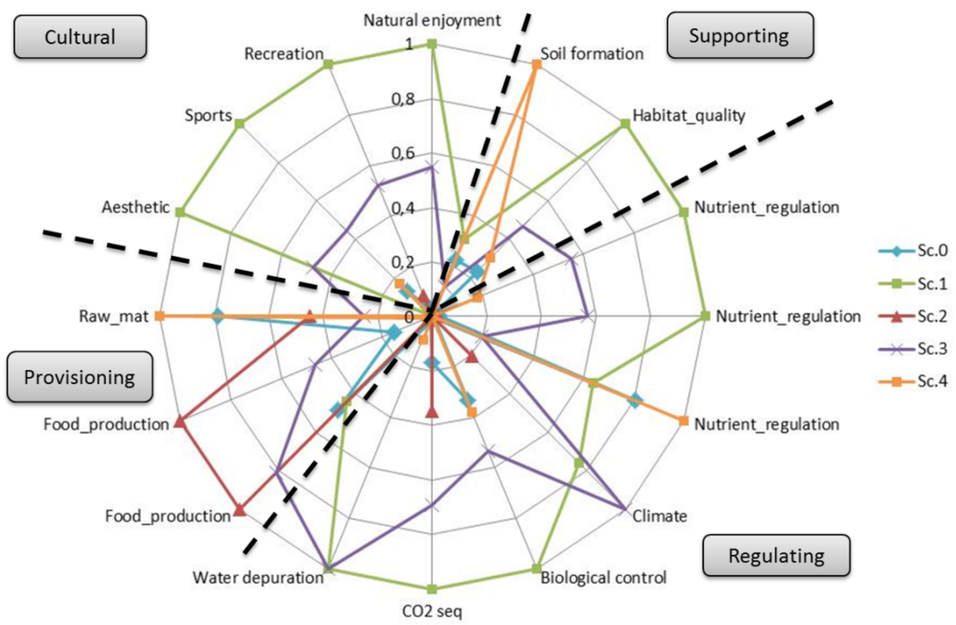


Figure 1. Radial plot representing the relative contribution of ecosystem services for each scenario: Sc. 0, blue line, present conditions; Sc. 1, green line, conservation and restoration; Sc. 2, red line, intensifying agriculture; Sc. 3, purple line, conservation and production mixture; Sc. 4, orange line, land abandonment. Dashed lines indicate different ecosystem services categories (clock-wise: supporting, regulating, provisioning and cultural services).

The redundancy analysis (RDA) showed the relation between ecosystem services across land planning scenarios. In all scenarios, more than 90% of the total variance was explained by the first three axes, where the first axis contributed to more than 50% of the total variance, and the second axis added at least 25% more (Table 2).

Table 2. **Eigenvalues and portion of the accumulated variance attributed to each major component after the redundancy analysis (RDA) in the 5 scenarios as in Figure 1.**

	Scenario 0			Scenario 1			Scenario 2			Scenario 3			Scenario 4		
	PC 1	PC 2	PC 3	PC 1	PC 2	PC 3	PC 1	PC 2	PC 3	PC 1	PC 2	PC 3	PC 1	PC 2	PC 3
Eigenvalue	8,38	3,93	2,00	8,43	4,69	1,87	8,88	4,26	1,46	8,19	4,64	2,15	9,36	3,84	0,99
Explain portion	0,52	0,24	0,12	0,52	0,29	0,11	0,55	0,26	0,09	0,51	0,29	0,13	0,58	0,24	0,06
Accumulated portion	0,52	0,77	0,89	0,52	0,82	0,93	0,55	0,82	0,91	0,51	0,80	0,93	0,58	0,82	0,88

We found two ecosystem services bundles consistent across the five scenarios. The first bundle was related to the production of material goods and included the services food provision, climate regulation (temperature), nutrient regulation (C and N) and biological control. The second bundle was related to socio-cultural activities, including all cultural services plus carbon sequestration. Also, in scenario 1 (conservation and restoration) and 3 (intensifying agriculture and conservation), raw materials were associated to the provision of material goods bundle, and in scenario 2 (agricultural intensification), the economic indicator of food production (gross value) was related to the socio-cultural bundle.

4. Discussion

The five scenarios evaluated as potential alternatives for the development of the studied agroecosystem show distinctive distributions of ecosystem services. In the present conditions, scenario 0, very low regulating services are provided and low cultural services are observed which is characteristic of rural areas submitted to high people migration, not efficiently used for food production and with low expectancies of development because of non-structural populations. In contrast, after extending conservation and restoration of riparian habitats all along the river banks results in an outstanding increase of the values of regulating and cultural services but does not favour productive services. It is clear that well-structured riparian forests contribute to buffer floods and meteorological changes, retain nutrients, and are also attractive sites for recreational activities (Stutter et al., 2012) Extending intensive agriculture, scenario 2, increases food production but lowers and gives no value to other services. Scenario 3, restoring degraded riparian zones in a belt corresponding to the public domain (land aside rives up to the line of the water level during the maximum ordinary flood) and extending intensive agriculture to abandoned agricultural fields, results in an increase of food provision with respect to the present conditions and also a clear increase of many regulating, supporting and cultural services. Finally, scenario 4 (continuing land abandonment trends) will provide more raw materials and will increase soil formation during the process of land abandonment, including nutrient accumulation in the soil and as the plant community develops, but will result in a general decrease of most of the other ecosystem services (Fig. 1).

These results show the potential to keep a balanced provision of ecosystem services, including food and raw materials, if a combination of productive land uses and conservation and restoration of degraded sites is planned. This can be the way to orientate societies in rural areas towards sustainable development because they don't have the control of the decision making process about use of the natural resources due to their non-structured populations and low technical capacity (Plieninger et al., 2006). Intensifying a land use to obtain just one or a few ecosystem services decreases the provision of other services as they all are part of the nature network. This last strategy is not the adequate to be incorporated as part of a sustainable development plan for agrarian based socio-ecological systems in rural areas which are, usually, made of a high proportion of old people with low potential to incorporate young persons to their societies (Vos and Meekes, 1999).

Scenario planning has been used successfully in a range of contexts (Costanza et al., 2015). Using it combined with ecosystem services assessment results in a practical tool to guide taking decisions about land use and cover changes under the perspective of sustainable development for rural territories.

5. Conclusions

Scenario planning based on the evaluation of ecosystem services is a valuable approach to orientate socio-ecological systems in rural areas towards sustainable development. A combination of conservation and restoration of degraded habitats and intensification of highly productive agricultural fields provides a more equitable balance of ecosystem services in floodplains of rivers in rural areas than other alternative scenarios as just extending agricultural uses or intensifying conservation and restoration of degraded sites.

References

Altieri, M.A., Letourneau, D.K., Davis, J.R., 1983. Developing Sustainable Agroecosystems. BioScience 33:45-49.

Biggs, R., Raudsepp-Hearne, C., Atkinson-Palombo, C., Bohensky, E., Boyd, E., Cundill, G., Fox, H., Ingram, S., Kok, K., Spehar, S. Tengö, M., Timmer, D., Zurek, M., 2007. Linking futures across scales: a dialog on multiscale scenarios. Ecology and Society, 12, 17.

Costanza, R., Kubiszewski, I., Cork, S., Atkins, P.W.B., Bean, A., Diamond, A., Grigg, N., Korb, E., Logg-Scarvell, J., Navis, R., Patrick, K., 2015.Scenarios for Australia in 2050: A Synthesis and Proposed Survey. Journal of Future Studies 19:49-76.

Felipe-Lucia, M. 2015. Analysis of ecological and social interactions along the flow of ecosystem services. Suggestions for the management of the river Piedra floodplain. University Pablo de Olavide, Seville, Ph. D. Thesis, 242 pags.

Felipe-Lucia, M.R., Martín-López, B., Lavorel, S., Berraquero-Díaz, L., Escalera-Reyes, J., Comín, F.A. 2015. Ecosystem services flows: Why stakeholders' power relationships matter. PLOS ONE, DOI:10.1371/journal.pone.0132232.

Gonzalez, M., Garcia, D., 2011. Riparian Quality Index (RQI): A methodology for characterising and assessing the environmental conditions of riparian zones. Limnetica, 30: 235-254.

Marsden, T., Banks, J., Renting, H., Van Der Ploeg, J.D., 2001. The Road Towards Sustainable Rural Development: Issues of Theory, Policy and Research Practice. .J. Environ. Policy Plann. 3: 75–83.

Nelson, E., Mendoza, M., Regetz, J., Polasky, S., Tallis, H., Cameron, D.R., Chan, K.M., Daily, G.C., Goldstein, J., Kareiva, P.M., Lonsdorf, E., Naidoo, R., Ricketts, T.H., Shaw, M.R., 2009. Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. Frontiers in Ecology and the Environment 7:4-11.

Plieninger, T., Ho, F., Spek, T., 2006. Traditional land-use and nature conservation in European rural landscapes. Environmental Science and Policy 9:317–321.

Porter, J., Costanza, R., Sandhu, H., Sigsgaard, L., Wratten, S., 2009. The Value of Producing Food, Energy, and Ecosystem Services within an Agro-Ecosystem. Ambio 38:186-193.

Stutter, M.I.,Chardon, W.J.,Kronvang, B., 2012. Riparian buffer strips as a multifunctional management tool in agricultural landscapes: introduction. J Environ Qual.4:297-303.

Trabucchi, T., Comin, F.A., Farrell, P.O., 2013. Hierarchical priority setting for restoration in a watershed in NE Spain, based on assessments of soil erosion and ecosystem services. Reg Environ Change 13:911–926.

Vos, W., Meekes, H., 1999. Trends in European cultural landscape development: perspectives for a sustainable future. Landscape and Urban Planning 46:3-14.

How to articulate multiple value dimensions of ecosystem services? A participatory integrated framework

Rita Lopes[1], Nuno Videira[2]

[1] CENSE – Center for Environmental and Sustainability Research, Faculdade de Ciências e Tecnologia, Universidade NOVA de Lisboa, DCEA FCT-UNL, 2829-516 Caparica, Portugal, rjl@fct.unl.pt.

[2] CENSE – Center for Environmental and Sustainability Research, Faculdade de Ciências e Tecnologia, Universidade NOVA de Lisboa, DCEA FCT-UNL, 2829-516 Caparica, Portugal, nmvc@fct.unl.pt.

Abstract

The concept of ecosystem services (ES) has been growing in research and policy agendas both in dissemination and implementation. This has been seen as an attempt to call attention for the importance of the ecosystems and also to promote their conservation and protection, which is essential for a successful sustainable development. The intensification of the use of this concept calls for new approaches capable of integrating ES values in decision-making. Starting from the focal question "how to foster the integration and articulation of multiple values of ES to inform decision-making?" we developed a three-step participatory framework, which is being tested in Arrábida Natural Park, a Portuguese coastal and marine protected area. The process starts with setting the scene, where we developed a methodology to implement a collaborative scoping process, which should be a first step when conducting a valuation and assessment process of ES. We combine an institutional and stakeholder analysis that allowed to identify key stakeholders, their interdependencies and institutional rules governing the area. A first participatory workshop gathered 21 participants engaged in a process of ES identification, recognition of threats and links to human wellbeing, as well as a preliminary screening of the social, economic and ecological importance of the identified ES. Results from this step were validated through an online survey. The second step aims to develop a deepening understanding through a participatory process to promote sharing and co-production of knowledge regarding the structure underlying the provision of a sustainable flow of specific ES. A participatory systems mapping workshop was organized gathering 20 participants who jointly developed causal loop diagrams depicting four ES perceived as highly important for the natural park – ecotourism, food provision, climate regulation, and biodiversity. These conceptual maps systematized knowledge on key indicators, leverage points, feedback loops and interrelationships influencing conservation of ES. The process ends articulating values, which is the third step. This phase was already implemented with the collaboration of the park management team. A participatory workshop was developed aiming to articulate the different ES values captured in the previous steps. The participants were asked to deliberate on social, biophysical and economic criteria associated to different alternative policies for the protected area, as well as, the rules for decision. The proposed framework intends to foster value articulation for decision-making support based on the integration of participatory methods and tools, implemented through a coherent and structured platform. The proposed deliberative approach creates the opportunity to accommodate scientific data together with plural stakeholder perceptions, thus supporting evidence and stakeholder-based assessments for management of ES.

Keywords: ecosystem services, values articulation, participatory workshops, tools and methods integration

Ecosystem Service Assessment of Measures to Mitigate Small-scale Hydropower Ecological Impact

Susanne Tellström[1], Morgan Fröling[2], Erik Grönlund[2], Paul van den Brink[2]

[1] Department of Ecotechnology and Sustainable Building Engineering, Mid Sweden University, Östersund, Sweden, susanne.tellstrom@gmail.com

[2,] Department of Ecotechnology and Sustainable Building Engineering, Mid Sweden University, Östersund, Sweden

Abstract

Hydropower is important for provisioning of renewable energy, but the ecological effects to watersheds and rivers used for hydro-electrical production has gained increased attention in recent years. Concerns in connection to small-scale hydropower plants are particularly pointed out, as small plants causes several issues for aquatic biodiversity while the energy output remains limited. Hydropower dams poses as migration barriers, e.g. limiting reproduction of migratory fish; the flow regulation regimes disturbs the natural seasonal flows and damages bottom fauna; and rivers adapted to hydropower have altered biotic factors removing entire ecosystems, such as seasonally flooded wetlands. Projects to mitigate such impacts while maintaining hydro-electrical production are presently discussed and in some cases start to be undertaken. One such project is planned in river Billstaån, Sweden, affected by three small-scale hydropower plants and historically also by timber floating. The main measures in the ecological restoration process include construction of fauna passages, deconstruction of an unused reservoir and reintroduction of freshwater pearl mussels. The restoration project is carried out by the company owning the hydropower plants in Billstaån, in a joint effort including local authorities and stakeholders, to benefit local biodiversity and strengthen the ecological status of Billstaån towards the European Water Framework Directive. In this study, the expected outcomes of the Billstaån river restoration project has been assessed in terms of ecosystem services. Note that ecosystem services were not considered in the project planning of the restoration project itself, but were suggested for later monitoring efforts and for enabling inclusion of indicators of economic and social development connected to the restoration results. As ecosystem services describe the value of ecosystems through their interaction with society, this is done to complement ecological monitoring with effects on human residents in the area. Two frameworks for ecosystem service assessment have been tested: *Corporate Ecosystem Service Review* (ESR) and *Toolkit for Ecosystem Service Site-based Assessment* (TESSA). Both frameworks have been useful for assessing the expected development of Billstaån, but each of them have specific limitations. While ESR was good for qualitative scoping and defining important ecosystem services, the corporate focus made the later steps of the ESR framework hard to implement in this type of case. TESSA worked well for providing tools for quantitative assessment, but at present the number of services covered by the toolkit was limited. This indicates that different methods for ecosystem service assessment provide different levels of understanding of the assessed system. The two frameworks used to assess Billstaån do complement each other in terms of scope, but combined they point at gaps in coverage. This study has shown that ecosystem service assessment provides a complementary perspective of the value of increasing ecological status in rivers affected by small-scale hydropower, but also that the ecosystem services methodology needs further development for this type of case.

Keywords: ecosystem service assessment, hydropower, ecological restoration, Corporate Ecosystem Service Review, Toolkit for Ecosystem Service Site-bases Assessment

1. Introduction

1.1. Ecosystem services

Ecosystem services are ecosystem functions used by humans, including harvestable goods as well as softer values connected to nature as base for recreation and culture, along with underlying processes for ecosystem maintenance and regeneration (MEA, 2005; TEEB, 2010; Fakari Rad et al., 2012). The ecosystem service concept thus interprets more benefits from nature than those commonly considered as natural resources. Through describing more of the links between ecosystems and human society more of the needs and demands on nature for human well-being can be understood. In the last decade ecosystem services have been academically explored as well as integrated into decision making and policy development on all levels (Gomez-Baggethun et al., 2010).

The European Environment Agency has proposed a nomenclature for Ecosystem Services, CICES, dividing them into three *sections* of services, namely: provisioning services, including water and material supply; regulating and maintenance services, including natural processes and flows affecting the balance of the ecosystems, and; cultural services, including human experience and perceptions of nature (CICES, 2013). According to other systems there is also an additional category of supporting services, including e.g. habitat services, underlying all other services (MEA, 2005; TEEB, 2010). In CICES such supporting services are considered as part of the underlying structure for the ecosystems, which cannot be directly used or consumed but are part of the ecosystem supply for ecosystem services. Since supporting services are not final outputs from the ecosystems, CICES excludes them and considers them better dealt with using other methods, e.g. environmental accounting.

1.2. The ecological restoration project in Billstaån

The river Billstaån is a water course situated in Jämtland County, Sweden. The river connects the lake Näkten with the lake Storsjön, see Figure 1. The area is a cultural landscape with ancient remains of human settlements since the Iron Age (Swedish National Heritage Board, 2016). Billstaån is a water course about 4.4 km long (Länsstyrelsen Jämtlands län, 2012) with an average flow speed of 4 m^3/s (Jämtkraft AB, 2015a). Today the main human use of river Billstaån is as provider of hydropower for electric production, which causes several ecological issues and limts e.g. recreational fishing.

The ecological status of Billstaån is considered as *poor* under the classification in the EU Water Framework Directive (2000/60/EC), representing the second lowest grade on a five graded scale where only the two highest steps, *high* and *good*, are in line with the framework goals (European Commission, 2015). The main environmental issues are the existing migration barriers, deficient continuity, and effects from the flow regulation (VISS, 2015; Länsstyrelsen Jämtlands län, 2012). These issues limit the value of river Billstaån as habitat for e.g. brown trout (*Salmo trutta*) despite a high habitat potential in terms of water quality, stream properties, etc. (Jämtkraft AB, 2015b).

To improve the ecological status an ecological restoration project will be performed in river Billstaån (Jämtkraft, 2015a). The restoration project is conducted by Jämtkraft AB, the owner of the three hydropower plants in Billstaån; the County Administrative Board in Jämtland; and local stakeholders, including the local municipality (Bergs municipality) and the fishing management organisations in the lakes connected to river Billstaån.

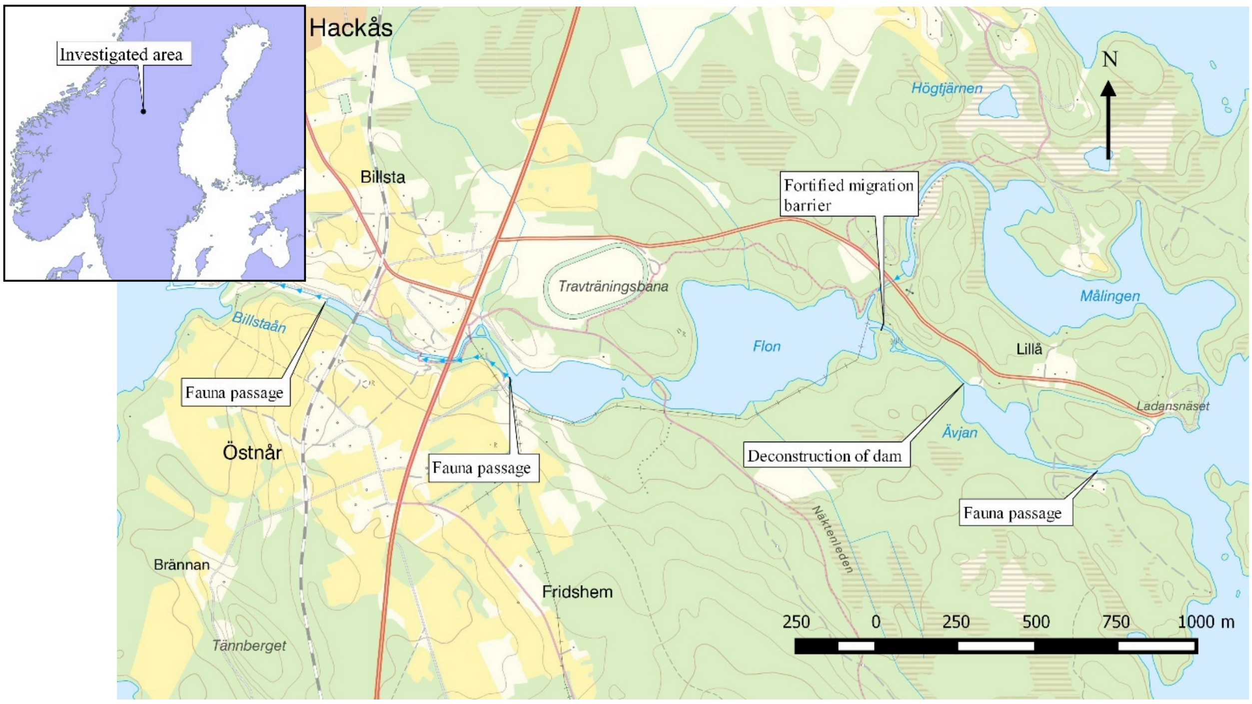


Figure 18. Map of river Billstaån and the planned restoration measures. The flow direction is from the right of the map, where lake Näkten is, to left of the map where the outlet in lake Storsjön is.

The river restoration project is part of the *Triple Lakes* program, a watershed management program including lake Näkten and two other nearby lakes. Triple Lakes works to address both historical and current environmental impacts so that the characteristic ecosystems of the three lakes can be better maintained in the face of global warming (LIFE, 2015; Triple Lakes, 2015). The main restorative measures in Billstaån includes construction of fauna passages at three of the dams in the river (see Figure 1), deconstruction of an unused dam restoring, a current lake-like area to streaming water, and reintroduction of freshwater pearl mussels (*Margaritifera margaritifera*).

Currently there are three small-scale hydropower plants situated in Billstaån, generating approximately 6.5 GWh a year (Jämtkraft AB, 2015c). There is a migratory brown trout population in Billstaån with good genetic status, which makes it plausible their spread will increase if the migration barriers can be removed. Due to topography and area limits to the construction sites available, traditional fish ladders have been deemed less efficient in connection to the hydropower dams included in the project (Jämtkraft AB, 2015a). Hence three fauna passages in the form of bypass channels are planned, since they enable migration for more aquatic species than just jumping migratory fish and fit better into the locality in Billstaån. Another benefit of bypass channels is that they are less demanding in terms of maintenance compared to fish ladders. Bypass channels are constructed to mimic smaller streams than the main water course and are less steep than fish ladders, making them available as migration routes for more species of fish and insects (Nöbelin, 2014). This type of fauna passages is also considered more interesting for Billstaån as it generates new aquatic environments and extended habitat areas, which gives substantially higher benefits to biodiversity compared to fish ladders.

One dam will be demolished in the restoration project which means lowering the present water levels in the currently dammed area in Ävjan (see Figure 1) by 2.5 m and affecting stream conditions and restoring about 300 m of river habitat.

The project also includes the reintroduction of freshwater pearl mussel, to be seen as bringing back a native species to the river. The freshwater pearl mussel is an indicator species for the Swedish national environmental goal *Flourishing lakes and streams* and *A rich diversity of plant and animal life* (Naturvårdsverket, 2015a; Naturvårdsverket, 2015b).

Freshwater pearl mussels are documented as beneficial for wild brown trout populations and river ecosystems in general as they provide properties of water purification through their water filtration and are considered an umbrella species (Degerman et al., 2009; Smith and Jepsen, 2008). Pseudo faeces from mussels provide nutrients for algae and detritus eaters, indirectly providing more sustenance for fish and other organisms eating invertebrates (Degerman et al., 2009; Smith and Jepsen, 2008).

Additional efforts to remove migration barriers connected to culverts, restoring waterways and breeding grounds (e.g. by moving back boulders removed to facilitate historical timber floating), reducing sludge and nutrient transport, and strengthening endangered species will also be undertaken. To safeguard the *Natura 2000* area of lake Näkten upstream the river, a partial migration barrier will be fortified to limit spread of planted Arctic char (*Salvelinus alpinus*), as well as diseases, from lake Storsjön downstream. This will allow migrating fish to migrate upstream to spawn, but not spread into lake Näkten and endanger its valuable habitat environment. After the restoration Billstaån is expected to be a Natura 2000 site. Based on information from both Jämtkraft AB and the County Administrative Board in Jämtland the ecological restoration efforts in Billstaån are expected to have both economic and social impact on the rural area where Billstaån is situated. This is connected to the high recreational fishing interest in brown trout, as well as a general need for rural development in the area.

1.3. Assessing ecosystem services

Two ecosystem service assessment frameworks were applied to the restoration project of river Billstaån: *Corporate Ecosystem Service Review* (ESR) and *Toolkit for Ecosystem Service Site-based Assessment* (TESSA). ESR was used to assess the expected restoration effects on ecosystem services provided by river Billstaån based in initial scoping and qualitative analysis, and for defining important services to consider in monitoring efforts and further assessment attempts. TESSA was used to assess some services quantitatively, towards monetary values, and introduce scenario thinking towards exploring the possible alternate state of river Billstaån after the restoration has been carried out.

The purpose of this report is to assemble the impressions of the frameworks for contrasting what ecosystem services have been assessed, the types of results achieved and the functionality of the frameworks for assessing the Billstaån case.

2. Methods

Corporate Ecosystem Service Review (ESR) and *Toolkit for Ecosystem Service Site-based Assessment* (TESSA) were chosen as methodological frameworks for assessing impact on ecosystem services from the ecological restoration of river Billstaån. As neither of these two frameworks are meant to assess ecological restoration efforts adjustments and alternations to their standard procedures were made to better fit the Billstaån case and the methodological choices are further described in this section.

2.1. Corporate Ecosystem Service Review, ESR

To conduct an initial assessment of the expected effects on ecosystem services from the restoration ESR was used, applying the first and second step of the framework to determine a study scope and generate an inventory of ecosystem services impacted by the restoration and defining ecosystem services important for the restoration outcome. ESR has been deemed feasible for immediate widespread use as a screening tool suitable for scoping assessments prior to more detailed studies (Bagstad et al., 2013), as well as suggested as a good starting point for exploration of ecosystem services and their relation to business performance (WBCSD, 2013). The requirements on expertise and input data for ESR are relatively low, being mainly user-based;

accessible from internal company knowledge, or being relatively easy to access in published research. ESR was thus considered as a good choice for assessing the ecological restoration in Billstaån, even though Jämtkraft AB is not the only stakeholder in the project.

ESR is developed for assessing dependence and impact on ecosystem services from an activity, directed towards the business world (Hanson et al., 2012; WBCSD, 2013). The assessment is qualitative and defines priority services, which are further investigated towards business planning and company policy making to limit unsustainable use of resources and benefit marketing, etc. ESR defines priority services based on connections to business results but as the focus of assessing Billstaån was the expected restoration outcomes, the weighting to define important services was instead based on future monitoring interest and possibilities for monetary valuation of services (Tellström, 2015). While assessing the river restoration the later steps of ESR, directed towards concrete business operations, were not included as they were not relevant for the restoration setting.

The ESR assessment was conducted within a system boundary including the water body and 100 m from shoreline (Tellström, 2015), based on Swedish shoreline protection legislation (Swedish Environmental Code, 2009:532). This area represents the area where restoration measures will take place and ecosystem services directly related to the river are present, including some parameters from the surrounding landscape while maintaining focus on the river ecosystem. The option to review the river catchment area was discussed, as that level is sometimes suggested as most accurate for investigating water habitats, but it was dismissed as the restoration measures will only have direct impacts on a local level.

2.2. Toolkit for Ecosystem Service Site-based Assessment, TESSA

TESSA was used to quantify values on some ecosystem services in connection to the restoration and to start exploring the future alternate state of Billstaån as a restored river. TESSA is intended for assessment of sites important for biodiversity, under threat from exploitation, to provide material that can inform decision makers and impact development plans (Peh et al., 2013; Peh et al., 2014). The framework includes a number of services commonly interesting and important for such cases. The method was used as it might have been used on a consultant basis. The time limit was set to three weeks. Time, available data and laboratory resources at Mid Sweden University gave which methods that were used out of the available ones in the TESSA toolkit. Nine of the 27 methodologies in the framework were used, several of them being slightly altered to better suit the setting and information available for the site in Billstaån (further details in Tellström, 2016). Material from the restoration project funding application was used as a basis for collecting information and was further complemented with literature studies, field measurements, and interviews with stakeholders directly involved in the restoration project as well as stakeholders in the local vicinity of Billstaån.

2.3. Scope: Assessed ecosystem services

The ESR assessment of Billstaån included the 29 ESR framework standard services, covering provisioning, regulating, cultural and supporting services. Two additional services were added due to importance in the restoration setting: *energy provisioning*, to be able to indicate the importance of the current hydro-electrical production taking place in Billstaån; and *recreational fishing*, to directly address the fishing interest used as a main argument for the restoration efforts and not only include it as one of many activities included in the ESR service recreation and ecotourism (Tellström, 2015). Energy provisioning is not commonly considered as an ecosystem service, e.g. in CICES it is included as a *benefit* that can be acquired from ecosystem but requires input from technical inventions for extraction (Turkelbloom et al., 2014), but it was added within the frame of ESR to represent the business interests of Jämtkraft AB. In the TESSA assessment of Billstaån, ecosystem services connected to global climate regulation, water, wild goods and nature-based recreation were included. Data on carbon storage, water quality, flood protection, timber value, visitor numbers and visitor interests were collected and assessed (Tellström, 2016). Services included in TESSA but not assessed for Billstaån are found in the TESSA categories cultivated goods and harvested wild goods, which were hard to assess due to the small size of the assessed area and lacking information.

As further described in Table 1 the two assessment frameworks have some overlap in terms of assessed ecosystem services, but all services were not directly transferrable between the frameworks.

Table 1. Ecosystem services included in ESR and TESSA, respectively, and notation on what services were included in this study and assessed by both frameworks.

Ecosystem services assessed in the ESR of the restoration in river Billstaån	**Corresponding ecosystem service category in TESSA**	**Services included and assessed by both frameworks**
Crops	Cultivated goods	
Livestock	Cultivated goods	
Capture fisheries	Harvested wild goods	
Aquaculture	Cultivated goods	
Wild foods	Harvested wild goods	
Timber and other wood fibres	Cultivated goods / Harvested wild goods	Yes
Fibres and resins	Cultivated goods / Harvested wild goods	
Animal skins	Cultivated goods / Harvested wild goods	
Sand	Harvested wild goods	
Ornamental resources	Cultivated goods / Harvested wild goods	
Biomass fuels	Cultivated goods / Harvested wild goods	
Freshwater	Water-related services	Yes
Genetic resources	-	
Biochemicals, natural medicines, and pharmaceuticals	Cultivated goods / Harvested wild goods	
Maintenance of air quality	-	
Global climate regulation	Global climate regulation	Yes
Regional/local climate regulation	-	
Regulation of water timing and flows	Water-related services	Yes
Erosion control	-	
Water purification and waste treatment	Water-related services	Yes
Disease mitigation	-	
Maintenance of soil quality	-	
Pest mitigation	-	
Pollination	-	
Natural hazard mitigation	-	
Recreation and ecotourism	Nature-based recreation	Yes
Ethical and spiritual values	Nature-based recreation	Yes
Educational and inspirational values	Nature-based recreation	Yes
Habitat	-	

Energy provisioning	-	
Recreational fishing	Nature-based recreation	Yes

3. Results

3.1. Assessment of restoration project efforts in terms of ecosystem services

Two frameworks for ecosystem service assessment have been tested: *Corporate Ecosystem Service Review* (ESR) and *Toolkit for Ecosystem Service Site-based Assessment* (TESSA). Both frameworks have been useful for assessing the expected development of Billstaån, but each of them have specific limitations. While ESR was good for qualitative scoping and defining important ecosystem services, the corporate focus made the later steps of the ESR framework hard to implement in this type of case. TESSA worked well for providing tools for quantitative assessment, but at present the number of services covered by the toolkit was limited.

Table 2 gives a summary of the results from the ESR and the TESSA assessments of the river Billstaån restoration project, including priority services identified in ESR and the selected services assessed by TESSA. Full results can be found in the two assessment reports, concerning ESR and TESSA, respectively (Tellström, 2015; Tellström, 2016). As can be seen in Table 2, only four services could be assessed from qualitative information in ESR into monetary values endpoints using TESSA tools. This was partly because TESSA did not provide assessment methodologies for all ESR priority services. The present toolkit for water-related services covered by TESSA does not include methodologies that generate results that can be transferred into monetary values.

The four services that was possible to follow through the table (both assessing their qualitative importance for the project and giving approximate monetary values of their potential change) was *timber and wood fibres*, *global climate regulation*, *recreation and ecotourism*, and *recreational fishing*. Out of these, only the recreational services were considered as a priority service in ESR. Out of the services assessed by TESSA, freshwater was also a priority service in ESR, but the measurements on water quality was not transferable into a monetary value. Thus, we could identify that that TESSA at the time of this assessment did not cover all services suggested as priority services by the ESR assessment.

When applied in the assessment settings of the restoration of river Billstaån, ESR was found basically to process existing internal knowledge and complement it with general research, while TESSA addressed collection of external information from e.g. site measurements and stakeholders outside the assessors group. Compared to TESSA, ESR provided a greater opportunity for capturing the importance of factors which had not been considered earlier (and transfer them into ecosystem services) by initially suggesting inclusion of a large number of services into the assessment. TESSA, on the other hand, provided a more developed methodological basis which could be directly transferred into monitoring of ecosystem service development at the site, after the restoration has been finished. The TESSA alternate state perspective also supports to consider and to present expected restoration outcomes in a more structured way than from working with ESR.

3.2. Observations on usability of the frameworks

In the ESR assessment several issues related to the framework scope emerged during the study, partly relating to how the restoration project is not company-owned and includes stakeholders with low direct economic interest in the outcome (but are more aligned towards ecological and possible social benefits). The ownership situation was known in advance, but was not considered as the obstacle it turned out to be. As a tool for initial ecosystem services assessment ESR helped in the process of starting the translation of expected restoration outcomes into ecosystem services thinking, but the strong business focus in ESR led to final results that do not apply to the information needs in an ecological restoration context. Choice of assessment perspective for the ESR turned out to be a challenge, indicating how both dependency and impact related to ecosystem services and such analysis depends on both timeframe and scale considered (in turn depending on the viewpoints of the assessor/s). Another problem encountered due to the strict form of working with the ESR impact matrix is how some services could not attain a priority service status due to gaps in knowledge, posing as risk factors in projects at this scale. Relating to this is the difficulty in knowing when the ESR impact matrix could be considered complete in terms of information quality, indicating a need for internal as well as external knowledge connected to the assessed activity.

TESSA is meant for application in areas threatened by exploitation, which is not the case for river Billstaån as the intent behind ecological restoration is to directly enhance and fortify biodiversity. As such, for the Billstaån case, this made some of the TESSA process and guidelines less obvious in terms of interpretation. The reversed approach in terms of expected development for the assessed site also indicated how it generally is much harder to establish gains from changes to an ecosystem than valuing the losses from removed ecosystem services. Describing the alternate scenario thus turned out more speculatively than expected, suggesting some limitation for such efforts when applied to cases outside the scope suggested by TESSA.

As the TESSA toolkit does not include support to weigh the importance of the ecosystem services included in the framework methodology compared to other services in the ecosystem as a whole, the relevance of the assessment results compared to the total ecosystem service output from the system was hard to establish. This became evident since the ESR, covering a larger number of services, had been done and most of the services pointed out as important by ESR was not included in TESSA. Furthermore, this indicates assessments based on TESSA alone can have problems to determine if the assessed services are the services most relevant for the investigated site, its beneficiaries and the prospected development. TESSA is still very usable for making an assessment of some values on the certain ecosystem services included in the framework and for capturing the alternate state as a future scenario for the investigated site.

4. Discussion

The ESR and TESSA frameworks differs both in terms of number of ecosystem services assessed and how they are categorised. ESR is based on the nomenclature used in the Millennium Ecosystem Assessment, while TESSA divides ecosystem services into categories based on types of services that can be assessed using similar methodologies. ESR aims to sort available information into the ecosystem service concept and to provide an overview of plausible impacts from an activity on ecosystem services. TESSA is more focused on making measurements on site and collect quantifiable data directly from stakeholders. These differences give different levels of ambition driving the information collection processes and for necessary structure of such efforts, even though both ESR and TESSA are intended for use by non-experts in ecosystem service assessment.

The results of this study indicate that ESR and TESSA mainly are suitable for different types of assessment goals. In an ecological restoration setting, as the project in river Billstaån, neither of them provided all the information desired. By combining ESR and TESSA an overview of expected restoration impact on ecosystem services and more detailed studies on certain services could be managed. It should be noted that in another case the services covered by TESSA could have been more the same services as the ESR priority services making the quantitative assessment from TESSA more interesting.

Table 2. Total ecosystem service assessment efforts towards describing the expected ecological restoration outcomes in river Billstaån as ecosystem service effects.

ESR					TESSA			
Ecosystem services	**Assessed levels of dependence and impact**	**Identified monitoring interests**	**Identified market connectors**	**Considered as priority service**	**Corresponding TESSA service category**	**Tool used**	**Generated quantitative values**	**Generated monetary value**
Timber and wood fibres	Medium / Unknown	Not investigated further (since not high/high regarding dependence/impact)	-	No	Harvested wild goods	Wild goods M4	Yes	55 - 600 SEK/year based on type of extracted goods from 2.4 ha future forest in the Ävjan area
Freshwater	High/ High	Water quality; freshwater pearl mussel population	Prices on drinking water	Yes	Water-related services	Water M5	Yes	Quantitative values for this service were water sample data, not estimated into monetary terms
Global climate regulation	High / High	Carbon capture capability; energy production	Carbon taxation	No	Global climate regulation	Climate M1, M2, M5, M7	Yes	320 000 – 496 000 SEK/year in CO_2 emission licenses representing carbon capture of 3.2 ha future forest in Ävjan
Regulation of water timing and flows	Unknown/ High	Not investigated further (since not high/high regarding dependence/impact)	-	No	Water-related services	Water M1, M3	Only qualitative assessment of flood protection was carried out	No quantitative data for monetary valuation accessible
Erosion control	High / High	River depth; soil removal rate	Costs for restoring river depth or riverside	Yes	No correspondence with TESSA services	-	-	-
Recreation and ecotourism	High / High	Visitor numbers; fishing licenses; local business development	Guest nights; general local turnover; property price development; maintenance costs for bridges, parking lots, etc.	Yes	Nature-based recreation	Recreation M1	Yes	1 000 000 SEK/year from turnover of restaurant in old mill; 24 000 – 28 000 SEK/year from ticket sales to *Årets Näck*
Habitat	High / High	Observed species (populations and/or individuals); biological indicators	SEK/kg caught fish; savings from not implanting fish	Yes	No correspondence with TESSA services	-	-	-
Energy provisioning	High / High	Energy production; efficiency changes	Energy prices; maintenance costs at hydropower facilities	Yes	No correspondence with TESSA services	-	-	-
Recreational fishing	Medium / High	Not investigated further (since not high/high regarding dependence/impact)	-	No	Nature-based recreation	Recreation M1	Yes	73 000 SEK/year estimated value on sold fishing permits

The importance of the services that presently are not covered by tools in TESSA would have been less evident if the ESR had not been carried out. The results of the total effort for assessing restoration outcomes as ecosystem services in the Billstaån case show how a combination of ESR and TESSA can provide deeper understanding of ecosystem service assessment results, in terms of interpretation, and how ecosystem service impact can be presented in different manners towards various interested parties.

Ecosystem service assessment seems to be potentially useful in terms of considering impact for more stakeholders and adding socio-economic factors to what is considered as the total restoration project results. Through this departing from common ecological monitoring it is also possible to increase and expand communication of restoration results to include material more easily approached by various stakeholders and decision makers. It has thus been proved how ecosystem service thinking generates new information that gives a more balanced picture of the planned activities in terms of restoration effects on the river ecosystem while including people as beneficiaries in addition to biodiversity in general. A main use for the assessment results probably will be in future communication of the restoration outcome and in relation to monitoring the restoration impact on the local area.

ESR and TESSA address different issues, sustainable business development and sustainable land use respectively. Put together the assembled results provide an interesting scale in terms of the various levels of investigation, intended uses and possible future application for the ecosystem service concept. Both ESR and TESSA provided new information for the restoration project in Billstaån, but not in a way directly transferrable into operational practice within the project. ESR contains steps for business planning, but those steps were not pursued due to no direct business motivation for the restoration. TESSA contains sections on how to present assessment results to decision makers, but as the decision makers in the Billstaån case already have decided to do something capturing the usability of the assessment results is more complex. The results this far is thus a complementary part of analysing the expected restoration impact, which could be further developed into direct actions included in the restoration to improve its performance in ecological as well as socio-economic terms. Further research efforts can be directed towards how the assessment results from ESR and TESSA can be presented and integrated in the restoration of river Billstaån for the benefit of the assessed area.

5. Conclusions

Hydropower is important for provisioning of energy, but the ecological effects to watersheds and rivers used for hydro-electrical production has gained increased attention in recent years. Projects to mitigate such impacts while maintaining hydro-electrical production are presently discussed. One such project is planned in river Billstaån, Sweden.

By assessing the expected outcomes of the restoration of river Billstaån as ecosystem services knowledge about the restoration impact has been transferred into the ecosystem service concept. The two frameworks used, ESR and TESSA, was manageable for arranging already existing information about the restoration project into ecosystem services as well as collecting new information to estimate some service values. Both ESR and TESSA provided interesting results, but both frameworks also lacked inclusion of important factors in the ecological restoration setting.

ESR was used to get an overview of ecosystem services in relation to the expected restoration outcomes and for identification of five priority services, having high impact on the restoration outcomes as well as having high dependence on the service to achieve the desired results. As the restoration of Billstaån is outside the business focus of the ESR framework, several of the later steps in ESR were not applicable.

TESSA worked well for providing tools for quantitative assessment, and some TESSA results could be translated to monetary values, but at present the number of services covered by the toolkit was limited. TESSA included no tools to assess if the services covered in the framework are the most relevant for the investigated site. Several of the ecosystem services indicated as priority services for the Billstaån case by ESR was not covered by TESSA. It is possible that in other cases the identified priority services could align better with the services covered in TESSA.

Both frameworks indicate that negative impacts on the ecological status of river Billstaån can be mitigated by the restoration measures as studied when using the concept of ecosystem services. The estimated monetary values from TESSA indicate that at least at society level there actually is a pay-back time for the river Billstaån restoration project, meaning the project is not solely a cost to achieve better ecological standard in the river.

This study has shown that ecosystem service assessment provides a complementary perspective of the value of increasing ecological status in rivers affected by small-scale hydropower, but also that the ecosystem services methodology needs further development for this type of case.

References

Bagstad, J. K. , Semmens, D. J. , Waage, S. , Winthrop, R., 2013. A comparative assessment of decision-support tools for ecosystem services quantification and valuation. Ecosystem Services, nr. 5 2013, p. 27-39.

Degerman, E., Alexanderson, S., Bergengren, J., Henrikson, L., Johansson, B-E., Larsen, B.M. & Söderberg, H., 2009. Restoration of freshwater pearl mussel streams. WWF Sweden, Solna.

European Commission, 2015. Ecological status and intercalibration.

Fakari Rad, M., Fröling, M. Grönlund, E., 2012. Including Ecosystem Services in Sustainability Assessment of Forest Biofuels. World Bioenergy 2012 Proceedings, The Swedish Bioenergy Association, 2012, p. 75-78. http://www.diva-portal.org/ (accessed 15.04.2016)

Gomez-Baggethun, E., de Groot R., Lomas L.P., Montes C. (2010). The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes. Ecological Economics, nr. 69, p. 1209-1218.

Hanson, C. , Ranganathan, J. , Iceland, C. , Finisodre, J., 2012. The corporate ecosystem services review: guidelines for identifiying business risks and opportunities arising from ecosystem change. Version 2.0. Washington, DC: World Resources Institute. http://www.wri.org/publication/corporate-ecosystem-services-review (accessed 15.04.2016)

Jämtkraft AB. (2015a). Miljökonsekvensbeskrivning angående anläggande av vandringsvägar och utrivning av damm i Billstaån.[Environmental impact assessment concerning construction of fauna passages and deconstruction of reservoir in Billstaån].

Jämtkraft AB. (2015b). Samrådsunderlag angående anläggande av vandringsvägar och utrivning damm i Billstaån: Billsta kraftverk, Strömbacka kraftverk, Ävjandammen och Näktens regleringsdamm [Consultation paper concerning construction of bypass channels and deconstruction of dam in Billstaån: Billsta power plant, Strömbacka power plant, the Ävjan dam and regulating dam of Näkten].

Jämtkraft AB. (2015c). Års & Hållbarhetsredovisning 2014 [Annual & Sustainability report 2014].

LIFE, 2015. LIFE - Triple Lakes: Catchment restoration and preventive action for aquatic habitats in a climate change perspective. http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=5033&docType=pdf (accessed 15.04.2016)

Länsstyrelsen Jämtlands län [County Administrative Board of Jämtland], 2012. Biotopkartering

2010: Jämtlands län [Biotope mapping 2010: County of Jämtland]. Reference Nr: 582-8016-2011.

MEA: Millennium Ecosystem Assessment. (2005). Ecosystems and Human Well-being Synthesis. Island Press, Washington, D.C., United States of America.

Naturvårdsverket [Environmental Protection Agency]. (2015b). Ett rikt växt- och djurliv [A Rich Diversity of Plant and Animal Life]. Miljömålsportalen. Available at: http://www.miljomal.se/sv/Miljomalen/16-Ett-rikt-vaxt--och-djurliv/ (accessed 15.04.2016)

Naturvårdsverket [Environmental Protection Agency]. (2015a). Levande sjöar och vattendrag [Flourishing Lakes and Streams]. Miljömålsportalen. Available at: http://www.miljomal.se/sv/Miljomalen/8-Levande-sjoar-och-vattendrag/ (accessed 15.04.2016)

Naturvårdsverket, 2007. Bilaga A till handbok 2007:4: Bedömningsgrunder för sjöar och vattendrag [Appendix A for handbook 2007:4: Assessment criteria for lakes and streams] . Available at: https://www.naturvardsverket.se/Documents/publikationer/620-0148-3.pdf (accessed 15.04.2016)

Nöbelin, F., 2014. Naturliknande fiskvägar i södra Sverige [Nature-like fish ways in southern Sweden]. Havs- och vattenmyndigheten, rapport 2014:11. Havs och Vattenmydigheten [Swedish Agency for Marine and Water Management], Göteborg, Sweden. Available at: https://www.havochvatten.se/download/18.41e6a25314de0341350b797d/1445857638411/rapport-2014-11-naturliknande-fiskvagar.pdf (accessed 15.04.2016)

Peh K.S.-H, Balmford A.P. , Bradbury R.B. , Brown C. , Butchart S.H.M. , Hughes F.M.R. , Stattersfield A.J. , Thomas D.H.L , Walpole M. , Birch J.C., 2014. Toolkit for Ecosystem Service Site-based Assessment (TESSA) Version 1.2.

Peh K.S.-H., Balmford A.P., Bradbury R.B., Brown C., Butchart S.H.M., Hughes F.M.R., Stattersfield A.J., Thomas D.H.L , Walpole M., Bayliss J., Gowing D., Jones J.P.G, Lewis S.L., Mulligan M., Pandeya B., Stratford C., Thompson J.R., Turner K., Vira B., Willcock S., Birch J.C. (2013). TESSA: A toolkit for rapid assessment of ecosystem services at sites of biodiversity conservation importance. Ecosystem services, nr. 5, p. 51-57.

Smith A. and Jepsen S., 2008. Overlooked Gems: The Benefits of Freshwater Mussels. Available from: http://www.xerces.org/wp-content/uploads/2009/01/mussel_article.pdf (accessed 15.04.2016)

Swedish Environmental Code, 2009. Lag (2009:532). Strandskyddsområde. Kapitel 7, paragraf 14. [Law (2009:532). Shoreline protection. Chapter 7, paragraph 14].

Swedish National Heritage Board, 2016). Fornsök. Availailable at: http://www.fmis.raa.se/cocoon/fornsok/search.html?utm_source=fornsok&utm_medium=block&utm_campaign=ux-test (accessed 15.04.2016)

TEEB: The Economics of Ecosystems and Biodiversity. (2010). The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB.

Tellström, S. (2015). Priority ecosystem services connected to the restoration of river Billstaån: Findings from Corporate Ecosystem Service Review. Mid Sweden University, Östersund. Available at: http://www.diva-portal.org/ (accessed 15.04.2016)

Tellström, S. (2016). TESSA valuation of effects on ecosystem services from the ecological restoration of river Billstaån. Mid Sweden University, Östersund. Available at: http://www.diva-portal.org/

Triple Lakes, 2016. Super restoration - Billstaån. http://triplelakes.se/index.php/en/project-actions/super-restoration-billstaan (accessed 15.04.2016)

Turkelbloom F. , Raquez P. , Dufrêne M. , Raes L. , Simoens I. , Jacobs S. , Stevens M. , De Vreese R. , Panis J.A.E. , Hermy M. , Thoonen M. , Liekens I. , Fontaine C. , Dendoncker N. , van der Biest K. , Casaer J. , Heyrman H. , Meiresonne L. , and Keune H., 2014. CICES Going Local: Ecosystem Services Classification Adapted for a Highly Populated Country. Ecosystem Services, 1st edition, Elsevier, Boston. Editors: Sander Jacobs, Nicolas Dendoncker, Hans Keune, p.223-247.

WBCSD: World Business Council for Sustainable Development, 2013. Eco4Biz: Ecosystem services and biodiversity tools to support business decision-making. Version 1 April 2013.

VISS: Vatteninformationssystem Sverige [Water Information System Sweden], 2016. Billstaån - SE695108-144630.

The Role of Re-vegetation on Carbon CycleS Management on the Rehabilitation of Open-Coal Mining Area at Tropical Region

Cahyono Agus[1], Pamungkas B. Putra[1,2], Eny Faridah[1,3], Richard R.P. Napitupulu[1,4], Dewi Wulandari[1,5)]

[1]Faculty of Forestry UGM Yogyakarta, Indonesia. Email: cahyonoagus@gadjahmada.edu

[2]Ministry of Environment and Forestry, Indonesia. Email: pamungkas_buanaputra@yahoo.co.id

[3]Faculty of Forestry UGM Yogyakarta, Indonesia. Email: enyfaridah@ugm.ac.id

[4]Faculty of Agriculture, Universitas Jambi, Indonesia. Email: napitupulu_richard@yahoo.co.id

[5]SEAMEO BIOTROP, Bogor, Indonesia. Email: d.wulandari@biotrop.org

Abstract

Open mining is one of anthropogenic disturbance in tropical forest ecosystem that drastically leading on land degradation and damages. Rehabilitation of extremly degraded areas in post open-mining through re-vegetation by fast growing species is expected to speedly recovering the organic-carbon stocks and their cycles. The purposes of the study were to measuring 1) carbon stock in the aboveground biomass, understorey, forest floor, and soil; 2) CO_2 emissions of soil respiration. The study was conducted in the coal mine concession area of PT. Berau Coal, at Site Binungan in Berau, East Kalimantan, Indonesia in September to October 2014. Data were collected from 10 plots that representing the ecosystem dynamics of coal mining land, consist of: secondary forest, degraded forest; non-active mining pits; backfilling post-mining; re-vegetation forests of the stands of 2 years-old Johar (*Senna Siamea);* 1, 3 and 7 years-old of Sengon (*Paraserianthes falcataria);* mixed forest of 7 years-old of Sengon (*Paraserianthes falcataria) and* 3 years-old of meranti (*Shorea sp.)*, and mixed forest of 9 years-old of mangim (*Acacia mangium)* + 2.6 years-old *Shorea sp.* Allometric method was used to calculate the aboveground biomass and their carbon stocks. Destructive method was used to obtain the biomass of understorey, litters, and soil organic carbon. CO_2 emissions of soil respiration were measured using method of dynamic closed-box with IRGA type EGM 4 PP Systems. Re-vegetation by fast growing species of *Acacia mangium* until the age of 9 years-old showed that carbon stocks at aboveground biomass was 45 Mg $C.ha^{-1,}$ that getting closer to the former stock at secondary forests (74.1 Mg $C.ha^{-1}$). Revegetation by fast growing plantation forest (1 to 9 years-old) had the total carbon stocks about 0.19 to 0.95 Mg $C.ha^{-1}$. Litters in the 1 to 9 years-old re-vegetation forest floor stored 0.12 to 4.97 Mg $C.ha^{-1}$. Soil organic carbon in the secondary natural forest which previously was 28.5 $Mg.ha^{-1}$ decreased to 4.3 $Mg.ha^{-1}$ due to forest-clearing and open pit coal mining, but, gradually increased again to 23.2 $Mg.ha^{-1}$ after 9 years revegetation of *Acacia mangium* plantation. The high production of CO_2 from soil respiration of 1,173 mg CO_2 $m^{-2}h^{-1}$ occurred in the secondary forests, but decreased to 583.3 mg CO_2 $m^{-2}h^{-1}$ since the backfilling process. Nevertheles, soil respiration rate increased along with re-vegetation ages, with the highest rate (1,334 mg CO_2 $m^{-2}h^{-1}$) at the 7-year-old of N-fixer species of *Paraserianthes falcataria*, because of high quality organic matter and higher microbial activities. Environmental restoration in open coal mining areas through re-vegetation by fast growing plantation will restore their carbon stocks and carbon dynamic, nearly similar to their former secondary forest conditions.

Keywords: global carbon change, open coal mining, revegetation, soil CO_2 emissions, tropical forest.

1. Introduction

Coal mines become one of anthropogenic disturbance on tropical forest ecosystem drastically leading on land degradation and damage. It is the impact of coal exploitation process using surface mining method by dismantling the vegetation, soil and rock. These activities includes the change of landscape, the change and loss of the stands structure, the increase of greenhouse gases, the decrease in soil productivity due to changes in the nature and condition of the physical, chemical and biological properties of soil such as the decrease of soil pH and the increase of soil solubility of heavy metals (Uchijima, 1991 in Kobayashi, 2004; Widyati, 2009; Ussiri *et al.*, 2014). Environmental damage may be worse as post-mining land left opened without any restoration and rehabilitation efforts.

Deforestation due to mining also raises carbon emissions of greenhouse gases such as carbon dioxide. Related to the issue of global warming and climate change, land clearing and conversion to mining would surely become the spotlight of the world. Mining causes a change in the balance of the natural carbon cycle as it accelerates the dismantle of carbon sinks into the atmosphere from fossil fuel and terrestrial biosphere reservoirs in the form of organic compounds in vegetation, aboveground and soil residual organic matter biomass (Rustad *et al.*, 2000; Raich and Tufekcioglu, 2000).

The considered issue of climate change and global warming related to coal mine is an attempt of reclamation/restoration of post-mining environment through rehabilitation and revegetation which able to increase carbon stocks and reduce terrestrial ecosystem carbon emissions as payoff of carbon emissions from mining activities. Meanwhile, the information on emissions and carbon sequestration in post-mining activities has not been known entirely. Therefore, a study on carbon cycle and the factors controlling the emission of various patterns of post-mining rehabilitation is needed. The result is expected to provide a guide for post-mining reclamation, rehabilitation, and revegetation aligned with the reduction of CO_2 emissions.

This study aimed to compare soil carbon emissions of various terrestrial ecosystems in the coal mine area; and to measure the carbon balance of terrestrial ecosystems in the coal mining area at tropical region.

2. Methods

The study was conducted on 25 September – 5 October 2014 in the coal mine concession PT. Berau Coal Site Binungan in Sambaliung, Berau District, East Kalimantan (102^0 35' 02'' – 102^0 37' 03'' east longitude and 03^0 53' 35'' – 03^0 55' 37'' north latitude). The precipitation analysis in Januari 2000 - Desember 2012 indicated Type B climate. The annual mean precipitation of 2,134 mm/year, the highest was in 2010 of 3,725 mm/year and the lowest was in 2004 of 1,253 mm/year.

Data were collected from 10 plots representing the terrestrial ecosystem dynamics in the coal mine areas are: HD0 (secondary forest); HT0 (post-clearing forest); HT1 (non-active post-mining forest); HT2 (backfilling post-mining forest); HJ2 (2-year-old johar revegetation forest); HS1 (1-year-old sengon revegetation forest); HS3 (3-year-old sengon revegetation forest); HS7 (7-year-old sengon revegetation forest); HS9 (9-year-old sengon + 2.8-year-old meranti revegetation forest); and HM9 (9 year-old acacia mangium + 2.6-year-old meranti revegetation forest).

Each plot was established in each observed ecosystem purposively. The site is determined after the survey of observed ecosystem type throughout the mining concession therefore the plot can represent the condition of various ecosystems.

Measurement of soil carbon dioxide emission rate was conducted by sample plot establishment of 50 cm x 50 cm quadrant of 5 replicates in a systematic sampling within each unit plot. Carbon dioxide emission was calculated after the removal of understorey on forest floor by using chamber of diameter of 31.4 cm and height of 15 cm connected to IRGA model EGM-4 PP System. CO_2 efflux was measured and recorded for 2 minutes with interval 20 seconds. Measurement of CO_2 emission acceleration was conducted five sub-sampling in a plot unit and each sub sampling was conducted 3 repetitions. To analyze data of IRGA, by using the equation as follows (Tagesson, 2006):

$$F = (\Delta C/\Delta T) * V^{-1} * \rho * 3600 * A^{-1}$$

Description: F= Flux/emission CO_2 of soil (mg $CO_2.m^{-2}.hour^{-1}$); $\Delta C/\Delta T$= CO_2 efflux of soil/time interval during observation (µ $mol.mol^{-1}.detik^{-1}$);V= volume of chamber (m^3); **ρ**= CO_2 density (1,9638 $kg.m^{-3}$) calculated based on 1 mol CO_2 of 44.01 kg in volume of 22.41 m^3 in STP; 3600= 1 hour in seconds; A= chamber area (m^2).

The carbon balance presented in this study solely based on carbon stocks of carbon reservoir (stands, understorey, litter and soil) (the method is not presented here), the distribution of carbon reservoirs and carbon released through soil respiration in forest ecosystems in the coal mining concession.

Results of the observation presented in descriptive quantitative. Analysis of the data used the software of Microsoft Office Excel 2007 with data tabulation and calculation in the form of tables and graphs.

3. Results

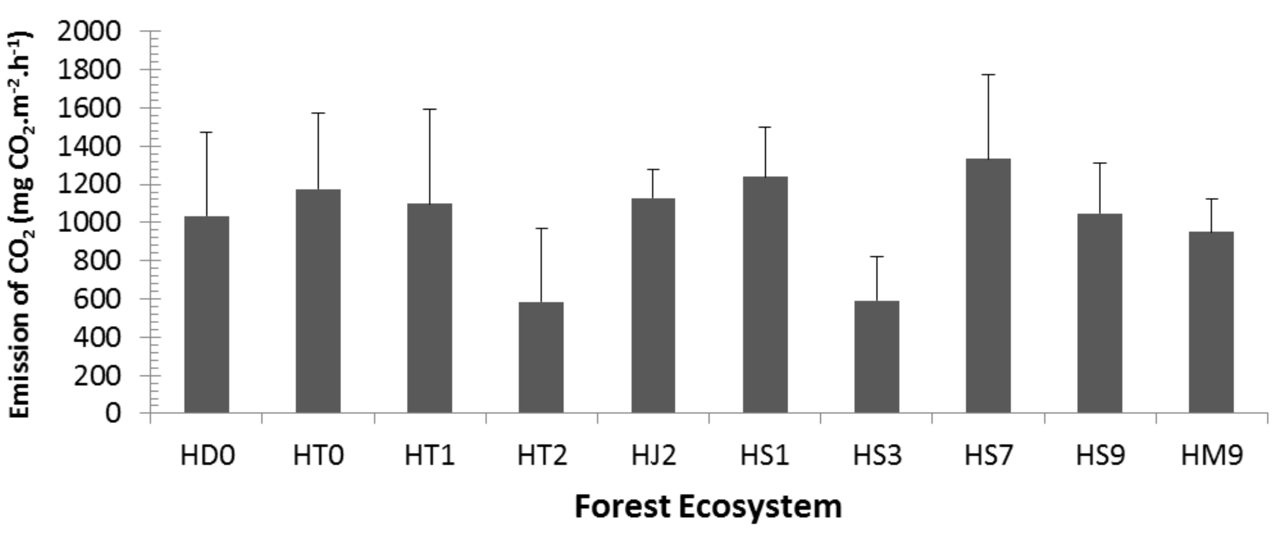


Figure 1. Mean of CO_2 emission on the surface of the soil at the period of 9:30 am to 1:00 pm in a various ecosystems in coal mining area

The results of CO_2 flux measurements and calculations (Figure 1) shows that there is a dynamics of soil emissions in different forest ecosystems in coal concessions. The mean of flux for all the observed forest ecosystems in the coal mining area subsequently from the lowest to highest are: HT2 (584.5 mg CO_2 $m^{-2}hour^{-1}$) < HS3 < HM9 < HD0 < HS9 < HT1 < HJ2 < HT0 < HS1 < HS7 (1333.7 mg CO_2 $m^{-2}hour^{-1}$).

Figure 1 shows that the variability of soil respiration is very high. Vegetation of forest cover cannot be used as the primary predictor. Same with the opinion of Raich and Schlesinger (1992) that several reports indicate that soil CO_2 emissions as the effect of land use change/land cover has increased, while others showed a decline or no change.

Table 1 illustrate terrestric carbon cycle can be disrupted due to the role of human activity. Coal mining is an example of human interference which may alter the natural carbon cycle. Logging and clearing of tropical forests for coal exploitation has increased the release of carbon through soil respiration processes, which was 24.7 Mg $C.ha^{-1}.year^{-1}$ emitted from the soil surface covered by secondary forest vegetation (HD0) to 28.0 – 26.2 Mg $C.ha^{-1}.year^{-1}$ of open land (HT0 and HT1).

The value of soil CO_2 emissions may not be significantly different, but there is a major disadvantage of the lack ability of carbon sequestration. The ecosystem HD0 even releases carbon through plant and soil respiration yet plays a major role in absorbing and storing carbon through photosynthesis. While the ecosystem HT0 and HT1 have no ability to absorb the carbon which has been released.

Damage of the forest ecosystem in the mining area will gradually recover through post-mining revegetation. Total carbon being stored in the aboveground biomass, understorey, litter and soil of 105.94 $Mg.ha^{-1}$ in secondary forests will decrease as there is land clearing into 4.29 $Mg.ha^{-1}$ and increase into 70.65 $Mg.ha^{-1}$.

While the carbon distribution in revegetation ecosystems of the 9-year-old is similar to secondary forest ecosystems (baseline) based on the composition of the carbon reservoir. The carbon distribution of understorey biomass to the total reservoir in the secondary forest ecosystem was 69.9% and in the 9-year-old revegetation forest was 63.9%. The carbon distribution of litter to total reservoir in the secondary forest ecosystems was 3.2%, while in the 9-year-old revegetation forest was 3.3%. The carbon distribution of soil to the total reservoir in the secondary forest ecosystems was 26.9%, while in the 9-year-old revegetation forest was 32.8%.

Table 1. Reservoir, distribution, and flux of carbon in various forest ecosystems in coal mine concession area

	Ecosystem									
	HD0	**HT0**	**HT1**	**HT2**	**HJ2**	**HS1**	**HS3**	**HS7**	**HS9**	**HM9**
Carbon Reservoir (Mg. ha-^{1})										
Plant:										
AGB Plants	74,05	0	0	0	1,37	0.69	3.45	43.49	28.04	44.80
Understorey	0	0	0	0	0,50±0,47	0.19±0,18	0.88±0,92	0.95±0,35	0.22±0,18	0.36±0,33
Forest Floor:										
Litter	3,39±1,07	0	0	0	0,12±0,23	0,42±0,45	0,86±1,70	4,97±2,19	1,19±1,6	2,32±1,05
oil (0-10 cm)	28,5	4,29	32,82	10,94	12,54	7,58	11,31	23,98	15,38	23,17
Total	105,94	4,29	32,89	10,94	14,53	8,69	16,5	72,44	44,83	70,65
Carbon Distribution (% total)										
Plant Biomass	69.9	0	0	0	12,9	9,9	26,2	60,6	63	63,9
Litter	3,2	0	0	0	0,8	4,7	5,2	6,8	2,7	3,3
Soil	26,9	100	100	100	86,3	85,4	68,5	32,7	34,3	32,8
Carbon Flux (Mg C.ha^{-1}.year^{-1})										
Litter	5,8	0,0	0,0	0,0	0,0	3,5	0,7	8,7	5,2	6,8
Soil	24,7	28,0	26,2	13,9	26,9	20,8	14,0	31,8	25,0	22,7

4. Discussion

Tropical forest soils have a very important role on the global carbon cycle mainly due to the issue of global warming and climate change. This is the result of the soil ability to produce and release carbon dioxide into the atmosphere. Production of carbon dioxide referred as soil respiration (CO_2 flux) is caused largely by soil organism of soil microorganism respiration during a process of organic matter decomposition and root respiration. While it partly contributed by chemical oxidation of carbon-contained soil material (Lundegardh, 1927 in Raich and Schlesinger, 1992, Schulze 1967, Konda *et al*., 2010).

The estimation value of CO_2 flux on the soil surface drawn from the entire observed ecosystems in this study tends to be higher than the result of other study on tropical areas. Plot HDO as tropical secondary forest has soil CO_2 emission value of 1089 mg CO_2 $m^{-2}hour^{-1}$, whereas other study is 838 mg CO_2 $m^{-2}hour^{-1}$ (Adachi *et al*. ,2006), 602 mg CO_2 $m^{-2}hour^{-1}$ (Raich and Schlesinger, 1992), and 343.8 mg CO_2 $m^{-2}hour^{-1}$ (Ishizuka *et al*., 2002). The same result is on *Acacia mangium* forest, in this study the value of soil respiration is 949.6 mg CO_2 $m^{-2}hour^{-1}$ while Konda *et al.* (2010) is 417.46 – 656.01 mg CO_2 $m^{-2}hour^{-1}$. The difference on the soil CO_2 emission value of this study with others can be explained as follows: The first, there are different methods of measurement. This study used closed dynamic chamber while other studies used static chamber and open chamber method. Norman *et al*. (1997); Jarvis (1997) in Pumpanen *et al*. (2004) suggest that closed dynamic chamber produce higher value of 23-36 % than static method. It is due to turbulence in the chamber by the fan (Janssens *et al.*, 2000 in Ryan and Law (2005). The second is the difference in measurement time series. The value of soil CO_2 emission of this research is the daily value which is the result of the soil surface CO_2 flux measurement without repetition. Whereas in other studies, the values of soil CO_2 emissions are is the results of serial measurements or annual mean. It is likely there are similarities in the daily emission values with the results of other studies.

The release of carbon dioxide in the soil respiration is a complex process, not merely the influence of a single process, but sometimes the lack of a process can be replaced by another process. It highlights the difficulties in the interpretation of soil respiration measurement results (Buyanovsky and Wagner, 1995 in Raich and Tufekcioglu, 2000). Change of land use/land cover for coal mining concession is very dynamic result on the change in the biomass production, organic matter, soil microorganism abundance, and microclimate of an ecosystem. Furthermore, these changes may certainly affect the dynamics of the release/carbon dioxide emission from the soil either increased or decreased.

As the forest ecosystem (HD0) turns into a disturbed ecosystem of post-mining open land (HT1) without any vegetation, it evidently has higher CO_2 emissions. Understanding the decomposition process of soil organic matter by microbiology and respiration process play a major role in soil respiration is not applicable to explain this anomalous condition. It is estimated that soil CO_2 emissions in HT1 is derived from chemical oxidation of carbon-contained soil material in this case is coal. It is contrary to Konda *et al.* (2010) states that the chemical oxidation of carbon-contained soil material has a small contribution to soil CO_2 emissions.

In HT2 ecosystem which is an open-land result of backfilling showed the lowest CO_2 emission. CO_2 efflux from the soil surface tends to increase along with the post-mining activities through revegetation. CO_2 efflux increasing trend of revegetation plots depicted as a sigmoid curve, gradually increasing at the early age stand and achieve its optimum at 7-year-old and then decreased when they are older.

In the early revegetation (HJ2 and HS1), the release of soil CO_2 tends to increase as a result of root respiration and overhaul process of organic matter by microbes. Root respiration component may be a major factor in the enhance of soil CO_2 efflux from LCC which covers most of the land revegetation. Additionally, soil temperature and light intensity factors contribute to soil CO_2 efflux.

Ecosystem in plot HS7 show the highest CO_2 efflux compared with other ecosystems. The density of forest floor covers by understorey and litter which are higher than other ecosystems significantly affects soil CO_2 release. In this ecosystem, three components of soil respiration optimally influence namely root, litter and soil organic matter respiration (Raich and Schlesinger, 1992).

Meanwhile, the CO_2 efflux measurement on ecosystem HS3 of 592.2 mg CO_2 $m^{-2}hour^{-1}$ shows contradiction on the tendency of CO_2 efflux increase of early revegetation plots. Temporary estimation on the condition is the land infertility indicated by sengon stands suboptimal growth and the presence of weeds leading to low soil respiration ability.

The role of terrestric ecosystems on global carbon cycle cannot be neglected as their capability in storing and releasing carbon. Carbon is captured from the atmosphere in the form of CO_2 through photosynthesis then stored by plants in the reservoir of living web, litter and soil carbon. Carbon is released into the atmosphere through the natural process of plant and soil respiration, and unnatural process such as anthropogenic disturbance (Ciais *et al.*, 2013).

Farrar (1985) and Amthor (1989) in Ryan (1991) explain the carbon release of the terrestric ecosystem to the atmosphere as the impact of plant respiration less than 50% from gross primary production. Plant respiration is almost the same with net primary production. Based on the explanation, the measurement of carbon release of terrestric ecosystem certainly will produce high value on vegetation-covered land than uncovered-land. However, it will be balanced with higher carbon stocks in vegetation-covered land due to its biomass production mechanism or net primary production (June et al., 2006).

Plant respiration is crucial because it has very important role in the carbon cycle in terrestric ecosystems. However, it can be presented in the study due to its difficulty. This study presents the carbon balance (Table 1) solely based on carbon stocks of carbon reservoir (stands, understorey, litter and soil), the distribution of carbon reservoirs and carbon released through soil respiration in forest ecosystems in the coal mining concession.

5. Conclusions

The release of CO_2 through soil respiration tends to increase as the tropical natural forest is opened for coal mining in the level of 1173 mg CO_2 m^{-2} $hour^{-1}$, then decreases into 583.3 mg CO_2 m^{-2} $hour^{-1}$ in the backfilling area.

CO_2 of soil respiration tends to increase as the revegetation is processed. CO_2 enhances along with the revegetation aging process with the highest on plot HS7 of 1334 mg CO_2 m^{-2} $hour^{-1}$. The height of CO_2 production is the impact of organic litter decomposition and root respiration. In the perspective of CO_2 emission, it seems having strongly negative impact, however it is positively beneficial from the perspective of land/soil productivity and vegetation growth.

Carbon balance is composed based on the parameter of carbon biomass reservoir of stand, understorey, litter, and soil; carbon reservoir distribution; and carbon release through soil respiration. The trend of increasing value of total carbon and carbon distribution pattern of its composition shows revegetation is able to restores the post-mining environment.

To reduce soil CO_2 emission, land clearing should be done right after the period of the topsoil stripping and soil cover excavation, and conducted backfilling on non-active open-pit area as soon as possible for a better result.

References

Adachi M., Y.S. Bekku, W. Rasidah, T. Okuda, and H. Koizumi. 2006. Differences in Soil Respiration Between Different Tropical Ecosystems. Abstrak. Applied Soil Ecology. 34(2-3): 258-265.

Ciais, P., C. Sabine, G. Bala, L. Bopp, V. Brovkin, J. Canadell, A. Chhabra, R. DeFries, J. Galloway, M. Heimann, C. Jones, C. Le Quéré, R.B. Myneni, S. Piao and P. Thornton. 2013. Carbon and Other Biogeochemical Cycles. In: Climate Change 2013. The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Ishizuka, S., H. Tsuruta, and D. Murdiyarso. 2002. An Intensive Field Study on CO_2, CH_4, and N_2O Emissions from Soils at Four Land-Use Types in Sumatra, Indonesia. Global Biogeochemical Cycles. 16(3): 22(1) – 22(10).

June T, A. Ibrom, G. Gravenhorst. 2006. *Integration Of NPP Semi Mechanistic – Modelling, Remote Sensing And GIS In Estimation CO_2 Absorption of Forest Vegetation In Lore Lindu National Park*. BIOTROPIA 13: 22 – 36.

Kobayashi, S. 2004. Landscape Rehabilitation of Degraded Tropical Forest Ecosystems-Case Study of The CIFOR/Japan Project in Indonesia and Peru. Forest Ecology and Management (201):13-22.

Konda R., S. Ohta, S. Ishizuka, J. Heriyanto, and A. Wicaksono. 2010. Seasonal Changes in The Spatial Structures of N_2O, CO_2, and CH_4 Fluxes from *Acacia mangium* Plantation Soils in Indonesia. Soil Biology and Biochemistry. 42:1512-1522.

Norman, J.M., Kucharik, C.J., Gower, S.T., Baldocchi, D.D., Crill, P.M., Rayment, M., Savage, K., dan Striegl, R.G. 1997. A comparison of six methods for measuring soil-surface carbon dioxide fluxes. JOURNAL OF GEOPHYSICAL RESEARCH, 102(D24): 28,771-28,777,

Pumpanen J., P. Kolari, H. Ilvesniemi, K. Minkkinen, T. Vesala, S. Niinistö, A. Lohila, T. Larmola, M. Morero, M. Pihlatie, I. Janssens, J.C. Yuste, J.M. Grünzweig, S. Reth, J.A. Subke, K. Savage, W. Kutsch, G. Østreng,W. Zieglerm, P. Anthonim, A. Lindroth, P. Hari. 2004. Comparison of Different Chamber Techniques for Measuring Soil CO_2 Efflux. Agricultural and Forest Meteorology. 123 : 159-176

Raich, J.W., dan A. Tufekcioglu. 2000. Vegetation and Soil Respiration: Correlation and Controls. Biogeochemistry. 48(1): 71-90

__________, dan W.H. Schlesinger. 1992. The Global Carbon Dioxide Flux in Soil Respiration and Its Relationship to Vegetation and Climate. Tellus. 44B: 81-99.

Rustad, L.E., T.G. Huntington, and R.D. Boone. 2000. Control on soil respiration: Implications for climate change. Biogeochemistry. 48(1):1-6

Ryan M.G. 1991. Effects of Climate Change on Plant Respiration. Ecological Application. 1(2):157-167.

Schulze, E.D. 1967. Soil Respiration of Tropical Vegetation Types. Ecological. 48(4):652-653.

Tagesson, T. 2006. Aspects of the carbon cycle in terrestrial ecosystems of Northeastern Småland. Swedish Nuclear Fuel and Waste Management. Stockholm, Sweden.

Ussiri, D.A.N., P.A. Jacinthe, dan R. Lal. 2014. Methods for determination of coal carbon in reclaimed mine soil: A review. Geoderma Journal 214-215:155-167.

Widyati, E. 2009. Kajian fitoremediasi sebagai salah satu upaya menurunkan akumulasi logam akibat air asam tambang pada lahan bekas tambang batubara. Tekno Hutan Tanaman 2 (2): 67-75.

Integrating ecosystem services into regional spatial planning: the case of Lisbon Metropolitan Area

André Mascarenhas[1,2], Tomás B. Ramos[1], Dagmar Haase[2,3], Rui Santos[1]

[1] CENSE – Center for Environmental and Sustainability Research, Departamento de Ciências e Engenharia do Ambiente, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Portugal

[2] Lab of Landscape Ecology, Department of Geography, Humboldt-Universität zu Berlin, Germany

[3] Helmholtz Centre for Environmental Research – UFZ, Germany

Abstract

The concept and framework of ecosystem services (ES) brings together different dimensions of sustainable development (ecological, social, economic). Therefore, it has the potential to support sustainable spatial planning. However, ES are still poorly integrated in spatial planning practice. Among the manifold reasons for such poor integration are insufficient knowledge, tools and data that help making explicit the ES supplied by a given territory, how they affect human well-being, how they are affected by planning decisions, as well as the trade-offs that usually spatial planning deals with. This research presents a framework for ES integration in spatial planning. The framework covers critical issues such as the identification of priority ES, the assessment of effects of land-use and land cover (LULC) changes on ES provision under alternative scenarios, as well as stakeholder engagement. The framework is tested in Lisbon Metropolitan Area (LMA), Portugal, which hosts over a fourth of the country's population and has been undergoing a suburbanization process. Highly urbanized areas co-exist with agricultural and forest areas, as well as areas designated for nature protection. Considering also that it is a southwestern European coastal region, climate change and urban-rural linkages are crucial aspects for spatial planning, a process that has to mediate conflicting LULC goals and interests. The priority ES identified, for example flood protection or climate regulation, can be regarded as nature-based solutions to tackle such planning challenges. The assessment of effects of main drivers of LULC change (e.g. population dynamics) on ES supported a critical analysis of planning options, like the Metropolitan Ecological Network, a green infrastructure for the whole region. The framework developed in this research provided several advantages for ES integration in spatial planning, for example taking into account the views and perceptions of planners and other stakeholders, alongside specific planning proposals. It also contributed with new insights for further developing strategic environmental assessment processes.

Keywords: ecosystem services; spatial planning; scenarios; stakeholder engagement; Lisbon Metropolitan Area

Problem framing of a transdisciplinary research process using the Social-Ecological framework in the montado landscape of Alentejo Portugal

Helena Guimarães, Nuno Guiomar, Diana Surová, Sérgio Godinho, Teresa Pinto Correia, Audun Sandberg, Federica Ravera, and Marta Varanda

Abstract

The montado is a high nature value farming system of the Mediterranean region with a long history of human and nature interactions. Several types of montado cover a considerable surface of the Alentejo region (Portugal). Therefore, this social-ecological system is of paramount importance to the region and has been the subject of research work for a long time. However, sixty-five years of studies regarding the montado have not been able to prevent the sustainability problems faced today. There is a need of more collective actions between relevant actors including the scientific community towards the sustainable management of the montado. Transdisciplinarity can be, thus, a mean to achieve this collective action. While putting in practice such endeavour two questions arise; how do we cope with changes and threats faced by such complex system and how do we manage knowledge? Rather than accumulate knowledge, the challenge is, integrating efforts and common reflections between science and society for an effective use. Indeed, effective use and management depends on choices made by individuals and collectives that have outcomes of a systemic character – and the feed-back of these systemic effects on the rule-making and thus on the choices made in the next turn. Therefore, the Institutional Analysis and Development framework and Social-Ecological framework were considered paramount to understand past transdisciplinarity efforts, as well as, to design future ones. The present work is aimed to apply both frameworks to identify and understand how to promote transdisciplinary processes that may contribute to the sustainability of the montado system in the Alentejo region. This empirically application was based on literature review and primary data obtained by spatial analysis, surveys and participatory approaches. Results show that the lack of consensus regarding the system boundaries is one of the major challenges in transdisciplinarity efforts, along with the size of the resource system, and current governance system. We conclude that a tailored long term transdisciplinary process should be promoted mainly based on a montado typology that should be defined by all relevant actors.

Keywords: Transdisciplinarity, sustainability, Social-Ecological Framework

Linking ecosystem services and biodiversity

Joachim Spangenberg, Josef Settele

Abstract

Biodiversity is a key ingredient for the provision of ecosystem services; without it, they would not exist. However, the relation between both is anything but linear, as has been shown in a wealth of case studies. Preserving ecosystem services has become a major policy goals on the global (UNCSD), regional (EU) and national level. The hopes are flying high that this will contribute to biodiversity conservation, but there are concerns that an ESS focus might affect conservation negatively. The aim of the paper is to structure the complex relationship in a way that encourages targeted future research, thus validating hopes for and avoiding risks to biodiversity. It also aims at systematising the way organisms are classified according to their service potentials. After clarifying the terminology, we go on to describe both sides of the coin, classifying first the services by object (with a look on trade-offs and synergies) and then the organisms by services (subdivided into three classes of organisms and their relation to service provision). This double view permits asking questions which can guide future research, if not implementation of biodiversity or ESS conservation programs. One of the reasons for widely spread confusion is that the systematiques resulting from the two different perspectives are significantly distinct, and research and policy programs taking just one of the two perspectives into account easily fall short of realising their intentions. In particular the case of organisms contributing to biodiversity without any known contribution to whatever ecosystem service deserves more attention than it is given in the current literature. More research on developing integrated perspectives is needed to come up with reliable approaches paying adequate tribute to both biodiversity and ESS. We identify some research gaps and propose research questions.

Keywords: Biodiversity, Ecosystem Services ESS, research gaps, perspectives

Methodological proposal to nationally assess the performance of the Program of Payment for Ecosystem Services (PPES) of Costa Rica

Sergio A. Molina Murillo (1), María José Avellán Zumbado (2), Carla Padilla Salas (3)

(1) National University of Costa Rica (UNA) and University of Costa Rica (UCR). Email: sergiomolina@una.cr

(2) National University of Costa Rica (UNA). Email: maria.avellan.zumbado@una.cr

(3) National University of Costa Rica (UNA). Email: carla-ps@hotmail.com

Abstract

The Program of Payment for Ecosystem Services (PPES) of Costa Rica, created in 1997 with the latest Forestry Law, is the first nation-wide program of its nature in a developing country. Its objective is to ensure the provision of environmental (ecosystem) services resulting from the protection of forest and the establishment of forest plantations by financially compensating land "owners". Although focused specifically on the protection of biodiversity and water resources, the mitigation of greenhouse gases, and the provision scenic beauty, the PPES also aims to provide developing opportunities to small farmers. With almost 20 years, the program has been the subject of study by many local and international scholars; however, there is not yet an official methodological approach to assess its performance. Given our recent experience developing an instrument for evaluating and monitoring the PPES at indigenous territories, we were approached by the Ministry of the Environment to design and pilot-test an integrated methodology to evaluate and monitor the PPES nationally. Measuring all the potential impacts is not feasible nor efficient; thus, the proposed methodology aims to evaluate nationally the PPES in several key aspects, excluding administrative ones since they are covered by an alternative protocol. After an extensive review of the literature an initial array of criteria and indicators were proposed along environmental, social and economic dimensions. Such indicators required to be valid, measurable, with periodic and accessible information, and of national coverage. The initial list (38 criteria and 54 indicators) was later refined through working meetings with personnel from the program administrators (FONAFIFO and SINAC), two workshops with key experts, and an additional personal consultation process with 20 highly involved actors. Using the classification methodology (i.e., rating each dimension or criteria from 1 to 10), the dimensions and the final 17 criteria (with 27 indicators) were weighted by 51 key actors from the academia, NGO, research institutes, independent forestry professionals, government institutions, professional societies, indigenous representatives, and key informants of SINAC y FONAFIFO. With 38.6%, the environmental dimension was weighted slightly more important than the social one with 31.3% and the economic one with 30.1%. Then, we proceeded to construct the baseline considering all 5 923 active and valid contracts for the period 2010-2014. Key results indicate that during this period the PPES covered 5.4% of the national territory, 58% of the contacts were assigned to farmers with less than 50 hectares (18% of the total available budget for the period), 16% of assigned contracts are located within indigenous territories (17% of the total available budget for the period), and 55% of contracts were located in the least developed districts of the country. It is estimated that the program generated in the field close to 30 thousand jobs, most of them not-qualified. The next assessment is schedule for the year 2020 and will consider the period 2015-2019, time when a comparison could be made. The proposed methodology provides for the first time a formal mechanism to evaluate the national Program of Payment for Ecosystem Services.

Doing good for both livelihoods and biodiversity? A framework for analysing interventions in community forestry management

Clare Barnes, Frank Van Laerhoven, Maria Joao Ferreira Dos Santos, Peter Driessen, Rachel Claus, and Mary Ann George

Abstract

Forests in developing countries are difficult to manage for livelihood benefits whilst simultaneously conserving biodiversity. On the one hand, Common Pool Resource (CPR) scholarship has shown how institutions for collective action can solve appropriation (overharvesting) and provision (underinvestment) dilemmas, thus avoiding the kind of resource collapse commonly referred to as the tragedy of the commons. Scholars associated with the Sustainable Livelihood Approach (SLA) on the other hand, can be argued to have mainly focused on the livelihood benefits associated with good forest governance. This branch of scholarship has shown how institutions for access to livelihood capitals affect forest dwellers' ability to develop sustainable livelihood strategies. In this paper we merge the two bodies of literature to create an analytical framework that can be used to analyse the impact of external actor interventions on interrelated goals of biodiversity conservation and livelihoods improvement in forest dependent communities. To create the framework, we draw on two strengths of both approaches. Firstly, we argue that a community's ability to deal with appropriation and provision dilemmas is influenced by their access to livelihood capitals (e.g. positively through knowledge of sustainable harvesting techniques, or negatively though closeness to markets) (the focus of SLA) as well as functioning forest institutions (the focus of CPR scholars). Secondly, the SLA applied to CPR contexts, can aid our understanding of the causal mechanisms between external actor interventions and a community's ability to deal with appropriation and provision dilemmas through two pathways: activities directed at facilitating forest institutions (CPR), or their access to livelihood capitals (SLA). To illustrate our framework we apply it to a case of external actor interventions in community forestry in Andhra Pradesh, India. Our data collection includes semi-structured interviews and focus group discussions in the intervention and control communities, corroborated by forest plots. We find that the focus of external actors on bamboo auctions leads to increased access to economic capital (monetary gains), human capital (bamboo auction skills) and social capital (bridging networks with external agencies) in the short term but with a negative spill over effect on nearby non-bamboo community forests. Without attention for building strong forest institutions, the early economic gains may provide an incentive to overharvest and underinvest (appropriation and provision dilemmas) and thus translate into long-term losses for biodiversity and ultimately livelihoods. Thus, the framework proves useful for analysing causal relations between external actor interventions and their influence on a community's ability to deal with appropriation and provision dilemmas, which ultimately affects forest biodiversity and livelihoods of forest dependent communities.

Keywords: Common Pool Resources, Sustainable Livelihoods Approach, development interventions, biodiversity, livelihoods

Evaluation of potential environmental impacts of forest topsoil erosion on aquatic biota: a case study in Portugal

Paula Quinteiro[a], Marijn Van de Broek[b], Ana Cláudia Dias[a], Bradley G. Ridoutt[c], Gerard Govers[b], Luís Arroja[a]

[a]Centre for Environmental and Marine Studies (CESAM), Department of Environment and Planning, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal

[b]Katholieke Universiteit Leuven, Division of Geography, Celestijnenlaan 200E, 3000 Leuven, Belgium

[c]Commonwealth Scientific and Industrial Research Organisation (CSIRO), Private Bag 10, Clayton South, Victoria 3169, Australia; and University of the Free State, Department of Agricultural Economics, Bloemfontein 9300, South Africa

* Corresponding author. Tel.: +351 234 370 349; Fax. +351 234 370 309. *E-mail address*: p.sofia@ua.pt (P. Quinteiro)

Abstract

High concentrations of suspended solids (SS), particularly in the clay and silt size fractions, can be a significant stressor to the ecological integrity of aquatic ecosystems, degrading the water quality and directly affecting the aquatic biota, namely macroinvertebrates, algae and macrophytes. The main goal of this work was to test the applicability of the method proposed by Quinteiro et al. (2015, 2014) to assess the potential damages of eroded soil on ecosystems for macroinvertebrates, algae and macrophytes. To demonstrate how this newly SS ecosystem method can help to improve the environmental assessment in forestry, results were compared with the earlier commonly used impact categories from ReCiPe method. A case study was performed for *Eucalyptus globulus* stands in Portugal. Four *E. globulus* stands installed in the *Beira Interior* and *Alto Alentejo* regions (Portugal) were studied. The functional unit was defined as one hectare of land under production forestry management. *E. globulus* is managed as a coppiced stand in short rotations of typically 12 years each during three successive coppice rotations (one revolution). The system boundary includes all the forest management operations such as site preparation, stand establishment, stand tending and felling. The relevance of the impact from SS delivery to freshwater streams is shown, providing a more comprehensive assessment of the SS impact from land use systems on aquatic environments. The SS impacts ranged from 15.5 to 1234.9 $PDF.m^3.yr.ha^{-1}.revolution^{-1}$ for macroinvertebrates, and from 5.2 to 411.9 $PDF.m^3.yr.ha^{-1}.revolution^{-1}$ for algae and macrophytes. For some stands, SS potential impacts on macroinvertebrates have the same order of magnitude than freshwater eutrophication, freshwater ecotoxicity, terrestrial ecotoxicity and terrestrial acidification impacts. For algae and macrophytes, most of the stands present SS impacts of the same order of magnitude as terrestrial ecotoxicity, one order of magnitude higher than freshwater eutrophication, and two orders of magnitude lower than freshwater ecotoxicity and terrestrial acidification. The SS impact results allow concluding that the increase of SS in the water column can cause biodiversity damage and that the calculated impacts can have a similar or even higher contribution to the total environmental impact than the commonly used ecosystem impact categories of the ReCiPe method. A wide application of the framework and method developed at a local scale will enable the establishment of a regionalised SS inventory database and a deep characterisation of the potential environmental impacts of SS on local aquatic environments.

The Water Retention Index: Using land use planning to manage water resources in Europe

Ine Vandecasteele[1*], Inés Marí i Rivero[1], Claudia Baranzelli[1], William Becker[2], *Ilda Dreoni[1], Carlo Lavalle[1], Okke Batelaan[3]*

[1] European Commission, Joint Research Centre, Institute for Environment and Sustainability (IES), Ispra, Italy.

[2] European Commission, Joint Research Centre, Deputy Director General, Ispra, Italy.

[3] School of the Environment, Flinders University, Adelaide, Australia.

*Corresponding author: ine.vandecasteele@jrc.ec.europa.eu, Tel: +39 0332783591

Abstract

Water quantity management remains an issue in Europe, resulting in numerous periods of regional flooding and drought annually. Land management can be a powerful natural approach to reduce the impacts of such fluctuations in water flow through the landscape, especially in upstream source areas. The Water Retention Index has been developed as a tool to look at the potential effects of changing land use patterns on the water retention capacity of a river catchment. It reflects the relative storage potential of water in a landscape, which can be used as a measure of the ability to regulate water flows in various land use scenarios. The index is comprised of parameters which take into account retention in vegetation, water bodies, soil, and bedrock, as well as the influence of slope and artificially sealed areas. These parameters are combined to give the final composite indicator. Since the parameters representing the contribution of vegetation, soil and sealed areas are land-use dependent, the index can also be used to assess future land use scenarios. We used the index to assess the impacts of various natural land management strategies on water retention at the Pan-European scale. Land use simulations were made using the EUCS100 model up to 2030 for 3 scenarios: increasing the relative amount of grassland in upstream areas; afforestation in upstream areas, and afforestation in riparian zones. All scenarios showed an overall improvement of the index as opposed to that for the 2030 baseline or 'business-as-usual' scenario. The scenario having the greatest effect on overall relative water retention was afforestation in upstream areas, although results varied greatly depending on the region. The Water Retention Index can be used as an indicator of potential water quantity regulation benefits of land use scenarios - it is currently being further developed for use in policy support at the European scale.

Keywords: Water retention, Soil physical properties, Land use

1. Introduction

Water quantity regulation is the capacity of the landscape to intercept, retain and store the water flowing over and through it. De Groot (2002) states that water regulation is the role of land cover in regulating runoff & river discharge. Several approaches have been taken to quantify water regulation, including using infiltration capacity and/or soil water storage capacity (Smith, 2006, TEEB, 2010, Laterra, 2012), baseflow volume (Smith, 2006), storm-water run-off (Tratalos, 2007), groundwater recharge (O'Farrell, 2010) and canopy storage or interception (Guo et al., 2000). Some studies have also estimated the total storage capacity of the landscape (Reager, 2013), as well as the time to fill this capacity (Posthumus, 2010). The majority of these methodologies, however, are data-intensive and/or require specific models to be used.

Our aim was therefore to develop a comprehensive indicator which could be calculated at a larger scale using more readily available data. The Water Retention Index (WRI) reflects the relative capacity of the landscape to regulate or retain water at Pan-European scale, using proxy data to estimate the contribution of the following physical processes:

- Interception by vegetation
- Storage in surface water bodies
- Infiltration and retention in soil
- Percolation to groundwater stores

Several land use derived parameters were included so that the indicator can be re-computed for various land use scenarios. The index can therefore be used as a measure of the effectiveness of the landscape in managing water quantity and therefore reducing the risk of both flooding and water shortages for both the current situation and future scenarios. Several potential land management scenarios were used to test the indicator. In what follows we present the methodology used to compute the index and the first results at Pan-European scale for the selected land management scenarios.

2. Methods

2.1. Compilation of the WRI

The Water Retention Index (WRI) is computed as shown in figure 1. The retention/storage components vegetation (R_v), water bodies (R_{wb}), soil (R_s), groundwater (R_{gw}) and the slope together describe the physical capacity of the land to retain water. This reflects the maximal potential retention of water in the natural environment. These parameters are given scores ranging from 0 to 10 based on their assumed impact on overall water retention according to the available literature, and combined reflect the natural retention capacity. In a final step the soil sealing is taken into account (sealed areas are assumed to have no retention capacity) to calculate the final water retention index.

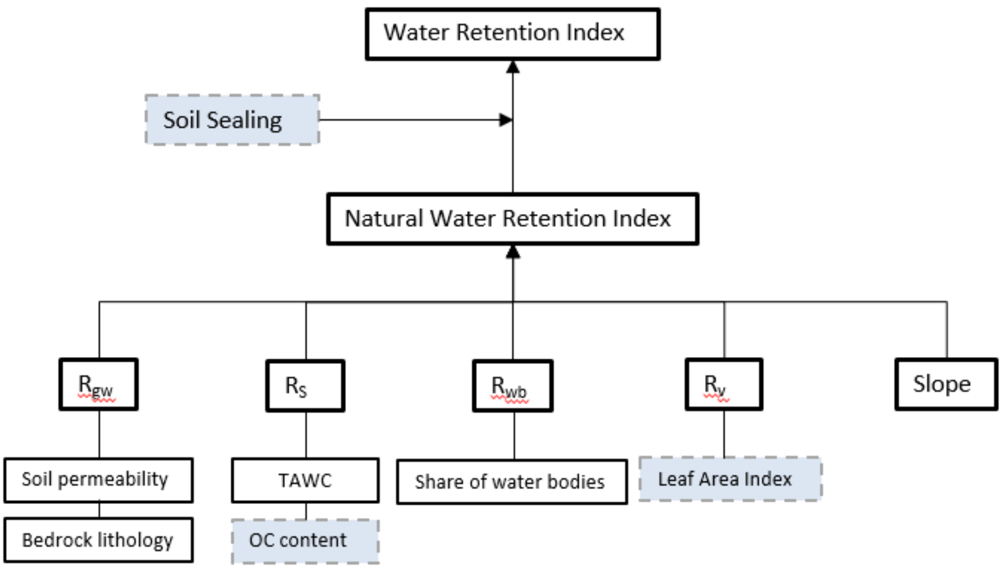


Figure 1. Schematic overview of the structure of the composite indicator. Parameters in boxes with dotted lines are updated based on land use and therefore dynamic in time.

A major requirement in developing the index was to be able to use it to assess provision of water regulating services for future land use scenarios. The land use model EUCS100 is used within the JRC Ispra for various applications, mostly related to policy assessment (Lavalle et al., 2011). The model has as base map the CORINE refined land cover for 2006 (Batista et al., 2013), and can model changing land use patterns on an annual basis up to 2050. In order to do so it combines demand-driving data from various sources with a compilation of suitability factors and allocation rules which can be altered according to the scenario parameters. The LAI and soil sealing are thus both re-computed using the simulated land use for the required year, and the R_s parameter is adjusted according to the changing organic carbon content over time. The remaining parameters are kept constant in time. Figure 2 gives shows the various input parameters for the WRI as calculated for the 2006 base year. In the following we discuss each parameter in more detail.

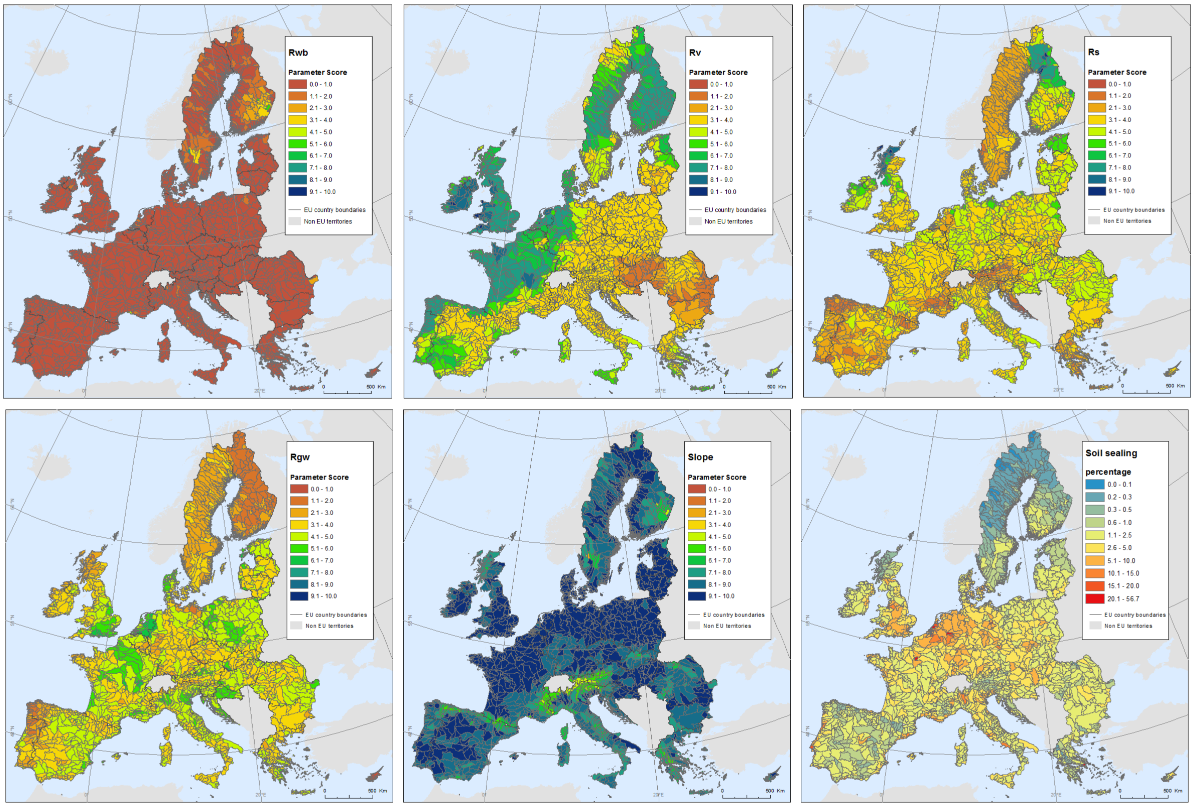


Figure 2. Overview of the input parameter scores at river basin level (all given as scores from 0 to 10 as used to compute the final index, except for soil sealing, which is given in %).

Retention in vegetation (Rv)

As in Van Dijk and Bruinzeel (2001), we assume that the canopy capacity, and therefore the potential amount of water intercepted, is linearly related to the leaf area index (LAI). The LAI gives the green leaf area coverage per unit ground surface area (Watson, 1947), and ranges from a value of zero (bare ground) to over 10 (dense forest). This is a commonly used parameter in estimating interception by vegetation (Muzylo et al., 2009). Maps of LAI can be derived from satellite imagery. We calculated the average LAI per CORINE land use class and per climate zone (Metzger et al., 2005) for the period 1999-2003. Projected LAI maps for subsequent years are re-computed directly from these average LAI values and the forecasted land use map. This makes this index dynamic in time and allows us to alter the R_v component with our simulated land use per scenario.

Retention in soil (R_s)

The potential of the soil to retain water is primarily determined by soil texture, bulk density and organic matter. The finer the texture of a soil, the greater the surface area of the particles, cohesion, and capillary rise, so the greater the potential to retain water. The highest water holding capacities, however, are found in fine rather than very fine material (Klocke & Hergert, 1990) since soils having very high clay content (so very fine textures) are usually quite compact and only semi-permeable. Organic matter has a high affinity for water, so that as the percentage of organic matter in the soil increases, the water-holding capacity increases (Rawls et al., 2003; Wang et al., 2013). For the base year, the potential soil water retention (R_s) is based on the Total Available Water Content (TAWC) from the European Soil Database (ESDB) (Hiederer, 2012) at 1km resolution. This is computed taking into account the soil texture, bulk density, organic carbon content and soil depth (Wosten et al., 1998). The map gives continuous values (between 0 and 118mm) which were re-scaled to range between 0 and 10. We used the changes in organic carbon content over time to project the Rs parameter, assuming a soil with a higher organic carbon content to have a proportionally higher water retention capacity. We estimated the average expected changes in organic carbon content with land use conversions between cropland (arable, permanent crops) - grassland (pastures, semi-natural vegetation), and forests based on an extensive review of available literature (Bormann, 2007, Bauer & Black, 1981; Bewket & Stroosnijder 2003; Breuer et al. 2006; Bronson et al. 2004; Franzluebbers et al. 2000; Murty et al. 2002; Neill et al. 1997; Strebel et al. 1988; Hajabbasi et al. 1997; Lumbanraja et al. 1998; Davidson et al. 1993; Reiners et al. 1994; Laganiere et al. 2010; Simansky et al. 2013). The expected changes per 5-year timestep are given in table 1.

Table 1. Estimated changes in soil bulk density and organic carbon content

Land use conversion	Assumed forward change →	Assumed backward change ←
Crops → Grassland	+1.25%	- 5%
Crops → Forest	+ 3.75%	- 8.75%
Grassland → Forest	+ 2.5%	-3.75%

The organic carbon was assumed to reach equilibrium in the soil after a period of 20 years (consistent with the IPCC Tier 1 approach, Hiederer, 2013; Jones et al., 2005). The relative changes expected per annum per land use conversion were calculated in 5 year timesteps between 2006 and 2030. We assumed the R_s parameter to vary directly proportionally to these potential losses or gains of organic carbon, and therefore applied the same % changes calculated for the organic carbon directly to the R_s value.

Retention in groundwater (Rgw)

The type of lithology present and its relative permeability gives an indication at this scale of how much water can infiltrate and potentially percolate down to groundwater reserves. Lewis et al. (2006) present a methodology to assign permeability indices according to the type of lithology and predominant flow mechanism (fracture, intergranular or mixed). We used a similar approach, assigning estimated permeability scores for each major lithology based on the average of the range of permeability per major lithology group reported by Domenico and Schwartz (1990), Gleeson et al. (2011), and Lewis et al. (2006), re-scaled between 0 and 10. We used the main lithology as compiled in the framework of the OneGeology project (http://www.onegeology.org/). The bedrock lithology map of Austria was integrated to complete the coverage to EU28. These average values were corrected for the influence of the surface soil typology. Unless bare rock is exposed, the permeability of the topmost soil/lithology will greatly impact the amount of water which reaches the groundwater store, and therefore also the amount which can be retained regardless of the relative permeability of the underlying bedrock. We used the Hydrological classification of soil as available from the ESDB (King, 1994) for this purpose. The 10 classes given were re-classified into 6 main categories with similar relative permeability, from very high to very low. The relative bedrock permeability was then reduced by a factor 0, 10, 20, 30, 40 or 50% depending on the hydrological category of the soil overlying it (ie. no reduction if overlying soil has very high permeability, up to 50% reduction if overlying soil has very low permeability).

Slope factor

The gentler the slope, the higher the overall water retention capacity – the greater the slope the faster the flow overland and the less time water has to infiltrate. Due to the higher erosion rates on steeper slopes, soils are also expected to be thinner and contain less organic matter. Soils in low-lying areas in contrast will be thicker, more weathered and more suited to dense vegetation cover. We used the European slope map as derived from the Global Digital Elevation Model (SRTM, NASA) (http://srtm.csi.cgiar.org/), re-scaled between 0 and 10 assuming a negative linear relationship between slope and potential water retention.

Soil Sealing

The share of impermeable surfaces directly affects the water retention capacity of a landscape. For the purposes of this indicator we assume that there will be no retention of water in completely impermeable/sealed areas, and therefore reduce the calculated natural retention directly by the degree (%) of soil sealing per unit area. In doing so we assume that water retention will only occur in non-sealed areas. In order to allow the parameter to be updated for future scenarios, we calculated the average percentage sealed area per land use class per country, based on the 2006 CORINE refined land use map and the European Soil Sealing Map (EEA, 2009). These values were then used to calculate the average soil sealing directly from the land use map for any given year.

2.1. Aggregation and Sensitivity Analysis

The aggregation of parameters in a composite indicator is a somewhat delicate step which necessarily involves subjective decisions on the weighting of each parameter. A common practice is to assign weights reflecting the belief of the importance of each parameter to the composite indicator; however, the weights do not typically reflect the true contribution of each parameter due to correlations between parameters (OECD, 2008). To understand the true importance of each parameter to the indicator, we performed a sensitivity analysis using an approach similar to that in Paruolo et al, 2013. We further adopted an optimisation procedure which iteratively adjusted the weights until the desired importance of each parameter was reached. This is explained in more detail below.

The structure of the WRI was:

$$WRI=w_{Rv}R_v+w_{Rgw}R_{gw}+w_{Rs}R_{sv}+w_{slope}\mathrm{slope}+w_{WB}R_{WB}*\left(1-\frac{R_{SS}}{100}\right) \quad (1)$$

where the *w* are the weightings to be assigned. The influence of each parameter on water retention capacity was taken to be equal. The final score reflects the relative capacity to retain water on a scale of 0 to 10 for each pixel. This map can then be further aggregated to catchment or regional level.

In order to understand the influence of each parameter for a given set of weightings, we performed a sensitivity analysis which quantified the "importance" of each variable (excluding R_{SS} which is a multiplying factor), using a variance-based approach to consider how much each indicator input contributes to var(*WRI*), the spatial ("inter-regional") variance of the WRI. To do this, we used *sensitivity indices* which measure the fraction of var(*WRI*) contributed by each parameter. The *first-order sensitivity index*, denoted S_i, i =1,2,…,k, where k is the number of input variables (in this case k=5), is defined as (Sobol, 1993),

$$S_i=\frac{\mathrm{var}[E(WRI|x_i)]}{\mathrm{var}(WRI)} \quad (2)$$

where x_i is the ith input variable to the indicator (i.e. the R_v, R_{gw}, etc.). This measure gives the fractional contribution to the (spatial) variance of the indicator, and is a widely-used measure in uncertainty and sensitivity analysis in physical sciences and engineering – see e.g. Saltelli et al., 2008 and Becker et al. 2011.

In order to calculate S_i, we adopted an approach proposed by Paruolo et al, 2013, which uses nonlinear regression. This approach is based on the fact that the expression $E(WRI|x_i)$ is essentially a nonlinear trend line through the scatter plot of WRI against x_i. Using an appropriate nonlinear regression method, one can therefore estimate $E(WRI|x_i)$ and then S_i by taking the variance of this curve. In contrast to the original approach however, we used penalised splines as the chosen method of nonlinear regression rather than local polynomial regression. For further details on this method we refer to Paruolo et al, 2013 and Ruppert, 2003.

The sensitivity indices of each input to the indicator were estimated by aggregating the WRI values to the catchment level - this was necessary because of the high number (some millions) of pixel-level data points, which caused some difficulties for the nonlinear regression. While this lost some accuracy in the estimation of sensitivity, it is still representative of the contribution of each input. A pixel-level analysis is however planned for future work.

As a starting point, a "naïve" weighting scheme was assigned, such that $wRv= wGw=wS=w\text{slope}=wWB$. The results of the sensitivity analysis using these weights are shown in Figure 3. One can notice immediately nonlinearities and skew in the distribution of each input parameter. The sensitivities are shown above each plot and also in Table 5 – they are far from the desired values, with slope for example having a higher influence than intended, with a sensitivity index of 0.5, and R_{wb} and R_{gw} having less than half the influence.

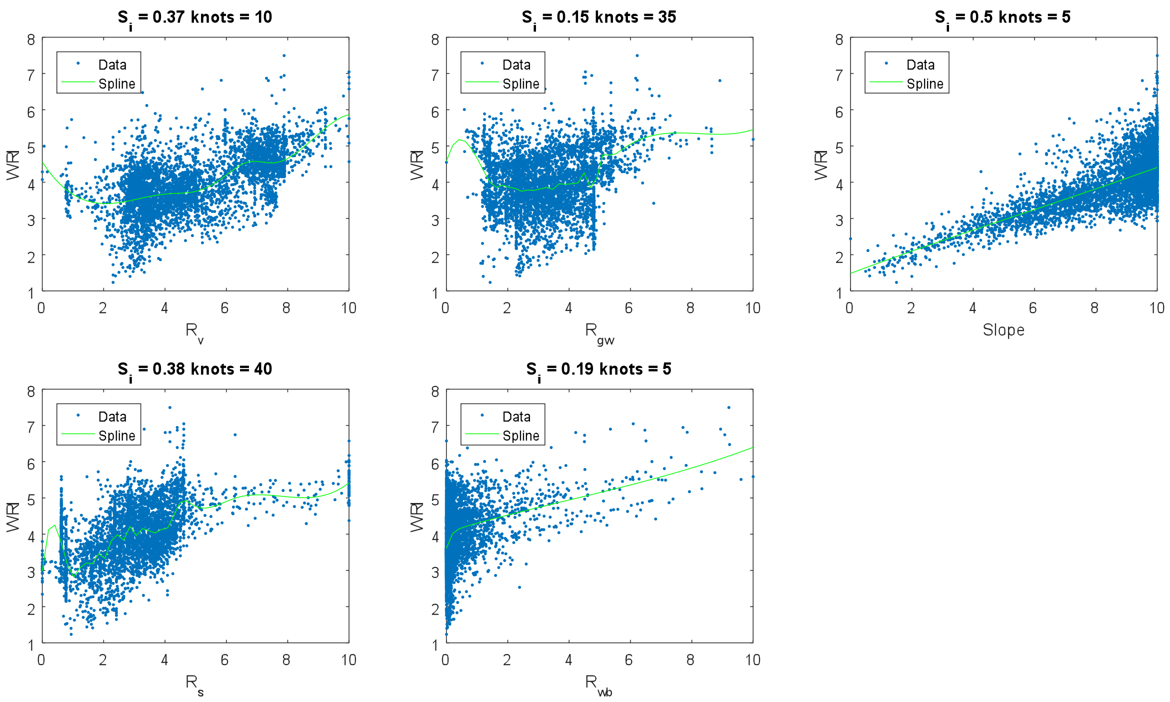


Figure 3. Sensitivity indices calculated for the input variables of the Water Retention Index 2006.

To adjust the weightings to more closely match the desired influence, we used an iterative approach which, using a nonlinear optimization algorithm, searched for the weights which minimized the difference between the sensitivity indices of the WRI and the desired sensitivity indices. The results of this endeavor are shown in Table 3: one can see that the sensitivity indices after optimization more closely reflect the aims of the indicator – each parameter now has an equal influence. The associated weightings are shown in the final column – these are the final weightings used in the WRI.

Table 3. Optimised weights and associated sensitivity indices

Indicator input parameter	**S_i before optimisation**	**S_i after optimisation**	**Optimised weighting**
R_v	0.367	0.281	0.17
R_{gw}	0.153	0.281	0.29
Slope	0.497	0.281	0.10
R_s	0.378	0.281	0.14
R_{wb}	0.193	0.281	0.28

2.1 Land use scenarios

Several scenarios improving natural water retention in the landscape were originally defined in work contributing towards the Blueprint to Safeguard Europe's waters (Burek et al., 2012). Here we focus on those directly dependant on changes in land use as simulated by the the EUCS100 model (Lavalle et al., 2011). The refined CLC land use/cover map (Batista et al., 2013) was used as basemap for the year 2006. To allow for comparison, a baseline, or 'business-as-usual' scenario was simulated up to 2030, taking into account the the current socio-economic and environmental trends and maintaining the current policy provision such as the CAPRI agricultural demands, and protection of Natura2000 sites.

Studies show that extreme events such as floods are most prevalent in catchments where deforestation occurs, and that this is especially true in catchments that are already flood-prone (Solin et al., 2011). According to Creed et al. (2011), forest management strategies can be planned in order to preserve hydrological flows and therefore reduce extreme events. We therefore looked at 2 scenarios where afforestation was highly encouraged; one in riparian zones, the other in upstream areas. In addition, we looked at a scenario where the conversion to grassland was encouraged. The land management strategies were summarized as:

- ***Afforestation in riparian areas (Riparian) -*** The suitability for forest was increased in the land use model for all potential riparian areas alongside rivers (as defined by Clerici et al., 2011), consistent with CAP targets (e.g. demand for agricultural land is not modified at regional level, therefore not decreased because of the afforestation).
- ***Afforestation in hilly and mountainous areas (Afforestation) -*** Conversion to forest from pastures, arable land, permanent crops and semi-natural vegetation was encouraged in areas above 500m in altitude and with slopes greater than 10%.
- ***Encouraged conversion to grassland (Grassland) -*** The demand for grassland/pasture was increased by 10% on slopes larger than 10%. Additionally, the maintenance of already present grassland/pastures was enhanced on land with slopes greater than 10%. The conversion of forest/natural vegetation to grassland was prohibited.

3. Results

3.1. Baseline Water Retention Index 2006-2030

Figure 4 (left) shows the resulting index computed for the base year 2006 at river basin level. The highest WRI values for the base year 2006 are found in the Atlantic environmental zone (having the highest LAI values, see figure 2), and in the Scandinavian countries, (having the highest density of surface water bodies, and lowest average soil sealing). The index gives especially low values in mountainous regions, due to a combination of usually quite low LAI value, low permeability and low soil water retention. This is due to the scarce and shallow presence of soil (usually the highest altitudes are composed of bare rock surfaces), and sparse vegetation.

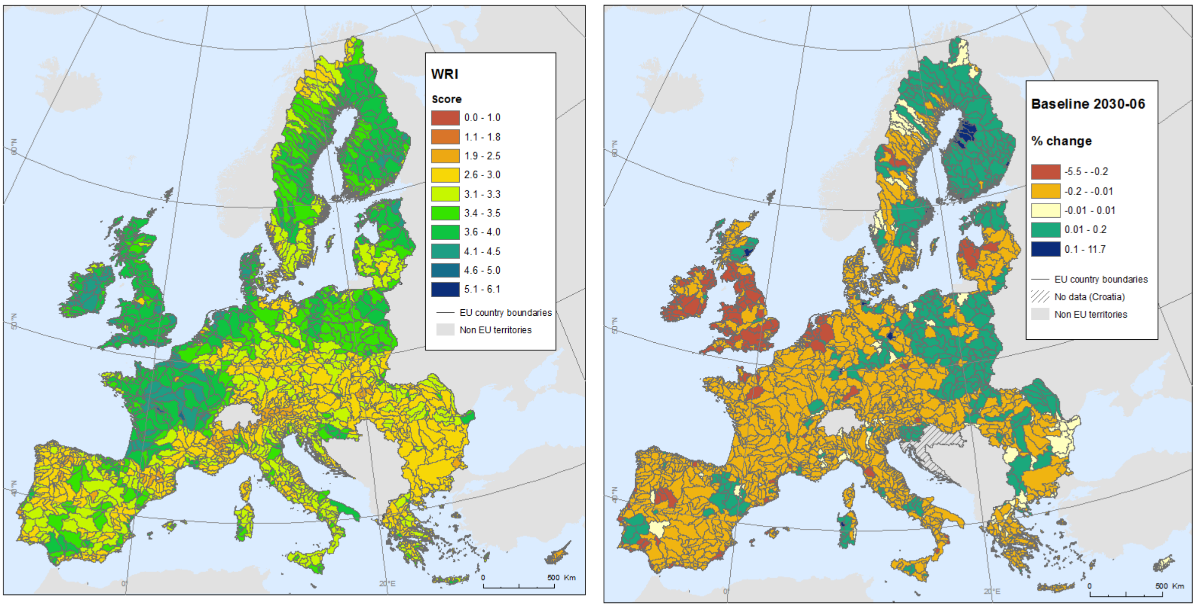


Figure 4. The final Water Retention Index calculated for the baseline scenario 2006 (left) and changes between 2006 & 2030 (right), shown at river basin level.

Figure 4 (right) gives the change in the indicator over time for the baseline scenario at the river basin level. The majority of western Europe, and especially the UK and the Netherlands show significant decreases in average water retention, whereas improvements over time are foreseen for Scandinavia and parts of eastern Europe.

3.2. Land management scenarios

Figure 5 shows the resulting changes in the WRI as calculated for each land management scenario for 2030, as compared to the 2030 baseline.

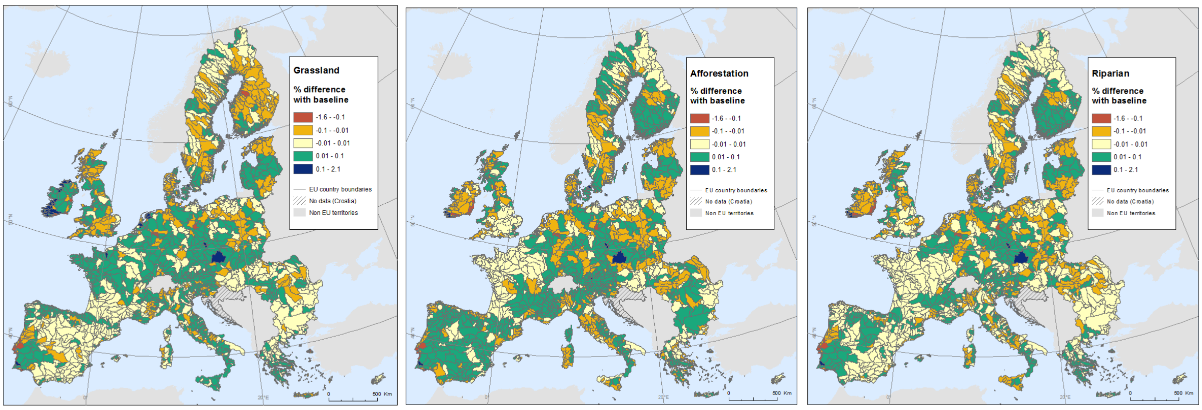


Figure 5. The final Water Retention Index calculated for each scenario as compared to the baseline 2030 value, shown at river basin level.

The afforestation scenario shows the greatest overall improvements as compared to the baseline. However, the results vary greatly spatially, meaning that the best management strategy to apply also varies depending on the region. For example, the grassland scenario actually gives much better results than either of the afforestation scenarios in the UK and especially Ireland.

4. Conclusions and Discussion

We present a composite indicator which takes into account the potential retention of water in vegetation, soil and groundwater to estimate the overall capacity of the landscape to retain water.

The influence of both slope and soil sealing on the final indicator value is also taken into account.

The indicator was computed at Pan-European scale at a resolution of 1 kilometer for the base year 2006, and for three land management scenarios for 2030, using output from the EUCS100 land use model.

The resulting indicator values for 2006 were highest in Atlantic Europe and Scandinavia, with lower values in mountainous regions. The difference in indicator value between 2006 and 2050 gives a more representative overview of where problems may arise. Some areas showed improvements, but the vast majority of regions had decreasing indicator values over that time period. This can be attributed to the expansion and increasing density of both urban and industrial areas.

The indicator can be used to assess alternative land use scenarios since all dynamic parameters are directly re-calculated based on the land use. Some significant changes were seen in the indicator when calculated for these scenarios as compared to the baseline. Of the 3 scenarios, afforestation in upstream areas showed the best overall results, although the best method used is highly dependent on the region where it is applied. This indicates that the index can be further developed to help assess various policy measures resulting in diverse land use scenarios over time.

There are, however, several uncertainties involved in the computation of the overall indicator. The projection of the indicator based on land use simulations means that the results are directly affected by the accuracy and uncertainty of the land use model. There is additional uncertainty both in the definition and scoring of the input parameters, and in the weighting used. A sensitivity analysis was carried out, and it was assumed that weightings should be assigned to give as equal as possible influences of each parameter on the final indicator value. However, some parameters may in reality have a greater influence on the water retention capacity than others.

It should also be noted that many additional parameters should ideally be taken into account (eg. Rainfall intensity, compaction of soil, artificial drainage structures/canals), but have not been included due to data limitations at the European scale.

The indicator presented aims at providing an overall assessment of the water retention capacity of the landscape. It has been specifically designed to allow forecasting with our land use projections, and for calculation at the European scale. The indicator thus provides a useful tool for policy support, and will in future work be used to assess the impact of land-use orientated polices on the potential of the landscape to regulate water flows both to counter water shortages and flooding events.

References

Batista e Silva, F., Lavalle, C., Koomen, E., 2013. A procedure to obtain a refined European land use/cover map. Journal of Land Use Science. DOI:10.1080/1747423X.2012.667450.

Bauer, A., Black, A.L., 1981. Soil carbon, nitrogen, and bulk density comparisons in two cropland tillage systems after 25 years and in virgin grassland. Soil Sci. Soc. Am. J. 45, 1166–1170.

Becker, W., Rowson, J., Oakley, J.E., Yoxall, A., Manson, G., Worden, K., 2011. Bayesian sensitivity analysis of a model of the aortic valve. Journal of biomechanics, 44(8):1499-1506.

Bewket, W., Stroosnijder, L., 2003. Effects of agroecological land use succession on soil properties in Chemoga watershed, Blue Nile basin, Ethiopia. Geoderma 111, 85–98.

Bormann, H., Breuer, L., Graff, T., Huisman, J., 2007. Analysing the effects of soil properties associated with land use changes on the simulated water balance: A comparison of three hydrological catchment models for scenario analysis, Ecological Modelling 209, p. 29-40.

Breuer, L., Huisman, J. A., Keller, T., Frede, H-G., 2006. Impact of a conversion from cropland to grassland on C and N storage and related soil properties: Analysis of a 60-year chronosequence, Geoderma 133, p. 6-18.

Bronson, K.F., Zobeck, T.M., Chua, T.T., Acosta-Martinez, V., van Pelt, R.S., Booker, J.D., 2004. Carbon and nitrogen pools of southern high plains cropland and grassland soils. Soil Sci. Soc. Am. J. 68, 1695–1704.

Burek, P., Mubareka, S., Rojas, R., De Roo, A., Bianchi, A., Baranzelli, C., ... & Vandecasteele, I. (2012). Evaluation of the effectiveness of Natural Water Retention Measures. *JRC Scientific and Policy Reports. Support to the EU Blueprint to Safeguard Europe's Waters. EU Commission Brussels*.

Clerici, Nicola; Weissteiner, Christof J.; Paracchini, Luisa M.; Strobl, Peter. 2011.Riparian zones : where green and blue networks meet : pan-European zonation modelling based on remote sensing and GIS. Luxembourg : Publications Office of the European Union.

Creed, I. F., Sass, G. Z., Buttle, J. M., & Jones, J. A. (2011). Hydrological principles for sustainable management of forest ecosystems. *Hydrological Processes*, *25*(13), 2152-2160.

Davidson, E., & Ackerman, I., 1993. Changes in soil carbon inventories following cultivation of 102 previously untilled soils, Biogeochemistry 20:161-193.

De Groot, R.S., Wilson, M.A., Boumans, R.M.J., 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. SPECIAL ISSUE: The Dynamics and Value of Ecosystem Services: Integrating Economic and Ecological Perspectives, Ecological Economics 41, 393–408.

Domenico, P.A., Schwartz, F.W., 1990. Physical and Chemical Hydrogeology, John Wiley & Sons, New York, 824 p.

EEA, 2009, Degree of soil sealing, 100m, http://www.eea.europa.eu/data-and-maps/data/eea-fast-track-service-precursor-on-land-monitoring-degree-of-soil-sealing-100m

Franzluebbers, A.J., Stuedemann, J.A., Schomberg, H.H., Wilkinson, S.R., 2000. Soil organic C and N pools under long-term pasture management in the Southern Piedmont USA. Soil Boil. Biochem. 32, 469–478.

Gleeson, T., Smith, L., Moosdorf, N., Hartmann, J., Dürr, H.H., Manning, A.H., van Beek, L.P.H., Jellinek, A.M., 2011. Mapping permeability over the surface of the Earth, GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L02401, doi: 10.1029/2010GL045565.

Guo, Z., Xiao, X. and Li, D., 2000. An assessment of ecosystem services: water flow regulation and hydroelectric power production. *Ecological Applications*, *10*(3), pp.925-936.

Hajabbasi, M. A., Jalalian A., Karimzadeh, H. R., 1997. Deforestation effects on soil physical and chemical properties, Lordegan, Iran, Plant and Soil 190: 301–308, 1997. 301

Hiederer, R., 2012. EFSA Spatial Data Version 1.1 - Data Properties and Processing. European Commission, Joint Research Centre, Institute for Environment and Sustainability. Publications Office of the European Union, Luxembourg. doi: 10.2788/54453.

Hiederer, R., Barbosa, A., Baranzelli, C., Grassi, G., Lavalle, C., 2013. IPCC Tier 1 Method for Estimating C-Stocks of Mineral Soils Applied to Modeled Land Use Change 2010-2050, JRC Scientific & Technical Report JRC87923, Publication Office of the EC, Luxemburg.

Jones, R.J.A, Hiederer, R., Rusco, E., Montanarella, L., 2005. Estimating organic carbon in the soils of Europe for policy support. European Journal of Soil Science, 56, 655–671.

King, D., Jamagne, M., Daroussin, J., Vanmechelen, L., Van Ranst, E., Hollis, J.M., Thomasson, A.J., Jones, R.J.A., Le Bas C., Ngongo L., 1994, A Geographical Knowledge Database on Soil Properties for Environmental Studies based on 1:1.000,000 scale ED soil map data. Final report of EC contract no. 3392004 Commission of European Communities (DGXI), Brussels, 49 p.

Klocke, N., Hergert, G., 1990. G90-964 How Soil Holds Water, Historical Materials from University of Nebraska-Lincoln Extension.

Laganiere, J., Angers, D., Pare, D., 2010. Carbon accumulation in agricultural soils after afforestation: a meta-analysis, Global Change Biology 16, p. 439-453.

Laterra, P., Orue, M.E., Booman, G.C., 2012. Spatial complexity and ecosystem services in rural landscapes. Agriculture, Ecosystems and Environment vol. 154, p. 56-67.

Lavalle, C., Baranzelli, C., Batista e Silva, F.B., Mubareka, S., Gomes, C.R., Koomen, E., Hilferink, M., 2011. A High Resolution Land Use/Cover Modelling Framework for Europe: Introducing the EU-ClueScanner100 Model. Computational Science and Its Applications - ICCSA 2011. B. Murgante, O. Gervasi, A. Iglesias, D. Taniar and B. Apduhan, Springer Berlin / Heidelberg. 6782: 60-75.

Lewis, M. A., Cheney, C. S., Ó Dochartaigh, B. É., 2006. Guide to Permeability Indices, British Geological Survey Open Report, Keyworth, Nottingham, CR/06/160N. 29pp.

Metzger, M.J., Bunce, R. G. H., Jongman, R. H. G., Mucher, C. A., Watkins, J. W., 2005. A Climatic Stratification of the Environment of Europe, Global Ecology and Biogeography 14, p. 549 - 563.

Murty, D., Kirschbaum, M.U.F., McMurtrie, R.E., McGilvray, H., 2002. Does conversion of forest to agricultural land change soil carbon and nitrogen? A review of the literature. Global Change Biol. 8, 105–123.

Muzylo, A., Llorens, P., Valente, F., Keizer, J.J., Domingo, F., Gash, J.H.C., 2009. A review of rainfall interception modelling, Journal of Hydrology 370 (2009) 191–206.

Neill, C., Melillo, J.M., Steudler, P.A., Cerri, C.C., de Moraes, J.F.L., Piccolo, M.C., Brito, M., 1997. Soil carbon and nitrogen stocks following forest clearing for pasture in the southwestern Brazilian Amazon. Ecol. Appl. 7, 1216–1225.

O'Farrell, P. J., Reyers, B., Le Maitre, D.C., Milton, S.J., Egoh, B., Maherry, A., Colvin, C., Atkinson, D., De Lange, W., Blignaut, J.N., Cowling, R.M., 2010. Multi-functional landscapes in semi-arid environments: implications for biodiversity and ecosystem services, Landscape ecology vol. 25, nr. 8 (2010): 1231-1246.

OECD, Organisation for Economic Co-operation and Development, 2008. Handbook on Constructing Composite Indicators. Methodology and User guide. Paris: OECD.

Paruolo, P., Saltelli, A., Saisana, M., 2013. Ratings and rankings: Voodoo or science? J. R. Statist. Soc .A 176, Part 3, 609–634.

Posthumus, H., Rouquette, J.R., Morris, J., Gowing, D.J.G., Hess, T.M., 2010. A framework for the assessment of ecosystem goods and services; a case study on lowland floodplains in England. Ecological Economics, 69 (7) pp. 1510-1523.

Rawls, W.J., Pachepsky, Y.A., Ritchie, J.C., Sobecki, T.M., Bloodworth, H., 2003. Effect of soil organic carbon on soil water retention. Geoderma 116, p.61– 76.

Reager, J. T., Famiglietti, J. S., 2013. "Characteristic mega-basin water storage behavior using GRACE." Water Resources Research 49.6: 3314-3329.

Reiners, W., Bouwman, A., Parsons, W., Keller, M., 1994. Tropical Rain Forest Conversion to Pasture: Changes in Vegetation and Soil Properties, Ecological Applications, Vol. 4, No. 2, pp. 363-377.

Ruppert, D., Wand, M.P., Carroll, R.J., 2003. Semiparametric regression, volume 12. Cambridge University Press.

Saltelli, A., Ratto, M., Andres, T., Campolongo, F., Cariboni, J., Gatelli, D., Saisana, M., Tarantola, S., 2008. Global Sensitivity Analysis - The Primer, John Wiley & Sons, Ltd.

Šimanský, V., 2013. "Soil organic matter in water-stable aggregates under different soil management practices in a productive vineyard." Archives of Agronomy and Soil Science 59.9: 1207-1214.

Solín, Ľ., Feranec, J., & Nováček, J. (2011). Land cover changes in small catchments in Slovakia during 1990–2006 and their effects on frequency of flood events. *Natural hazards*, *56*(1), 195-214.

Smith, M., De Groot, D., Bergkamp, G., eds. 2006. Pay: Establishing payments for watershed services. IUCN, 2006.

Sobol, I.M., 1993. Sensitivity estimates for nonlinear mathematical models, Mathematical Modeling and Computational Experiment, 1(4): 407-414.

Strebel, O., Boettcher, J., Eberle, M., Aldag, R., 1988. Quantitative und qualitative Veraenderungen im A-Horizont von Sandboden nach Umwandlung von Dauergruenland in Ackerland. Z. Pflanz. Bodenkunde 151, 341–347.

TEEB, 2010. The Economics of Ecosystems and Biodiversity: ecological and economic foundation. Earthscan, Cambridge.

Tratalos, J., Fuller, R.A., Warren, P.H., Davies, R.G., Gaston, K.J., 2007. Urban form, biodiversity potential and ecosystem services, Landscape and Urban Planning 83 (2007) 308–317.

Van Dijk, A.I.J.M., Bruijnzeel, L.A., 2001, Modelling rainfall interception by vegetation of variable density using an adapted analytical model. Part 1. Model description, Journal of Hydrology 247, p.230-238.

Wang, C., Zhao, C.Y., Xu, Z.L., Wang, Y., Peng, HH., 2013. Effect of vegetation on soil water retention and storage in a semi-arid alpine forest catchment, Journal of Arid Land, Volume 5, Issue 2, pp 207-219 .

Watson, D.J., 1947. Comparative physiological studies on the growth of field crops: I. Variation in net assimilation rate and leaf area between species and varieties and within and between years. Annals of Botany, 11: 41-76.

Wosten, J., Lilly, A., Nemes, A., Le Bas, C., 1998, Using existing soil data to derive hydraulic parameters for simulation models in environmental studies and in land use planning, Report 156, DLO-Staring Centre, Wageningen.

Track 2b. Food Security and Sustainable Agriculture

Session 2b-01

Session 2b-07

DIRECT, a tool for change: Co-designing resource efficiency in the food supply chain

Simon Lockrey[1], Karli Verghese[1], Maud Rio[2], Marshall Dwyer[3]

[1] Simon Lockrey, School of Architecture and Design, RMIT University, 124 LaTrobe Street, Melbourne, 3000, Australia, simon.lockrey@rmit.edu.au

[2,3] Maud Rio, University Grenoble Alpes, CNRS, G-SCOP, F-38000 Grenoble, France, maud.rio@g-scop.eu; Marshall Dwyer, Plenty Food Group – Hollar Initiative, Ringwood, Victoria 3131, Australia, marshall@hollarintiative.com

Abstract

The problem of food waste has captured global attention, with some estimates of up to 50% of food produced not making it to our plates. When combined with peak resources, climate change, and population growth, critical decisions need to be made before the waste issue starts to effect global food security. A key problem that actors in the food supply chain need to address is that of the current resource inefficiency, from farm to fork. This paper investigates a newly developed tool to help support better resource management for food manufacturers. Our primary contribution lies in our dissection of the participatory nature of the tool development i.e. how do we engage the industries involved for the best social, environmental and economic outcomes? As such, the proposition of the paper is that by using a co-design or a participatory process, we can co-develop a resource efficiency tool with and for food manufacturer that actually makes a difference. Firstly our paper elucidates the process that this project, the dynamic industry resource efficiency calculation tool (DIRECT), adopted. We explain how was it organised, and the resulting resource efficiency tool that comprises a method and a calculation module. Key calculation elements include; the establishment and validation of a 'true cost of waste' measure as a tool to support resource efficiency; and efficiency ratios that make sense to industry. Value predominantly lies in combining this quantitative efficiency calculation with complementary qualitative elements in DIRECT's project methodology and interactive information hub, as we explain. Secondly we cover the insights in using a participatory approach to DIRECT, including the barriers, challenges, and advantages we observed. As such, we detail who in industry was involved, where accountants through to 'factory floor' managers provide or withhold critical information. Next we explore the revelation that DIRECT must measure, yet also inform to provide guidance to stakeholders. We also explain why DIRECT's online mechanism connects industry actors for both sharing stories and creating joint resource projects. Finally our analysis identifies areas for future research. Our focus here is on how one may improve DIRECT in the next stages. This particularly relates to expanding the tool across more of the supply chain than what was previously designed. Other potential developments include; more cross industry linkages i.e. industrial ecology, mapping flows, mutualising resource transportation, resource and energy sharing; enriching the information hub and industry feedback; refined efficiency calculation; and more environmental parameters beyond waste. Cross-linkage with other disciplines is also suggested, such as economics expertise to improve business costs ratios, and strategic management input to build in value based decision making capability for DIRECT. We conclude by revealing the establishment of new food manufacturing projects for DIRECT, in terms of what the recent commissioners of said projects identify as the value the tool and process provide, and what that might mean for better food waste outcomes in the future. This consolidates the value of utilising co-design approach demonstrated in our paper, and justifies further research into broadening DIRECT's capability and adoption.

Keywords: Food Manufacturing, Resource Efficiency, Sustainability Tool, Food Waste, True Cost of Waste, Co-design, Stakeholder Engagement

Acknowledgements: We would like to acknowledge Plenty Food Group and Sustainability Victoria who commissioned this work. We would also like to thank Dr. Stephen Clune, who helped to set the DIRECT project up. Finally we would like to say a thank you to individuals and orgnaisations who participated in the development of DIRECT, and shared their time, knowledge and expertise.

Water scarcity footprint of a Portuguese wine (‘vinho verde’) applying different LCA-based methods

Paula Quinteiro 1, Ana C. Dias 1, Leandro Pina 1, Belmira Neto 2, Bradley Ridoutt 3 and Luís Arroja 1

1 Centre for Environmental and Marine Studies (CESAM), Department of Environment and Planning, University of Aveiro, Campus Universitário de Santiago, 3180-193 Aveiro, Portugal

2 CEMUC, Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal

3 Commonwealth Scientific and Industrial Research Organisation (CSIRO), Agriculture Flagship, Private Bag 10, Clayton South, Victoria 3169, Australia

E-mail contact: p.sofia@ua.pt

Abstract

This study is devoted to the water scarcity footprint of a Portuguese wine (the white ‘vinho verde’) using the current midpoint LCA-based methods: Pfister et al. (2009), Frischknecht et al. (2009) (ESM), Ridoutt et al. (2010), and Milà i Canals et al. (2009). The strengths and constraints of each LCA method are addressed and the wine production stages (disaggregated into foreground and background sub-systems) that mostly contribute to the water scarcity footprint are identified. The LCA-based methods differ significantly concerning the type of freshwater and characterisation factors (CFs) considered. The same functional unit (one bottle of ‘vinho verde’ with a total volume of 0.75 L) lead to different impacts : 1.0, 1.6 and 18.7 L eq, following the Pfister et al. (2009), Ridoutt et al. (2010), and Milà i Canals et al. (2009) methods, respectively, and 1.2 eco-points by using the ESM method. The inventory results obtained by using the method of Milà i Canals et al. (2009) differ significantly from the ones obtained by the other methods due to the consideration of land use effects. At the impact assessment level, a large variability of the results are mainly due to different modelling choices and CFs considered by each method. The results obtained by Pfister et al. (2009) and Ridoutt et al. (2010) identified the energy carriers from viticulture background sub-system and from the wine production background sub-system as the unit processes that contribute most to the water scarcity footprint (40% and 38 %, respectively). Concerning the ESM method, the energy carriers of the wine production background are responsible for more than 40% of the water scarcity footprint. Following the Milà i Canals et al. (2009) method, the viticulture foreground is responsible for more than 95 % of the water scarcity footprint. This study contributes to the on-going debate about the methods to be used to assess the impact derived from freshwater use under the LCA methodology. The high contributions of the background sub-systems show the relevance of widely include the freshwater use in LCA databases, avoiding duplication in data compilation and allow a spatially explicit water scarcity footprint.

Development of food security through integrated bio-cycles farming system in Manokwart, Papua, Indonesia

Ambar Pertiwiningrum[1)], Cahyono Agus[2)], Supriadi[3)], Arief Fahmi[2)], Richard P Napitupulu[2)], Nirma Yunitasari[2)], Ruslina Fajarwati[1)], Yudistira Soeherman[1)]

[1)]Faculty of Animal Science, Universitas Gadjah Mada Yogyakarta, Indonesia

[2)]Faculty of Forestry, Universitas Gadjah Mada Yogyakarta, Indonesia

[1)]Ministry of Village, Development of Disadvantaged Areas and Transmigration, Indonesia

Abstract

Indonesia's Law No. 18/2012 defines food security as the condition in which all people, in all households, at all times have sufficient food in both quantity and quality to enable them to live healthy, active, productive and sustainable lives, and that the food is safe, diverse, nutritious, equitably distributed and affordable, and does not conflict with religion, beliefs or culture. According to the Food Security and Vulnerability Atlas, Manokwari District in Province of West Papua was categorized as priority 2, strongly priority for improvement. The aim of this program was developing integrated bio-cycles farming system to improve their level of food security. The program was focused in Mansuburi and Wariori village, Masni Sub-district, Manokwari District, West Papua, Indonesia, from August 2015 for multi-years activities. Program was developed in cooperation between Kemendes PDTT (Ministry of Village, Development of Disadvantaged Areas and Transmigration); UGM Yogyakarta and local goverment of Manokwari District. The availability of food especially the production of rice, maize, cassava in Manokwari were relatively less developed. Based on the indicators of Normative Consumption per Capita Ratio (NCPR), the ratio of consumption to production in Manokwari was relatively high deficits (> 1.50) due to the limited rice area. Percentage of villages with no access to land and natural fresh water is quite low (<10%)., because of large area and high presipitation in Papua. The poverty was high (25-35%) causes a low access to food. About 30-40% of households have no access to clean water directly. Land conversion from forest area to Sawit estate area around Wariori river caused annual flooding that destroyed 60 ha of agricultural land during rain season since 2014, but the dried effect of El Nino phenomen in 2015 was strongly affecting agricultural production and food security. Development of master plan for food security 2015-2019 through (i) capacity building of human resources, (ii) natural resource management (iii) business management, would give smart and futuristic perpective program for food security. Facilitating menu 1 (improved seed and fertilizer), menu 2 (infrastructure of check dam, technical irrigation), menu 3 (hand-tractor, handsrayer, cultivator, transplator, composting unit), and menu 4 (rice milling unit, power threser, post-harvest machines) would be very usefull for food security, although delayed in execution. Technical assistance by expert from UGM Yogyakarta improved technical capabilty in managing natural resource for improvement of food security. The role of 2 assistants that were staying in the village was very important for community empowerment to support food security.

Keywords: community empowerment, Top of Form food security, integrated farming, master plan, world food program

Food Production, Population Growth, and Conflicts: Is Nigeria Food Secure?

Wilson Friday Ohioze, FMNES

National Open University of Nigeria (NOUN), Department Of Economics. ohiozewf@gmail.com

08062917009

Abstract

In recent years, Nigeria has been confronted with dwindling food production. This phenomenon has been exacerbated by activities of both the Boko Haram and the Fulani herdsmen; in the Northern part of the country, where the bulk of food is being produced. Yet, the growing population of the country with its demographic implications connotes further challenge in this area. These trends have witnessed the recent call for sustainable policies to promote food security. While extant studies have explored the effect of conflicts on food security in Nigeria, researches that have specifically investigated the interactions between the nation’s growing population, dwindling food production and conflict are rare. This study therefore, examines the possible interactions between agricultural food production, the nation’s increasing population, and conflict with a view to ascertaining how secured Nigeria is in terms of food production. The study is empirical in nature and it involved the use time-series data obtained from archival records which is typical of Quasi-Experimental design. Data which span from 1981 – 2013 were sourced from National Bureau of Statistics (NBS), Central Bank of Nigeria (CBN) and World Bank (WB). Trend analysis is employed to estimate the time series data to show the nexus between these variables. The empirical findings show that there is a positive relationship between population growth and food production in Nigeria. This is at variant with Malthus' postulation about the link between population and food production. However, the unending conflict especially in the north-eastern part of the country, has affected food production, hence, there is food insecurity. In sum, Nigeria is not food secured. The study therefore recommends that government should immediately diversify the nation's economy towards agriculture that would have mechanized farming as its focus. Also, the government should begin to take steps at addressing the rising population, by putting place polices to reduce population growth. Finally, there should be concerted effort at ending both the Boko Haram and the Fulani herdsmen insurgence in Nigeria.

Tropical Urban Ecological Model for Continuous Horticulture Production: a case study in the hydrographic basis of Tinguá, Rio de Janeiro, Brazil

Luiz Felipe Guanaes Rego 1, Veronica Maioli 2, Renata Fernandes Teixeira 3

1 Departamento de Geografia e Meio Ambiente da PUC-RIO

2 NIMA da PUC-RIO

3 PUC-RIO

Abstract

This article describes the research project called MUEPO (Urban Ecological Model of Vegetable Crop Production), coordinated by the PUC-Rio, which has developed a planting method for urban self-sufficiency that differs from the techniques of the tradition rural model, since it utilizes a labour-intensive model together with computer technology for year-round production per square meter, ensuring economic and environmental sustainability, based on the diversity of horticulture, the use of varieties of local seed with organic farming techniques that absorb organic matter and manage pest and disease organically. The former describes the method that accurately projected the weekly production from each of the small gardens (200-1500 square meters) via a production planning methodology in Tinguá, Nova Iguaçu, an area in the metropolitan area of the city of Rio de Janeiro. Using Geographic Information Systems (GIS) and remote sensing techniques, an integrated system was created for the optimal commercialization and distribution of production from the gardens, based on routing tools and GIS. The study indicates the potential of hundreds of small continuous and organic production gardens to be marketed and distributed efficiently and profitably, for the benefit of both peri-urban vegetable growers and consumers with low environmental impact. The article concluded that through this peri-urban vegetable production model can be a decisively contribute to the local urban self-sufficiency, controlling urban sprawl and reducing the urban footprint in tropical regions of the planet. It also raises the need for research that addresses the organic farming techniques and increases the number of species that can be utilized in the method through concrete efforts of multidisciplinary integration within this new paradigm of production geared for urban self-sufficiency that is economically and environmentally sustainable.

Keywords: continuous production of vegetables, organic farming, urban self-sufficiency, GIS, remote sensing.

1. Introduction

The global economy and the maintenance of life quality are supported by the services rendered by the ecosystem. These ecosystem services can range from tangible products such as animal species, food and water resources, to cultural services such as recreation and tourism (MEA 2005, De Groot et al., 2010, Trivedi et al. 2012, Guerry et al. 2015). Due to the numerous crises in biodiversity, water and the economy related to the expected increase of world population, the pressure on ecosystem services will increase considerably, threatening the assurance of supply (Moraes et al. 2013). Therefore, it is necessary that society, governments and businesses understand the limits of nature and develop methods, technologies and policies to ensure the sustainable use of ecosystems and their resources (Agenda 21 2001, Cohen et al. 2013).

Man's relationship with nature has become extremely out of balance, and this can be observed in recent changes to the planet's natural cycles and structures. These are occurring to such an extent that scientists have introduced the concept of a new geological era represented according to humanity's impact on the environment, called the Anthropocene (Walcacer, Lemos, Pires, & Guimarães, 2013). In addition to this, the planet's urban areas are becoming more crowded, as are their technical and scientific connection systems. In 2020, 50% of the world's population will be living in urban areas (UNFPA, 2011). In Brazil, 80% of the population already lives in built-up areas (IBGE, 2009).

Managing the flow of energy required to sustain cities is a problematic process, and this is applicable to energy in a wider sense, including the supply of raw materials for industry, agricultural production and all forms of waste disposal, as well as the effective use of electricity (Vuuren et al., 2012).

Other complex issues include the inadequate use of urban soil and the uncontrolled production of organic and industrial waste that could be recycled or reused (Lemos, 2013).

Cities require integrated solutions that reduce their system's entropy and make use of energy exchange cycles, reducing the impact to the environment and stimulating the sustainability of the system as a whole (Leff, 2004).

Cities should seek to determine the flow, waste and inconsistencies associated with their energy use. They should also clearly and transparently disclose their carbon footprint, a measure used to evaluate the pressure that human consumption puts on natural resources and enable urban populations to understand the options and choices they have in creating a balance between their city and the environment (Wackernagel & Rees, 1996).

Integrated actions that aim to transform the millions of tons of organic material produced in urban areas into fertilizer e sustaining millions of square meters of urban and suburban communal allotments e should be evaluated and tested (FAO, 2012).

In the current system, urban areas are supplied with vegetables grown in distant rural areas. The production is sent to urban centres over large distances involving a huge amount of energy. Within the cities it is sent to large distributers, after which it is spread throughout thousands of points of sale of varying sizes. It is through this network that the produce finally reaches the city's population (Araujo, Firetti, Ros, Narita, 2011).

The trade unit in rural areas is the hectare, which is used for the cultivation of relatively few plants and under the rigid specifications determined by the demand from urban areas. Therefore, rural production is made economically viable through mechanical technology, irrigation technique, chemical fertilizers, genetically modified seeds, pesticide based management systems and with high levels of mechanization and low labour costs (Albergoni & Pelaes, 2007).

Urban areas generate tons of unused organic waste, which is sent to landfills and causes considerable pollution. Communal allotments could make use of this enormous quantity of material, as it would enable organic cultivation methods to be sustained at a local level and with shorter transport distances, therefore reducing the amount of carbon emitted by cities (MMA, 2012).

Urban vegetable production requires specific factors that differ enormously from the more traditional rural production. Urban production grown in gardens or allotments is measured in m2 , involves a wide range of crops and uses large quantities of organic matter in the form of humus. An urban vegetable production model requires the use of a special management system in order to manage large numbers of small-scale productions and to supply one single trade unit (Rego, 1996).

The world's agricultural model is in need of a green revolution that will harmonize increases in production with protection of the environment and a higher absorption of labour (Rego, Gomes, Nina, Nunes, & Montenegro, 2013).

Peri-urban areas have been identified as possible restrictors of the urban sprawl through the productive use of these areas by raising vegetable crops, fruit-growing, floriculture, agriculture and intensive farming of small animals. On the other hand, the agricultural techniques used in these areas have been imported from traditional rural areas, such as the monoculture based on the hectare plantation unit; intensive mechanization and low manpower absorption; heavy chemical fertilization; phytosanitary control through agrochemicals; and the use of genetically modified seed varieties. These techniques of strong environmental impact become inadequate in urban and peri-urban areas, mainly due to the proximity between the areas under cultivation and the population.

This article describes the research project called MUEPO (Urban Ecological Model of Vegetable Crop Production), coordinated by the PUC-Rio, which has developed a planting method for urban self-sufficiency that differs from the techniques of the tradition rural model, since it utilizes a labour-intensive model together with computer technology for year-round production per square meter, ensuring economic and environmental sustainability, based on the diversity of horticulture, the use of varieties of local seed with organic farming techniques that absorb organic matter and manage pest and disease organically. (Rego, 2014).

The article discusses a theoretical application of the method in a watershed called Tinguá in the municipality of Nova Iguaçu (metropolitan area of the city of Rio de Janeiro) based on small 200 to 1500 square meter gardens that allowed for an accurate weekly identification of yield per each garden via production planning. Using geo-processing and remote sensing techniques, these gardens were integrated into a single marketing and distribution system, based on routing tools of Geographical Information System. The study indicates the potential of hundreds of small continuous and organic production units, efficiently selling and distributing for the benefit of both peri-urban vegetable growers and consumers, and with low environmental impact.

2. Study area: the watershed of Tinguá

The project study area was the Tinguá valley in Nova Iguaçu, the largest part of which is part of the REBIO-Tinguá (Biological Reserve), as can be seen in Figure 1.

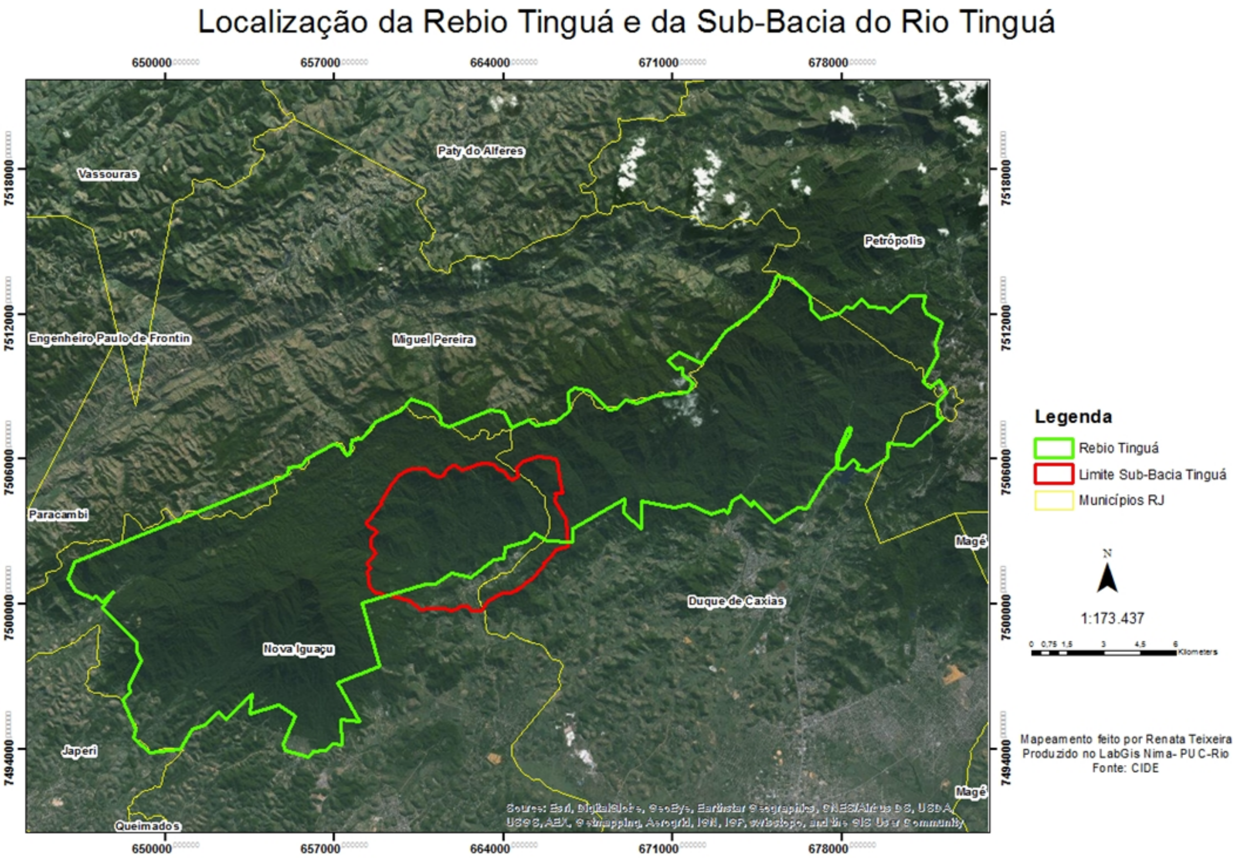


Figure 1. Location Map of Rebio Tinguá highlighting the sub-basin of the Tinguá river.

As shown in Figure 2, the largest part of the basin of the Tinguá River is occupied by well-preserved Atlantic rain forest, the southern region with plains of sparse urban area, and mostly used for seasonal crops, such as pumpkin and cassava that are of low financial return and heavy contamination of soil, groundwater, and rivers, due to the large amount of agrochemicals employed. The watershed is rich in water resources that are concentrated in the plain region, as can be seen in Figure 3.

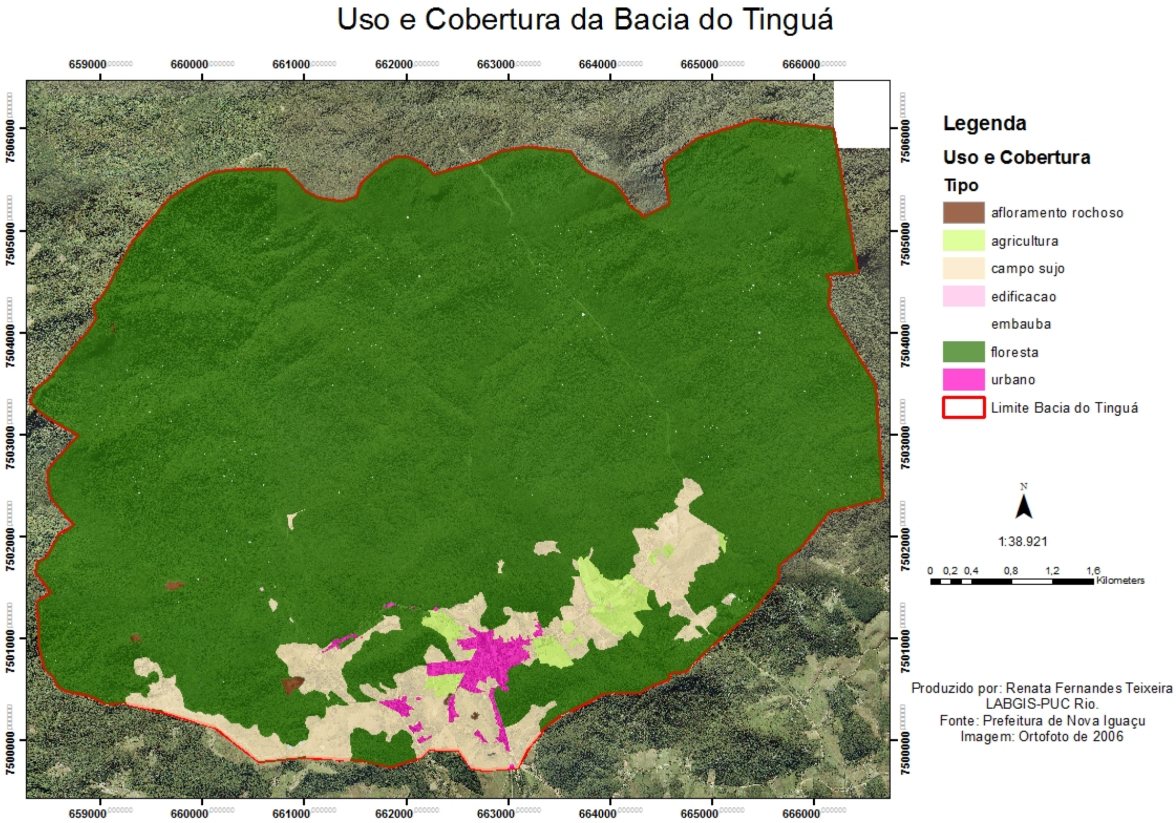


Figure 2. Map of land cover and land use of the Rebio Tinguá watershed from the visual classification of an orthophoto from 2007 with spatial resolution of 1m2.

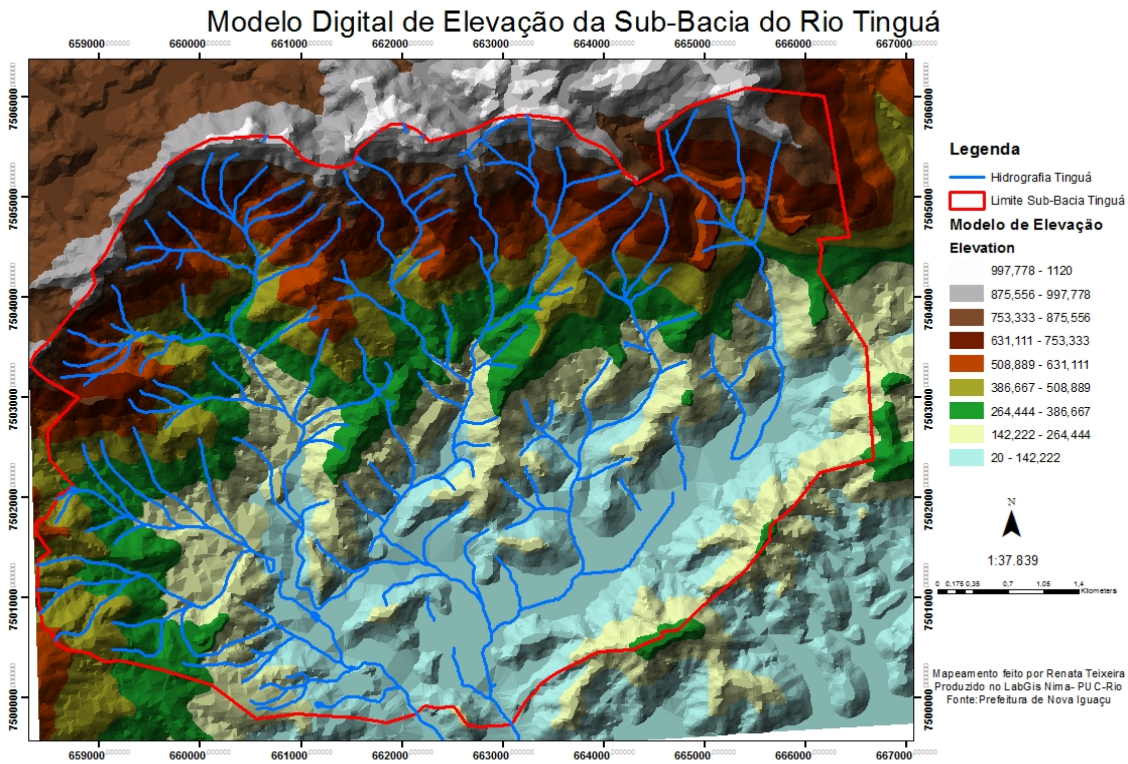


Figure 3. Map of the Tinguá river sub-basin with an estimate of the local hydrography.

3. Method

This study intended, from the analysis of the peri-urban landscape, to calculate the available areas for the implementation of a communal, continuous production model for urban commercialization, using image processing techniques and spatial analysis with geoprocessing tools. The ArcGis 10.3 software was used in both cases.

The spatial cropping defined by the watershed of the Tinguá River, part of the municipalities of Nova Iguaçu and Duque de Caxias in the Metropolitan Region of the State of Rio de Janeiro, Brazil, demanded the organization of a geographic database, involving vector data such as contour lines, roads, rivers, Landsat satellite images and high resolution orthophotos.

From the available data, a digital model of the basin area was generated, which allowed for manually extracting the boundary of the watershed and the local drainage network.

Using Orthophoto with spatial resolution of 1m2 with photo interpretation techniques, seven categories of coverage and usage were identified: rocky outcrop, agriculture, field, buildings, *embaúba* (Cecropia), forest and urban areas. The classification involved field work where these areas were identified and the desired category standards were geo-referenced. A classification key was produced to guide all the work of the photo interpreter. With some random points in the area of greatest class density, an accuracy of above 90% was attained.

By extracting agriculture and field classes, one grid was produced with a resolution of 100 meters by 100 meters as shown in Figure 4.

From the limits of each 100 x 100 cell, 133 units located southeast to the valley were selected, where there is a wider area of coverage and usage by the agriculture category. From this selection a new grid was created, with a resolution of 10 meters by 10 meters. This last grid was converted to vector format, with each cell a polygon corresponding to the spatial resolution of the original grid as can be seen in Figure 5.

From a buffer in the local access roads and rivers of the basin there was a subtraction from the 10m by 10m polygons file of the areas that were in these regions. The coverage and mapping were considered to eliminate the rectangles in areas of forests and buildings categories as can be seen in Figure 7.

Considering the data produced in the PUC-Rio MUEPO project, where 14 units of 10 meters by 10 meters would be able to produce per week 200 bags of assorted vegetables using a control and management system of activities with a computational environment and organic cultivation techniques, it was possible to calculate the productive impact of this production system in the landscape of the Tinguá valley (Rego, 2014).

4. Results and discussions

The maps in Figures 4 to 9 provide a consistent and methodological way to identify regions that would be able to be occupied with a pulverized model of vegetables production, composed by geo-referenced planting modules with 10 x 10, 100 m2, containing a culture and its growth stage in a given week.

In the study area in the southeast part of the valley with 133 modules of 100 x100, 10,000 m2, over 6500 planting units, 100 m2 modules had been mapped. This number represents around 325 gardens compatible with the Rio Hortas project described in Rego, 2014, which could supply 65,000 families with a bag of 2.5 kg of assorted vegetables per week. On the same basis, the production system would generate direct employment of 1300 gardeners and around 1625 m3 of humus would be consumed monthly, since it is used in the organic farming techniques.

The geo-referenced modulation system would allow the 6500 planting units to be controlled by a computerized system, where each module would have an identification and the owners would receive a weekly form with planting tasks, management and crops, indexed by planting units, modules, guaranteeing a global planning to allow hundreds of crops to be alternated in space and time dynamically, respecting the planting rotation by unit and the compiling bags for family self-supply, enabling a concrete link between the producer and the consumer, between a peri-urban area and urban consumption areas, such as condominiums, etc. The operational efficiency of this type of system would depend on the constant use of routing tools that would define the sequence of locations that would produce in a specific day, speeding up the composition of the bags and of the delivery system in the urban environment.

On the other hand, success would depend upon the processing of the massive production of the organic material of the cities sent to landfills, generating abundant production of humus, which would systemically and drastically reduce the ecological footprint of tropical cities, such as the Tinguá Valley.

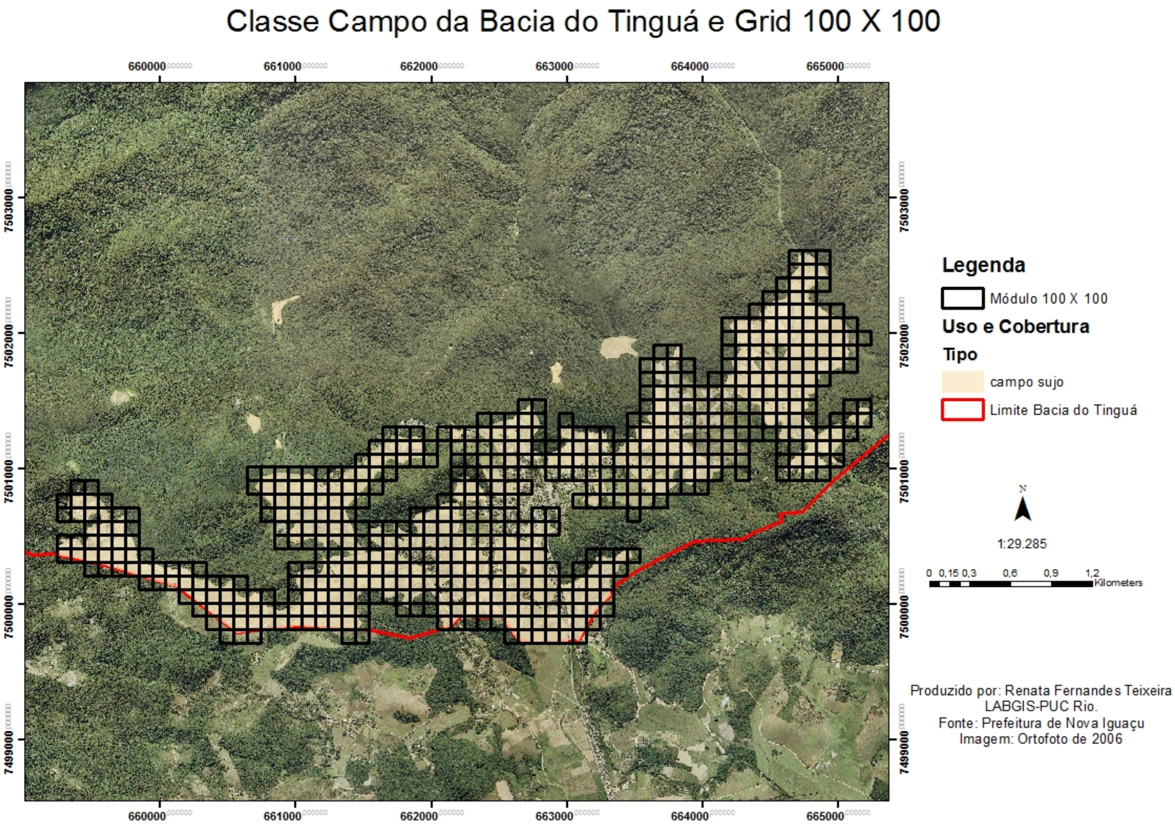


Figure 4. Map of the Grid with a resolution of 100 meters by 100 meters in the length of the two categories: agriculture and field in the basin of Tinguá.

Matriz de 10 X 10 da Bacia do Tinguá- Hidrografia e Ruas

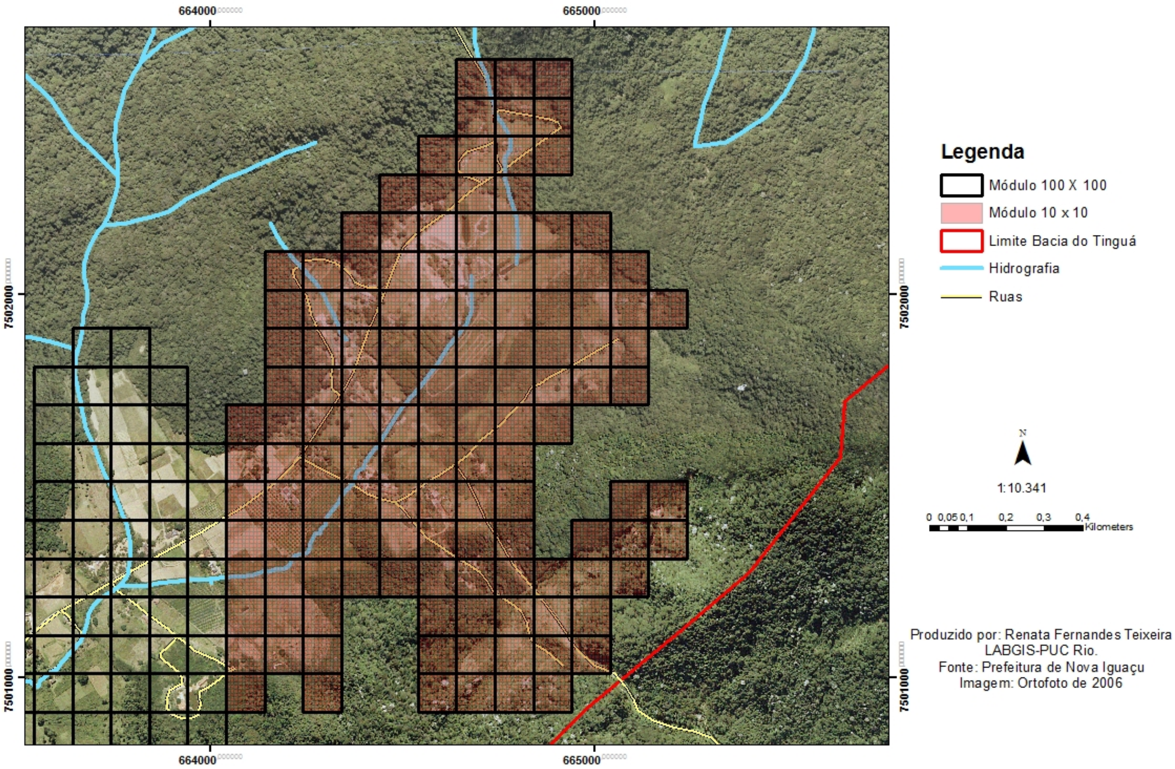


Figure 5. Map of the selected 100X100 cells that generated a new grid with 10X10 cells in the sub-basin of the Tinguá River.

Buffer de Rios e Ruas na Matriz de 10 X 10 Editada

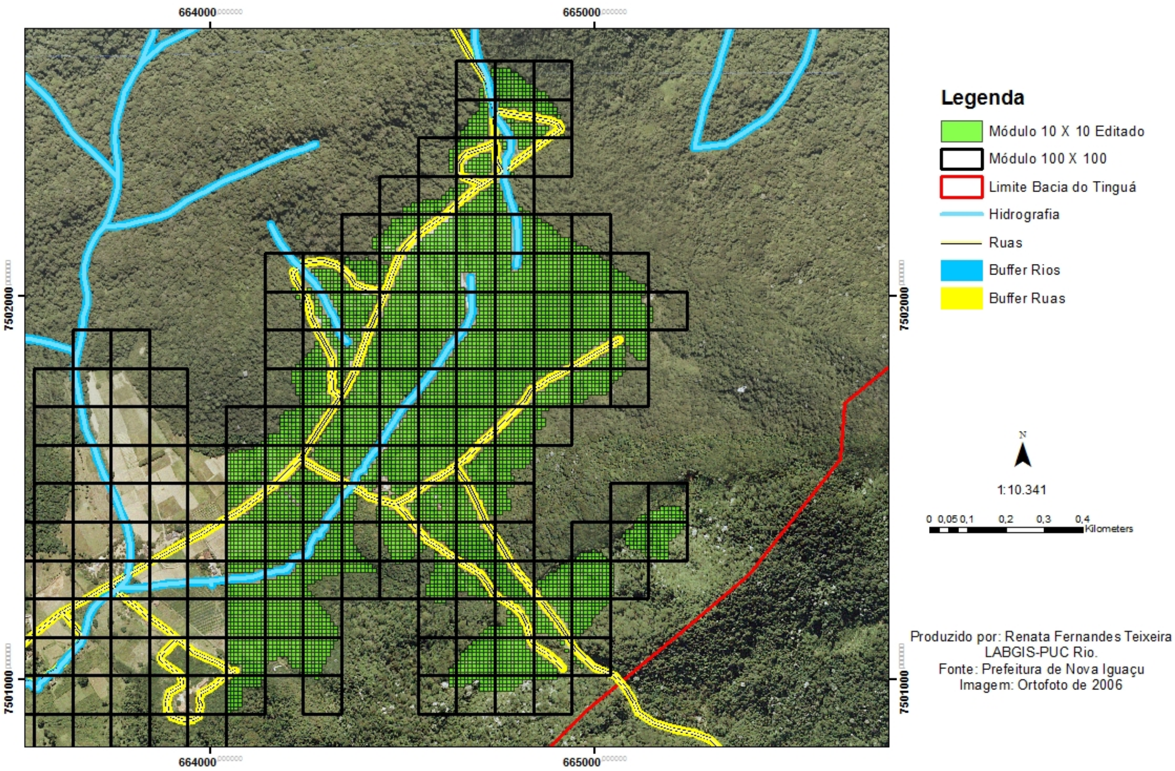


Figure 6. Map of the 10x10 matrix superimposed on the buffers of rivers and streets.

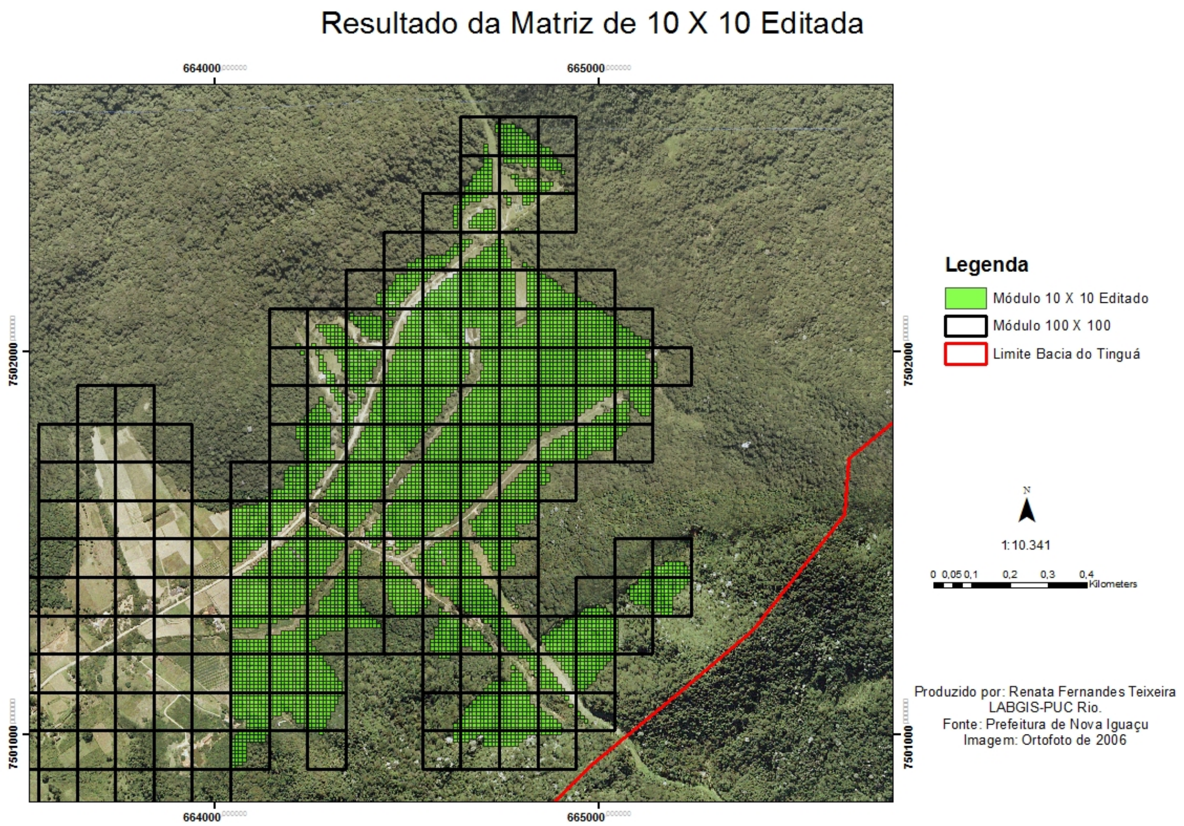


Figure 7. Map resulting from the 10X10 cells.

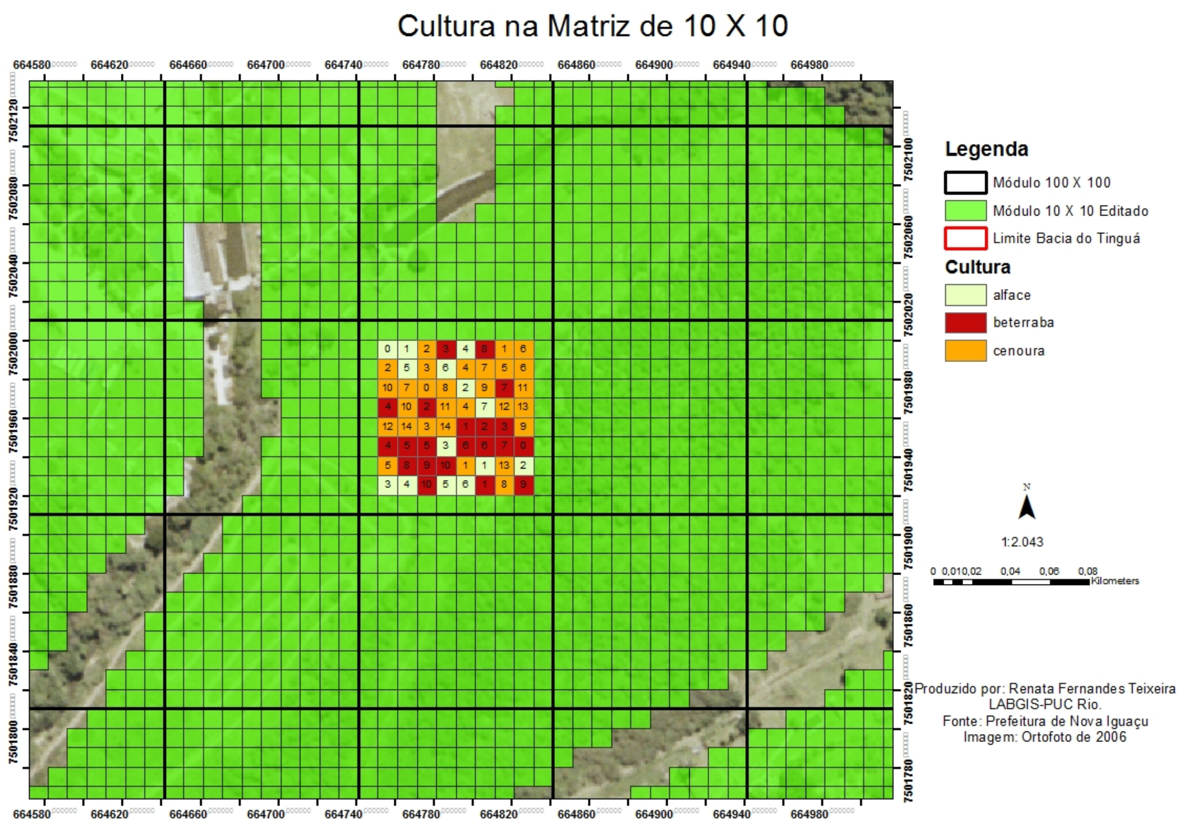


Figure 8. Detailed map of the 100X100 cells and 10x10 cells. In the centre are the units identified with culture and growth stage in weeks.

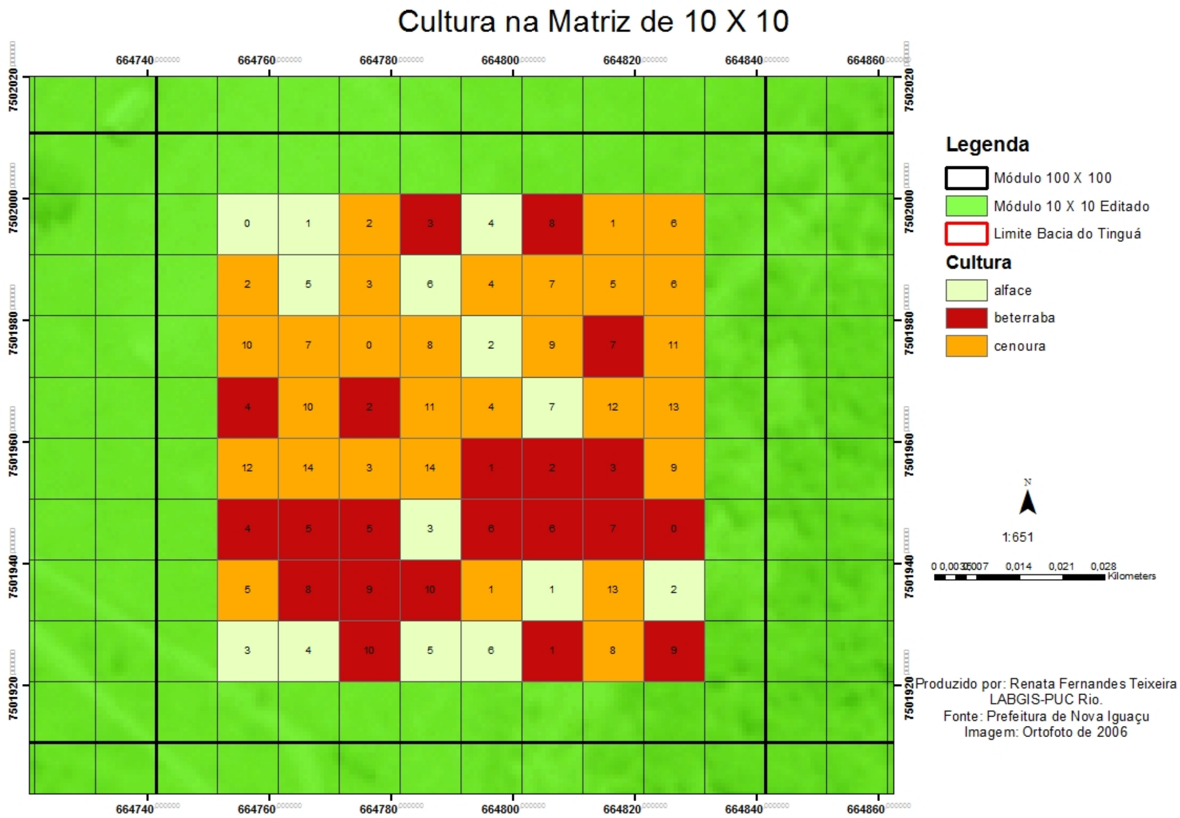


Figure 9. Detailed map of the 10x10 cells, planting modules, considering a lateral escape area, each 100 x 100 cell would hold 64 cells to be converted into geo-referenced planting units, diversified and multi-temporal.

5. Conclusion

Social and environmental issues are the great challenges of our time, and the contemporary metropolitan city should seek alternative solutions that make its relationship with the environment sustainable. In this context, peri-urban agriculture is a consistent way of greatly contributing to the improvement of people's quality of life and their relationship with finite natural resources.

Moreover, urban agriculture cannot be confused with self-supply activities that have occurred throughout the history of human occupation: productive and individual gardens, such as those of monasteries and small farming initiatives in towns and citadels. The success of the present initiative requires a complete overhaul of how we see and act in this field, seeking a new logic for planting and marketing.

The productive use of the peri-urban spaces with an organic and cooperative model as the one described in the present paper demands research regarding the multiple organic farming techniques, providing knowledge to subsidize farming practices based on local conditions of soil, climate and biodiversity, as well as the processing techniques of organic waste which demand adaptation to tropical conditions.

Peri-urban agriculture depends on the integration and composition of tools of virtual networks that enable both the exchange of knowledge and products among urban producers and the formation of production cooperatives, creating supply and trade links between the areas on the periphery and the dense urban centres.

Occupying and greening peri-urban spaces responsibly has a great potential to be explored, mainly in tropical and subtropical areas, helping cities to reverse their process of social and environmental disruption, for a synergy of low environmental impact that leads them towards sustainability.

Bibliography

- Agenda 21- Conferência das Nações Unidas sobre o Meio Ambiente e Desenvolvimento.2001. Brasília: Senado Federal, Subsecretaria de Edições Técnicas. 598p.
- ALBERGONI, L.; PELAES, V. Da Revolução Verde à agro biotecnologia: ruptura ou continuidade de paradigmas. Revista de Economia, Paraná, Brasil, v. 33, n. 1, p. 31-53, 2007.
- ARAUJO S.H., FIRETTI R., RÓS B.A., NARITA N. Os principais sistemas de comercialização de olerícolas. Pesquisa & Tecnologia, Campinas, Brasil, vol. 8, n. 2, 2011.
- BILWILLER . F. Modelo Matemático para Produção Continua de Olerícolas 1989. 70 f. Monografia de graduação - Departamento de Engenharia Elétrica da PUC-RIO, Rio de Janeiro, Brasil. 1989.
- Cohen, M., Vaccari, L. & Brunelli, M. 2013. Consumo e produção sustentáveis: um longo caminho a trilhas. In: Abrey & Rego (Orgs.). A ciência na Rio +20: uma visão para o future. Fórum de Ciência, Tecnologia & Inovação para o desenvolvimento sustentável. PUC-Rio, NIMA, 56-72p.
- IBGE 2009. Instituto de Geografia e estatística: Indicadores Sócio Demográficos e de Saúde do Brasil Diretoria de Pesquisas e Coordenação de População e Indicadores Sociais, Brasília, Brasil, 2009.
- De Groot, R.S., Fisher, B., Christie, M. 2010. Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. In: The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. Edited by Pushpam Kumar. Earthscan, London and Washington. Pp. 9-40.
- FAO, 2012. Organização das Nações Unidas para Alimentação e Agricultura: Criar Cidades Mais verdes. Programa de Horticultura Urbana e Periurbana Divisão de Produção e Proteção Vegetal (AGP) da Organização das Nações Unidas para Alimentação e Agricultura, Itália, 2012.
- FILGUEIRA, F.A.R., 1972. Manual de olericultura: cultura e comercialização de olerícolas, Editora Agronômica "Ceres", Sorocaba, Brasil.
- LEITE, M. P. Entre o Individualismo e a Solidariedade: Dilemas da política e da cidadania no Rio de Janeiro. REVISTA BRASILEIRA DE CIÊNCIAS SOCIAIS, São Paulo, Brasil, v. 15, n.44, p 73- 90, 2000.
- LEFF, E.,2004. Racionalidade Ambiental a Reaproximação Social da Natureza, editora Civilização Brasileira, Rio de Janeiro, Brasil.
- LEMOS, M.F.C., 2013. Cidades Saudáveis: Para a Resiliência Urbana no Contexto da Mudança Climática, in: Abreu, A.R.P., Rego, L.F.G., A ciência na RIO+20: uma visão de futuro, Editora PUC-Rio, Rio de janeiro, Brasil, PP. 230 – 241.
- MEA-Millenium Ecosystem Assessment Panel.2005. Ecosystems and Human Well-Being: Synthesis. Millenium Ecosystem Assessment Series (Island Press, Washington, DC).
- MISSELHORN, A; AGGARWAL, P; ERICKSEN,P; GREGORY,P; HORN-PHATHANOTHAI, L; INGRAM, J; WIEBE, K. A vision for attaining food security. Current Opinion in Environmental Sustainability, Londres, v 4, n.1, p 7–17, 2012.
- MMA, 2012. Política Nacional de Resíduos Sólidos, Ministério do Meio Ambiente, Brasília, Brazil 2012.
- Moraes, L.F.D.de., Kima, M.D.J.de. & Maioli-Azevedo, V. 2013. Serviços ecossistêmicos e biodiversidade. In: Abrey & Rego (Orgs.). A ciência na Rio +20: uma visão para o future. Fórum de Ciência, Tecnologia & Inovação para o desenvolvimento sustentável. PUC-Rio, NIMA, 130-143p.
- PRIMAVESI, A. 1998. Manejo Ecológico do Solo, Editora XXXX, São Paulo, Brasil.
- REGO, L.F.G. 2014. Urban vegetable production for sustainability: The Riortas Project in
- the city of Rio de Janeiro, Brazil. Habitat International 44, pages 510-516.
- REGO, L.F.G., GOMES, E.S.G., NINA I.P., NUNES, R., MONTENEGRO. M., 2013. Segurança Alimentar, in: Abreu, A.R.P., Rego, L.F.G., A ciência na RIO+20: uma visão de futuro, Editora PUC-Rio, Rio de janeiro, PP. 86 – 99.
- REGO,L.F.G. Hortas Comunitárias. Lavoura, Rio de Janeiro, Brasil, n.618, p 29 – 31, 1996.
- Trivedi, Mandar; Costa, Duarte; Meneses-Filho, Luis; Oakes, Nick; Mitchell, Andrew; Strassburg, Bernardo; Ortiz, Ramon; Seroa da Motta, Ronaldo; Guedes Pinto, Luis Fernando; Hall,

Anthony; Ometto, Jean Pierre. 2012. Think Pinc: Securing Brazil's food, water and energy with Proactive Investment in Natural Capital. Oxford, UK: Global Canopy Programme.

- UNFPA, 2011. Relatório sobre a Situação da População Mundial 2011, Fundo de População das Nações Unidas, New York, 2011.
- WALCACER, F., LEMOS, M.F.C.,PIRES,T.O.,GUNIMARÃES, V.T., 2013. Os desafios do antropoceno e as respostas da comunidade científica, in: Abreu, A.R.P., Rego, L.F.G., A ciência na RIO+20: uma visão de futuro, Editora PUC-Rio, Rio de janeiro, Brasil, PP. 230 – 241.
- WACKERNAGEL, M. and W. REES. 1996. Our ecological footprint: Reducing human impact on the Earth. New Society Publishers, B.C., Canada.
- VUUREN, D.P.; NAKICENOVIC, N.; RIAHI, K.; BREW-HAMMOND, A.; KAMMEN, D.; MODI, V.; NILSSON, M.; SMITH, K.R. An energy vision: the transformation towards sustainability — interconnected challenges and solutions. Current Opinion in Environmental Sustainability, Londres, v 4, n.1, p 18–34, 2012.

Sustainable Organic Agriculture: Challenges to Russia´s Agricultural Policy

Natalia Nesterenko, Nadezda Pakhomova, Knut Richter

Abstract

Agriculture as fundamental activity of man was traditionally considered as economic activity with important social functions. It provides a significant part of the world population with jobs and income. In recent years the model of organic farming is actively developing which focuses its attention mainly on the ecological aspects, the problems of greenhouse gas (GHG) emissions, etc. Follow the increasing consumer demand and environmental consciousness of people organic agriculture demonstrates stable growth (2015, for instance, growth in Germany by 11.1 percent). To estimate this new agriculture model, it is reasonable to take into account more thoroughly the social and economic dimensions. It cannot be ignored numerous examples of violating the law on minimum wageby eco-farmers to ensure their price competitiveness with conventional farms [http://www.zeit.de/2016/13/landwirtschaft-oekobauer-mitarbeiter-ausbeute].

To define future perspective of traditional and organic agriculture and to elaborate for this sector a proper government policy necessary to pay attention to the Paris Agreements, namely to the goal to limit global temperature rises to levels “well below 2 °C above pre-industrial ones” (the 1.5°C goal). Notice that the annual total non-CO2 greenhouse gas emissions from agriculture comprise about 10-12 % of global anthropogenic emissions. In the E.U. the agricultural sector accounts for 10 percent of the total EU GHG emissions and about 17 percent of the non-ETS GHG emissions; in Russia this sector accounts for 6.28 percent of the total GHG emissions (https://unfccc.int/files/ghg_emissions_data/application/pdf/rus_ghg_profile.pdf). Obviously, organic farming can significantly contribute to reducing GHG emissions from agriculture to adapt to climate change.

The contemporary agriculture is facing some other challenges. Agriculture is one of the sectors that are most vulnerable to adverse climate impacts: in accordance with expert estimations, global food production could drop by 17 percent for each degree of temperature rise because of extreme weather events (drought, flooding, etc.). Simultaneously, agriculture plays a significant role in ensuring food security for a growing world population: it is expected to grow by 60% by 2050 [http://www.arc2020.eu/2015/12/what-will-the-paris-agreement-mean-for-farming-food/].

These findings provide a basis for usefulness of different models of agriculture and of the elaboration of a balanced development strategy. This can be achieved addressing to the contemporary conceptions of sustainable development, which demonstrate a holistic view at the economic, ecological and social challenges to society and a balanced way of development goals and strategies at the international, national, regional levels, as well as at micro (namely, business) levels. In this respect the authors draw their attention at the “European Initiative for Sustainable Development in Agriculture”and to the concept of integrated farming to support their position of merging the advantages of traditional industrial methods with the requirements of the organic agriculture. Follow this Initiative, integrating farming could be characterized as a sustainable production system which allows farmers to optimize their farm management, to raise further awareness and continually improve everyday practice on farm in order to meet future environmental, economic and social challenges and hence achieve parallel progress in all dimensions of sustainable development [http://sustainable-agriculture.org/integrated-farming/].

Based on this concept the authors show that with respect to social and certain ecological problems traditional agriculture has not negligible advantages compared to ecological agriculture, especially if the attention is drawn to the above mentioned global task to supply the increasing world population with food and also to provide for this people proper quality of job and living conditions. Furthermore, the preferences to either traditional or to organic agriculture which can be found in the literature depend mainly on the perspective of the authors to the national, international, innergenerational and intergenerational aspects.

The authors also provide some overview on theoretical perception, on the plans and on the implementation of the ideas of sustainable agriculture in the Russian Federation with its significant potential. The huge agricultural land of 38.8 mil hectares, estimated by 2013, Jan. 1, has not seen any chemical fertilizers for many years, offers great opportunities, but so far, organic agriculture occupies only about 0.1 percent of this land.

The evaluation of the Russian Agriculture Policy in the light of these new challenges requires discussing some serious problems. The absence of a contemporary legal regulation in Russia constitutes serious barriers to dissemination of organic as well as integrated farming. The Russia´s national standard of organic agriculture (GOST R 56508-2015) approved by 2015, June 30, needs international acceptance, especially from the European Union. Under these circumstances, best international practices need application, including the EU experience to coordinate the agricultural and environmental policy, which is currently being adapted to the target settings of the Paris agreements. These are the following documents, which are developed and consistently implemented in the EU: Action Plan for the future of Organic Production in the European Union (Brussels, 24.3.2014. COM(2014) 179 final) which also contributes to the objectives set out in the Europe 2030 Strategy. In line with that document, the Common Agricultural Policy and the 7thEnvironment Action Program 2020 require attention. Notice, that in Russia there are no analogues of a number of the above-mentioned documents, making it difficult to conduct an effective public agricultural policy based on the principles of sustainable development. As a positive signal can be seen the development of the government draft plan of implementation of measures for the ratification of the Paris Agreement and its implementation. Among the activities of the plan that relate to the competence of the Ministry of Agriculture is the elaboration of Action plan to reduce greenhouse gas emissions and some other measures.

The authors provide also an analysis of the transition to the organic agriculture by implementing the methods known in the international arena, for various Russian regions.The authors identified factors, contributing to the development of organic agriculture and further have identified regions with the greatest potential for the development of organic agriculture, and the regions with a predominant development of traditional agriculture. The differentiation strategy of the development of organic farming should base on the currently existing opportunities and barriers. The authors suggest some recommendations for the modernization of social and environmental agricultural policy in Russia.

Under the conditions of an incomplete state policy, the Russian business shows anyway some initiatives. Among them, the experience of solving the problems of poultry farms waste with simultaneous production of electricity and increasing the energy efficiency, and the practice of voluntary eco-labeling of food, so-called a leaf of life. Overall, the principles of organic agriculture do not yet meet that attention of the business, as they deserve.

Keywords: traditional, organic and low carbon agriculture; sustainable development; agriculture and climate change; greenhouse gases emissions; market for organic products; organic standards and legislation; environmental agricultural policy.

Mapping multiple ecosystem services at the landscape scale to support investments in climate smart agriculture

Sean Patrick Kearney[1], Steve J. Fonte[2], Pablo Siles[3], Sean M. Smukler[1,4]

(1) Faculty of Land and Food Systems, UBC (2) College of Agricultural Sciences, CSU (3) Centro Internacional de Agricultura Tropical (4) The Earth Institute, Columbia University

Corresponding Author: Sean Patrick Kearney, sean.kearney@alumni.ubc.ca

Abstract

Farming on steep slopes and marginal lands is practiced by hundreds of millions of smallholder farmers around the world. These farmers, often with little capacity to relocate, are especially vulnerable to droughts and inundations, both of which are occurring with increasing frequency due to climate change. Surrounding communities are also vulnerable to environmental degradation (e.g. soil erosion, water contamination, increased run-off, loss of habitat and biodiversity) that often occurs when farmers on marginal lands seek to maximize profits through land clearing/burning, high pesticide and fertilizer use, and overgrazing. Agroforesty, silvopasture and organic agriculture are examples of alternative 'climate-smart' management practices that show promise to both increase farm resilience and mitigate climate change, while simultaneously enhancing the provision of critical ecosystem services. El Salvador is among the countries most vulnerable to climate change and was chosen as a study area representative of a large swath of sub-humid tropics across Central America dominated by smallholder agriculture. We used data from on-farm trials, landscape inventory and high-resolution satellite imagery from the mountains of northern El Salvador as inputs to spatially explicit models to 1) monitor ecosystem service indicators associated with climate-smart agricultural practices, 2) predict how indicators would change with widespread adoption, and 3) evaluate the potential for payments for ecosystem services at both the farm and landscape scale. Results of our field trials show that climate-smart agriculture can improve soil quality, increase carbon storage and benefit biodiversity without reducing yields. However, the current market value of individual ecosystem services at the farm scale may be low relative to farm-level monitoring costs. For example, model results show that carbon storage resulting from the adoption of agroforestry and silvopasture in the study area could lead to payments ranging from \$12 – 35 ha^{-1} yr^{-1}, but this amount may not incentivize farmers to change practices, especially after transaction costs. When ecosystem services were combined and assessed at the landscape scale, their value was substantial. Aggregated carbon payments for the 32,000 ha study area are expected to range from \$76,000 – 454,000 yr^{-1}, depending on adoption rates and carbon prices. This amount may be sufficient to support community-scale efforts to promote adoption, especially if bundled with payments for other services. While bundling is complicated at the farm-scale, it may be more feasible at the community scale, especially with the use of remote sensing to improve monitoring efficiency. Community-scale payments could also enable communities to achieve multiple ecosystem service benefits through a suite of interventions (e.g. agroforestry, silvopasture, fire management, afforestation, reforestation, etc.), allowing activities to be tailored to the various, and potentially changing, objectives of both smallholder communities and individual land managers. While current farmer practices stem from a complex intersection of environmental, socio-economic (e.g. land tenure), cultural and political factors, quantifying and valuing the ecosystem services provided by climate-smart agricultural practices is a critical step to ensuring widespread and sustained adoption.

Keywords: Agroforestry, Climate-Smart Agriculture; Ecosystem Services; Geospatial Land Use Modeling; Smallholder Agriculture

Effective factors on farmers' attitude toward multifunctional agriculture

Mohammad Sadegh Allahyari[1] and Sorush Marzban[2]

[1] Department of Agricultural Management, Rasht Branch, Islamic Azad University, Rasht, Iran. allahyari@iaurasht.ac.ir

[2] Department of Agricultural Management, Rasht Branch, Islamic Azad University, Rasht, Iran

Abstract

Agriculture has changed a lot regarding its definition and functions over the years, which include changes in the market supply, cultivation techniques and farmers' life and attitudes. In Guilan Province, the changes in social and economic systems have been associated with problems such as rural-urban migration, changes in patterns of rural life, the turning of farmland into residential land and changes in the rural productive and cultural context. The main aim of this study was to investigate the factors affecting farmers' attitude of the Shanderman District in Masal (Guilan Province in the north of Iran), towards the concepts of multifunctional agriculture. The number of farmers in the Shanderman District has reached about 4908 that, according to the Agricultural Service Center of Shanderman, are working in 38 villages, while there are 22 villages and 2326 farmers in Shanderman rural district and 15 villages and 2582 farmers in Sheykh Neshin rural district. The sample of the present study consisted of 209 subjects who were selected from the total population using the Bartlett *et al.* Table. All of the questionnaires were completed directly by the researcher through interviews. They were distributed between the Central District and Sheykh Neshin District using cluster sampling method, resulting in 100 and 109 questionnaires, respectively, which is in proportion to the farmers of the two districts. The first part of questionnaire consisted of farmers' profiles regarding individual, technical-agronomic, economic and social characteristics. The second part included items to identify the farmers' attitudes regarding different aspects of multifunctional agriculture. The validity of the questionnaire was assessed by professors and experts in the final questionnaire and Cronbach's alpha was used to determine the reliability by means of internal consistency. Alpha resulted in 0.844, which is considered an acceptable reliability value. Overall, the average scores of attitudes towards multifunctional agriculture show a positive tendency towards multifunctional agriculture, considering farmers' attitudes of the Shanderman district (SD = 0.53, M = 3.81). The results indicate that 35 farmers (16.7%) have a moderate attitude, 146 farmers (69.9%) have a positive attitude and 28 farmers (13.4%) have a very positive attitude toward multifunctional agriculture functions. Our results also highlight a significant difference between farmers' income source levels (F = 0.049) and agricultural literature review (F = 0.022) toward farmers' attitudes considering multifunctional agriculture (p < 0.05). Pearson correlations also indicated that there is a positive relationship between positive attitudes and family size, farmers' experience, size of land under cultivation, income, and social contribution activities. To assess the changes and to determine estimation equation for the expected attitudes of farmers toward multifunctional agriculture, we used multiple regression analyses. The results showed that the variation in the dependent variable depended on the farmers' experience in agricultural activities and their social contribution activities. This means that the variables included in the regression analysis are estimated to explain 12 percent of the variation in the dependent variable.

Keywords: Multifunctional agriculture, Attitude, Effective factor, Sustainable agriculture

Delphi for Sustainable Food Systems

Edith Callaghan 1, Liesel Carlsson 2

1 Acadia University, School of Business, Wolfville, Nova Scotia B4P 2R6 Canada, edith.callaghan@acadiau.ca[1]

2 Acadia University, School of Nutrition, Wolfville, Nova Scotia B4P 2R6 Canada, liesel.carlsson@acadiau.ca[2]

Abstract

Advances in food production and distribution have led to improved nutrition for many, greater global product choice, and enhanced efficiencies and productivity in food system industries. However, problems persist: over 805 million people do not have enough food, over 1.4 billion adults and 40 million children worldwide are overweight or obese and non-communicable (often diet-related) diseases are becoming a significant threat to human health globally. These nutritional imbalances exist within a context of diminishing biodiversity in the global food supply and diminishing capacity of the ecosystem services on which our food supply depends (e.g. oceans, land, soil). Further, our global food system has a profound impact on nations' economies and communities. Many economies, but in particular low-income regions and agrarian-based economies, are negatively impacted by global food market fluctuations. Across a number of domains, evidence is mounting that our global food system is failing to provide what is required for sustaining healthy productive lives. This failure runs counter to what should be expected from modern advances in agriculture, production, understanding of human health and wellness, etc. begging the question: "*Are we tracking and cultivating the correct indicators of success that will lead us to a global sustainable, secure food system that supports and is supported by healthy local communities?*" Authors will present results from a Delphi research process that brought together a diverse panel of food system experts to address this complex question. The objectives of this project were three-fold: First, to create a multi-disciplinary, geographically diverse community of practice to collaborate on solutions that will lead us to a sustainable, secure global food system; Second, to identify a clear, robust, and parsimonious vision of success with respect to identification of a sustainable food system; Third, to develop a comprehensive set of indicators that will make a substantial contribution to the process of sound cross-sectorial planning, decision making, and policy development, relevant at both global and local levels, for sustainable, secure food systems. Through our research process, the first two objectives were met. While the third objective was not fully met, a framework and method for identification of indicators to assess sustainability of community food systems was developed. This framework is grounded in the Framework for Strategic Sustainable Development (FSSD), and will be presented in full.

Keywords: Food, Community, Sustainability, Delphi, Indicators

Track 2c. Resource Exhaustion

Session 2c-04

Concrete recycling life cycle flows and performance from construction and demolition waste in Hanoi

Simon Lockrey[1], Karli Verghese[1], Enda Crossin[2] Hung Nguyen[3],

[1] Simon Lockrey, School of Architecture and Design, RMIT University, 124 LaTrobe Street, Melbourne, 3000, Australia, simon.lockrey@rmit.edu.au

[2,3] Enda Crossin, School of Engineering, RMIT University, 124 LaTrobe Street, Melbourne, 3000, Australia, enda.crossin@rmit.edu.au; Hung Nguyen, School of Business, IT and Logistics. Handi Resco Building, 521 Kim Ma, Ba Dinh District, Hanoi, Vietnam, hung.nguyen@rmit.edu.au

Abstract

Construction and demolition waste typically consist of a range of materials, derived from demolition or over supply in refurbishment and new build activities. As the developing world continues to reimagine cities, construction and demolition waste is a typical by product of this activity. Vietnam is one of these rapidly developing nations. As construction increases through a ramp up in development in Vietnam, the environmental performance of recycling the main constituent of construction and demolition waste, concrete, are not well documented. This paper addresses this lack of knowledge, by mapping the current recycling system and estimating construction and demolition concrete waste recycling performance in Hanoi now, and if positive changes were implemented. A review of existing literature, stakeholder interviews, field trips to construction/waste sites, and life cycle assessment are used to map and quantify environmental opportunities and performance of recycling construction and demolition concrete waste. By doing so, we investigate concrete waste management practices in Vietnam from a new perspective, via multi research methods. Insights developed reveal disposal practices and logistics pathways of informal and formal recyclers. This contribution includes the identification of constraints in the existing recycling system, and opportunities for change that may exist, including; value adding to concrete waste recycling options; learning from best practice; technological advancements in concrete recycling; concrete waste as an opportunity from an environmental standpoint; and avoiding landfill to benefit the environment. Finally, life cycle assessment helps in particular in estimating the environmental performance of the existing Vietnamese concrete recycling system, and for different potential recycling pathways. By doing so, we were able to conclude that concrete recycling that avoids landfill is a good environmental outcome in the Vietnamese context now, and in the future. These contributions are also linked to areas for further research, where life cycle inventory development could help deliver better environmental outcomes through the concrete recycling industry across Vietnam.

Keywords: Recycling, Vietnam, Concrete, Construction and Demolition, Life Cycle Assessment

Acknowledgements

We would like to acknowledge Professor Bob Baulch, Professor Ralph Horne and the Vietnam Research Partnership Support Scheme at RMIT University who commissioned this work. We would also like to thank Phuong Minh Nguyen, with whom we worked on data collection and analysis throughout the research. We also thank those individuals who participated anonymously in the interviews and shared their knowledge and expertise.

Benefit-cost analysis of four stormwater green infrastructure practices for Grand Rapids, Michigan, USA

Erik E. Nordman [1], Elaine Isely [2], Paul Isely [3], Rod Denning [4]

[1] Natural Resources Management Program, Biology Department, Grand Valley State University, 1 Campus Drive, Allendale, Michigan, USA 49401; nordmane@gvsu.edu

[2] West Michigan Environmental Action Council, 1007 Lake Drive SE, Grand Rapids, MI, USA 49506; esiseley@wmeac.org

[3] Economics Department, Grand Valley State University, 1 Campus Drive, Allendale, Michigan, USA 49401; iselyp@gvsu.edu

[4] Annis Water Resources Institute, Grand Valley State University, 740 W. Shoreline Drive, Muskegon, Michigan, USA 49441; denningr@gvsu.edu

Abstract

Grand Rapids, Michigan, USA is a medium-sized city located within the Lake Michigan watershed, one the five North American Great Lakes. Like many cities, Grand Rapids spends considerable money managing stormwater. Impervious surfaces collect and concentrate volumes of water and associated sediments and pollutants. This creates flooding, erosion, and pollution problems especially for downstream communities. However, stormwater quantity can be reduced and quality can be improved by mimicking natural hydrology, enhancing biodiversity, linking ecological and economic sustainability, taking an integrated approach at manageable scales, and viewing stormwater as a resource. Evidence is mounting that onsite stormwater management systems can be cost-effective but the detailed benefit-cost analyses are still lacking. Therefore the West Michigan Environmental Action Council, together with researchers from Grand Valley State University, estimated the economic benefits and costs of various green infrastructure (GI) practices. Each GI practice was standardized to treat 84.95 m^3 of stormwater per 2.54 cm event. The economic (net present value) analysis used a benefit transfer approach to estimate the capital, operations, and maintenance costs as well as the direct and indirect benefits. The suite of benefits varied for each GI practice and included (as appropriate) flood risk reduction; reductions in stormwater volume, phosphorus, total suspended solids, and air pollution; scenic amenity value; and CO_2 storage. A 3.5 percent discount rate was applied to all costs and benefits and each practice was analyzed over 50 years. Conserved natural areas had the largest net present value at \$131.37/m^3 WQv, followed by rain gardens (\$54.03/m^3 WQv), street tree planters (\$52.97/m^3 WQv), and porous asphalt (\$26.13/m^3 WQv). No one GI practice is appropriate for all situations. Rather the choice of GI practice will be driven by the site and budget. This benefit-cost analysis of GI practices has policy implications for Grand Rapids and other small to mid-size Midwestern cities. With the array of options available to manage stormwater on site, municipalities like Grand Rapids are well-positioned to adopt the GI practices that are most appropriate.

Keywords: green infrastructure, stormwater, benefit-cost analysis, street trees, porous pavement

1. Introduction

Local government units, including villages, cities, and counties, expend significant resources to manage stormwater. The City of Grand Rapids, Michigan, USA, for example, operates stormwater infrastructure valued at \$533 million (City of Grand Rapids 2014). These government entities have a strong incentive to reduce expenditures by reducing the volume of stormwater they manage. Reducing runoff volumes also reduces both the risk of floods and the amount of pollution entering the water courses.

The dominant paradigm in stormwater management for most of the 20th century was to move the water offsite as quickly as possible through ditches and pipes (“gray infrastructure”) and into the nearest stream or river. While effective at preventing ponding, moving large quantities of water, with its sediments and pollution, into water bodies resulted in flooding, erosion, and pollution problems for downstream communities. Since the 1990s an ecological paradigm has emerged that places stormwater quantity and quality within the context of integrated watershed management and low impact development. Stormwater quantity can be reduced and quality can be improved by, for example, mimicking natural (acceptable) hydrology, enhancing biodiversity, linking ecological and economic sustainability, taking an integrated approach at manageable scales, and viewing stormwater as a resource (Debo and Reese 2002).

The gray infrastructure paradigm emphasizes public infrastructure built, maintained, and operated by the municipality. Stormwater infrastructure is a pure public good, that is, it is non-rival (under normal circumstances, everyone can benefit from it without "using it up") and non-exclusive (once it is built, the municipality cannot exclude anyone from enjoying its benefits) (Weimer and Vining 2010). There is little incentive for private landowners to invest in stormwater management practices because the benefits of their actions would largely accrue to their neighbors. The ecological paradigm based on onsite management and low impact development, however, requires significant investments on private property such as rain gardens, green (vegetated) roofs, and porous pavement. The misalignment of incentives results in a market failure. In the absence of policy, actors in the marketplace will underprovide onsite stormwater management systems and practices. This will be the case even if onsite management is less expensive than the traditional sewer infrastructure. It is not just about the costs, it is about who pays them.

Evidence is mounting that onsite stormwater management systems can be cost-effective. The Center for Neighborhood Technology found that a municipal level green infrastructure plan could have significant net benefits for the community by reducing gray infrastructure capital costs by $120 million and providing more than $4 million in energy, air quality, and climate benefits annually .(Center for Neighborhood Technology 2014). If the net benefits of green infrastructure are positive, there is a compelling case that municipalities could save money and provide better environmental outcomes by providing incentives for private investment in onsite stormwater management through green infrastructure.

This paper analyzes the benefits and costs of stormwater management using green and gray infrastructure in the City of Grand Rapids, Michigan, USA. Specifically, it addresses four green infrastructure practices: porous asphalt, rain gardens, conservation of natural areas, and street trees (tree planters / pits). Three other practices (green roofs, bioretention infiltration basins, and rain barrels) are assessed in a separate paper. This benefit-cost analysis is part of the Rainwater Rewards project which includes a web-based stormwater value calculator that estimates the baseline stormwater runoff quantity, the reduced runoff quantity after the adoption of green infrastructure systems, and the net economic benefit of those systems (http://RainwaterRewards.com). The Rainwater Rewards calculator accessible tool for citizens, landowners, and policy makers to calculate the public benefits of green infrastructure and craft policy instruments (e.g. refunds, tax credits) that encourage private investment in green infrastructure.

The research team was inspired by the Center for Neighborhood Technology's Green Values calculator to create one specifically for the smaller Great Lakes cities of Grand Rapids and Muskegon, Michigan. Though the Green Values national calculator provides a reasonable estimate for green infrastructure benefits and costs nationwide, stakeholders in the West Michigan region desired to have a calculator specifically tailored to its location. The Rainwater Rewards calculator also has updated cost and benefit information. The Rainwater Rewards calculator will be the centerpiece of a community engagement curriculum on stormwater management through green infrastructure.

What we call green infrastructure in this paper goes by many names: low-intensity development (LID), stormwater best management practices (BMPs), stormwater management practices (SMPs), and others. While their definitions may differ slightly, they all refer to decentralized practices that reduce the quantity of stormwater entering watercourses. For the sake of consistency, we will simply refer to all of these practices as green infrastructure (GI).

1.1 Literature review

The most comprehensive resource to date is the Green Values Stormwater Toolbox Calculator from the Center for Neighborhood Technology (CNT) (2007). The CNT calculator used a relatively simple web interface that allows users to enter lot-specific information. It calculated the stormwater runoff volume under typical circumstances and estimates the reduction through the use of green infrastructure. Costs estimates considered both construction and operation and maintenance costs. The calculator estimated the following benefits: reduced air pollutants, carbon dioxide, compensatory value of trees, groundwater replenishment, reduced energy use, and reduced treatment benefits. Not every GI practice, however, delivers each of these benefits. CNT currently offers three versions of the calculator: the original, one for Chicago, and a national (USA) calculator.

Beauchamp and Adamowski (2012) used the CNT calculator and other valuation tools to estimate the value of GI compared to conventional infrastructure. GI development included reduced pavement designs, separate potable and non-potable water systems, greywater and blackwater sewage systems, and stormwater management using bioswales, wetlands, green roofs, and rain gardens. The planned development in the Montreal, Canada suburb of Vaudreuil-Dorion based on GI would cost 11-29 percent more than a conventional design. Housing values, however, were expected to increase by 15-27 percent which would offset the initial cost gap.

The Water Environment Research Foundation (WERF) developed a suite of spreadsheet-based best management practice and low impact development whole life cost models (Moeller and Pomeroy 2009). The cost tool includes nine different practices, including permeable pavements, rain gardens, and street tree planters. The cost models allow practitioners to estimate the capital, operations, and maintenance costs for each practice and compare the cost-effectiveness of each. The default spreadsheet is populated with standard values but allows the user to input locally-appropriate information about project costs, timelines, wages, and discount rates.

Researchers at the University of New Hampshire's Stormwater Center assessed the cost and performance of several low impact development practices including porous asphalt. They found that, contrary to conventional wisdom, porous asphalt had the lowest maintenance burden in terms of staff hours and the second lowest in annual costs. Porous asphalt also performed well in removing both total suspended solids and phosphorus (Houle et al. 2013).

The Forest Service analyzed the costs and benefits of street trees in Midwestern cities. They found that, for public (street) trees, the benefits outweigh the costs over a forty-year period. For small trees like a crabapple the net benefit was $160 (in 2005), while for medium and large trees the benefits were $640 and $2,320, respectively. The Forest Service analysis did not, however, use discounting when assessing these benefits. Street trees provide heating and cooling energy savings, increase property values, reduce stormwater volumes by intercepting rainfall, and reduce air pollution (McPherson et al. 2006).

Barnhill and Smardon (2012) facilitated a focus group around GI in Syracuse, New York, USA. They found three major barriers currently limit green infrastructure implementation. First is the homeowner financial cost. The costs of, for example, a residential rain garden are borne by the homeowner while the stormwater abatement benefits accrue to the community at large, especially downstream property owners – a classic market failure. The second barrier is a lack of knowledge about GI benefits, maintenance issues (including costs), and the use locally-appropriate practices. The third barrier is a failure to properly frame the issue. Framing GI in terms of neighborhood regeneration and sustainability can lead to more effective engagement. Engaging local stakeholders in developing GI can improve social equity.

1.2 Benefit transfer

The demand for environmental valuation information has outpaced research and funding for valuation projects. Consequently, many projects make up for the lack of data by using benefit transfer. Freeman (2003, 453) defines benefit transfer as "the practice of applying nonmarket values obtained from primary studies of resource or environmental changes undertaken elsewhere to the evaluation of a proposed or observed change that is of interest to the analyst." The location presently under investigation is commonly called the “policy site” and the location from which the values are drawn is the “study site.”

Johnston et al. (2015) reviewed the generally accepted methods of benefit transfer. Unit value transfer, though the simplest, has several drawbacks which make it less desirable for policy applications. Unit value transfer applies a single, unadjusted willingness-to-pay (WTP) value from the study site to the policy site. In most cases unit value transfers result in unacceptably high errors and are usually not recommended. Rather than simply transferring the WTP number from study to policy sites, benefit function transfer applies the mathematical function, including all or a subset of variables, to the policy site. Applying the function allows the researchers to adjust for differences between the sites and reduce errors. The adjustment also allows a wider range of contexts to serve as study sites. This is important where few, or no, study sites are sufficiently similar to the policy site. Johnson et al.’s ten-step procedure for conducting a benefit transfer was used to estimate values for stormwater GI in the Grand Rapids area.

2. Methods

2.1 Runoff estimation

The New York State Department of Environmental Quality created the Construction Stormwater Toolbox assist owner/operators comply with planning requirements under the New York State Pollutant Discharge Elimination System (SPDES). The Toolbox includes a design manual and a set of Excel-based runoff reduction worksheets (NYS Dept. of Environmental Conservation 2014). The worksheets are rigorous enough for SPDES compliance, yet flexible enough to be adopted in many circumstances. Much of upstate New York lies within the Great Lakes basin and has a climate similar to that of Michigan’s Lower Peninsula. After careful review, the project team deemed the New York State runoff reduction worksheets suitable for use in Michigan. The runoff reduction worksheets were used to establish baseline runoff volumes and to calculate the runoff reduced by implementing particular GI systems.

The project’s unit of analysis was the 2010 census block. Census blocks were chosen because they are well-established, publicly available, and are small enough for fine scale analysis. Individual parcels were not used because the project team did not want to give individual landowners the idea that they would be compensated for the estimated market and non-market benefits of green infrastructure on their properties. The census block provides the minimum level of aggregation necessary while enabling fine-scale analysis.

The Toolbox, as well as other studies (e.g. Houle et al. 2013), use the 90th percentile 24-hour rain event as the design criterion for stormwater management. In Michigan, the 90th percentile ranges from 1.96 cm to 2.54 cm (0.77-1.00 in) (Kuhns and Ulasir 2015). We chose to use the upper bound (2.54 cm) as the design criterion. We assumed that the GI practices would prevent all stormwater runoff for rain events up to and including 2.54. Ten years (2006-2015) of rainfall data from the Gerald R. Ford Airport in Grand Rapids were analyzed (Weather Underground 2016). The ten-year average annual rainfall in Grand Rapids was 101.60 cm (40.00 in) and ranged from 82.37 cm (2007) to 123.93 (2008) (32.43-48.79 in). The sum of rainfall events up to and including 2.54 cm averaged 70.99 cm (27.97 in) per year.

2.2 Economic valuation

The installation, maintenance and opportunity costs of the GI practices will be compared to the benefits of avoided stormwater runoff costs, pollution reduction, and aesthetic enhancement. These costs and benefits will be apportioned over the expected life of the system and analyzed using net present value (Formula 1).

$$i=0nBi(1+r)i-Ci(1+r)i$$

Where green infrastructure is compared to gray infrastructure, the net cost of green infrastructure was calculated by:

$Ci(1+r)i=Cigreen(1+r)i-Cigray(1+r)i$

The direct benefits include reduced maintenance from avoided stormwater and reduced environmental and health costs related to water pollution. Green infrastructure also has indirect benefits. Street trees and rain gardens enhance a neighborhood's aesthetic quality and may be measured through home prices. Street trees also remove air pollution and reduce energy costs by shading buildings.

Where possible, the value estimates were taken from projects in Grand Rapids and adjusted for inflation. In other cases, the values reported in peer-reviewed and gray literature from other locations were used. These values were adjusted to the present Grand Rapids context using benefit transfer methods. Costs for gray and green infrastructure systems were cataloged through literature review and conversations with local governments and service providers.

2.3 Value of avoided runoff

The direct cost of stormwater management was estimated from government documents. The City of Grand Rapids completed a sustainability plan which included a stormwater asset and capital plan (City of Grand Rapids 2014). The projected annual cost to provide the Existing Level of Service for stormwater management, including both fixed and variable costs, was $3.60 million in 2014. Stormwater reduction practices, however, only reduce variable costs. Fixed costs, such as system renewal (end-of-life replacement), inspections, and regulatory costs, were not included. Therefore only the annual variable costs (corrective and preventative maintenance) were used to estimate the value of avoided runoff. The city recognized that the existing level of service is inadequate. After careful review of three “level of service” scenarios, the city recommended pursuing Level of Service C (the lowest level) and increasing the annual budget for stormwater management to $10.38 million. This level focuses on maintaining critical infrastructure and high priority areas. The budget for inspections of catch basins and detention basins in Level of Service C includes $639,000 and $6,500, respectively. Unlike the inspection definition for other assets, inspection of catch and detention basins includes cleaning. Cleaning activities were listed under maintenance for the Existing Level of Service. Therefore catch basin and detention basin inspections were included in the variable costs. The city's report used 2014 dollars. After adjusting for inflation to 2015 dollars using the Consumer Price Index, the total annual maintenance cost is $2,898,804.

The stormwater management system processes runoff from the city's impervious surfaces. A feature extraction process using Landsat imagery with a ground sample distance of 30 m x 30 m found 5,128 ha (12,671 acres) of impervious surface in the city (Xian et al. 2011). That is 44% of the entire city area. At the average 101.6 cm (40.0 in) of annual rainfall, each hectare generates 9,651.93 m^3/year (137,940 ft^3/acre/year) of runoff, or 49,493,253 m^3/year (1,747,837,740 ft^3/year) for the whole city. Under Level of Service C, the annual maintenance cost per unit of stormwater treated is $0.0586/$m^3$/year ($0.0017/ft^3/year). The present value of 50 years of avoided stormwater at a discount rate of 3.5% under Level of Service C is $1.4219/$m^3$ of water quality volume (WQv).

2.4 Standardizing the green infrastructure practice

Each GI practice was standardized based on a WQv reduction of 84.95 m^3 (3,000 ft^3) for a 2.54 cm (1.00 in) rain event using the NYS Stormwater Construction Toolbox. The tool calculates the size of the GI practice needed based on the area's rainfall regime, total area, and impervious area. Asphalt and building roofs are typically 100% impervious surface. Rain gardens are assumed to be placed in residential areas. Analysis of Landsat imagery showed that residential areas in Grand Rapids have an average of 41 percent impervious surface. The corresponding areas that produce 84.95 m^3 WQv are a total area of 0.79 ha (1.96 ac) and an impervious area of 0.33 ha (0.81 ac). Residential areas, on average, have 14.3 residences per ha or just over 11 for 0.79 ha (0.07 ha per residence). If each of the 11 houses had a rain garden, each garden would need to have an area of 18.12 m^2 (195 ft^2). Conserving natural areas would reduce the total area that would generate runoff. We assumed that the conserved area would be replaced by an impervious surface. The tree planter calculator requires a maximum of 33% impervious surface. The corresponding acreage producing 84.95 m^3 WQv is 0.97 ha (2.40 ac) inclusive of 0.32 ha (0.79 ac) impervious acres (Table 1).

Table 40: Amount of green infrastructure required to reduce 84.95 m^3 of runoff per 2.54 cm rain event.

GI practice	Total area (ha)	Impervious area (ha)	Amount required to reduce 84.95 m^3 WQv per 2.54 cm event	Annual runoff avoided (m^3) (all events ≤ 2.54)
Porous asphalt	0.35	0.35	0.35 ha	2,374.51
Rain garden	0.79	0.33	0.02 ha	2,375.95
Conservation of natural areas*	0.35	0.00	0.35 ha	2,374.51
Tree planter / tree pit**	0.97	0.32	342 trees	2,374.51

*reduced total area by 0.35 ha, not actual stormwater volume
**reduced impervious surface area by 0.32 ha, not actual stormwater volume

Once the size of the green infrastructure practice was determined, the cost for each was estimated using the Low Impact Development (LID) Cost Tools from the Water Environment Research Foundation (WERF) (Moeller and Pomeroy 2009). The LID Cost Tools are Excel-based spreadsheets that have default parameters but can be modified for particular situations. The default case was modified to fit the Grand Rapids study area, including local and current wages and, where possible, cost estimates from local service providers. Each GI practices' size was adjusted based on the desired 84.95 m^3 WQv reduction (per 2.54 cm event). The default costs were adjusted for inflation to 2015 from 2005 using the Consumer Price Index from the US Bureau of Labor Statistics. Maintenance costs were scaled to the project size where appropriate. The City of Grand Rapids expects that its detention basins and rain gardens to have a 50 year life span. The city plans to replace porous pavement after 25 years (City of Grand Rapids 2014). We used these life span estimates in our model.

The capital and periodic operations and maintenance costs were combined into a present value calculation. A 3.5 percent discount rate was used for all present value calculations. This rate is appropriate for environmental projects with a lifespan of 30-75 years (Almansa and Martínez-Paz 2011). The City of Grand Rapids uses a 50-year infrastructure planning horizon which is replicated in this analysis.

2.5 Pollution Reduction

In addition to reducing stormwater volumes, GI practices reduce pollution entering waterways. The annual pollution load from a particular site can be estimated using the following formula (Landphair et al. 2000):

$$Loadlbs=0.2266\ Area\ ac\ Rainfall\ in\ Rv\ C\ (mgL)$$

Where R_v is the runoff to rainfall ratio and C is the pollution coefficient. The rainfall amount was the annual total for events ≤ 2.54 cm which totaled 70.99 cm. R_v was calculated for each GI practice using the NYS Stormwater Toolbox. Weiss et al. (2007) reviewed several sources and found that contaminant loads were fairly consistent. Values for C averaged 131+/- 77 mg/L (67% CI) for total suspended solids (TSS) and 0.55 +/-0.41 mg/L (67% CI) for total phosphorus. These average values were used in the calculations. All of the GI practices were sized to treat 84.95 m^3 WQv for a 2.54 cm event. The Minnesota Stormwater Manual reported the pollution reduction efficiency for various GI practices (Table 2).

Table 41: Pollution reduction from green infrastructure SMPs.

	Pollution reduction efficiency	
SMP	Total suspended solids	Phosphorus
Porous asphalt	74%	45%
Rain garden	85%	100%
Tree pit	85%	80%

The economic value of removing TSS and phosphorus was estimated from the treatment cost from a standard wastewater treatment plant. A 2007 report estimated that TSS removal costs $5.70/lb ($12.57/kg) and phosphorus removal costs $220/lb ($485.01/kg) (WSB & Associates 2008). Adjusted for inflation to 2015 using the CPI, these costs are $5.93/lb ($13.07/kg) and $251.25/lb ($553.91/kg), respectively. These values were based on the treatment plant's 30-year life cycle cost including capital and O&M costs. Multiplying the pollutant reduction amount (kg) by the unit cost ($/kg) resulted in the value of stormwater removal for each m^3 of WQv avoided per year (Table 3).

Table 42: Unit price of pollution reduction.

GI practice	**Annual pollution reduction (kg/m^3 WQv/year)**	**Economic value of avoided pollution ($/$m^3$ WQv/year)**
Porous pavement	TSS 0.09691 P 0.00032	TSS $1.27 P $0.14
Rain garden	TSS 0.11085 P 0.00048	TSS $1.45 P $0.32
Tree planter / tree pit	TSS 0.10989 P 0.00048	TSS $1.44 P $0.25
Conserve natural area	TSS 0.10989 P 0.00048	TSS $1.44 P $0.25

Reducing the volume of stormwater entering water bodies also reduces flooding risk in downstream locations. In 2013 the Grand River flooded the City of Grand Rapids causing an estimated $450 million in damages. The total water volume over the flood stage for the Grand River (above 5.49 m) for the entire flood period (4/21/2013-4/26/2013) was 111.29 million m^3 (3.93 billion ft^3) (USGS 2016). This comes out to $4.04/$m^3$ ($0.11/$ft^3$) of flood water. Though this was a large flood, it was not record setting. A flood of this magnitude has a 10 to 25-year recurrence time.

That is, a given year has a 4-10 percent chance of a flood of this size. Assuming a 25-year recurrence time, the annual expected damage would be $0.16/m^3 ($0.0044/ft^3). This is the conservative estimate. Using the ten year recurrence time would result in higher damage estimates.

The benefits of avoided stormwater volume, the avoided pollution, and the amenity value of volume reduction apply to all GI practices. Specific GI practices also yield other benefits.

Rain gardens also provide a scenic amenity. Polyakov et al. (2015) studied the amenity value of rain gardens placed at street intersections in Sydney, Australia. Rain gardens were found to increase the median property value by six percent for those within 50 m and four percent between 50 m and 100 m from the rain garden. Applying the six percent rate to Grand Rapids median sales price of $129,900 results in an effect of $7,794. At a 3.5 percent discount rate, the annualized value of a rain garden is $332 or $1.55/m^3 WQv/year ($0.044/ft^3 WQv/year) of runoff reduced.

Urban trees provide many ecosystem services beyond stormwater mitigation. The Midwest Community Tree Guide documented and quantified the benefits provided by urban trees (McPherson et al. 2006). The guide lists the benefits of street trees by unit (kWh of electricity saved, pounds of air pollutants avoided, etc.) as well as the price ($/unit) of each. The magnitude of the benefits changes as the tree grows in size and maturity. For this analysis, we used the guide's units and updated them with current and locally appropriate prices. In addition to the benefits described by McPherson et al., we also include the reduced flooding risk, reduction in total suspended solids, and reduction in phosphorus. Table 6 below shows the units, prices, and sources for each benefit. The avoided runoff volume estimates reported by McPherson et al. were substantially higher than those resulting from the NYS Stormwater toolbox. Therefore we conservatively used the lower estimate and applied the same runoff reduction rate across the trees' lifetimes (Table 4).

Table 43: Benefits of street trees (based on McPherson et al. 2006).

Benefit	**Price ($/unit)**	**Source**
Avoided runoff	$0.0586/m^3	City of Grand Rapids data
Electricity savings	$0.126/kWh	2014 EIA East North Central residential, adjusted for inflation
Heating savings	$0.009/kBtu	2014 EIA Michigan average residential natural gas price
CO_2 sequestered	$0.04/kg CO_2	EPA social cost of carbon for 2015, $40/ton CO_2
Air pollution avoided	Various	McPherson et al. values adjusted for inflation using CPI
Aesthetic value	0.81% of residential housing price	McPherson et al. percentage applied to Grand Rapids average housing sales price, $129,900
Flood risk reduction	$0.18/m^3 WQv/year	Current analysis
Total suspended solids	$1.45/m^3/year	Current analysis
Phosphorus	$0.24/m^3/year	Current analysis

Preserved open space areas have been shown to increase the property values of the adjacent lots. Thorsnes (2002) used a hedonic model of the Grand Rapids, Michigan area and found that forest preserves add 19-35% to the selling price of lots adjacent to the preserve. With average Grand Rapids homes selling for $129,900 in 2015, the 19% premium is $24,681. Annualized over 50 years at a 3.5 percent discount rate, the value is $1,052 per home per year. We also assume that the preserved natural area would be adjacent to 12 lots. The total amenity value is therefore $12,626. Our analysis assumes that the conserved natural area would otherwise be converted to 0.35 ha of 100 percent impervious surface (generating 84.95 m^3 WQv for a 2.54 cm event). The resulting amenity value is $5.32/$m^3$ WQv/year ($0.15/$ft^3$/year). Many of the services provided by mature (25 year old) street trees were adapted for the conserved natural area GI practice, including the following: carbon dioxide storage ($1.40/$m^3$/year); reduced air pollution ($0.60/$m^3$/year); avoided stormwater ($0.06/$ft^3$/year); flood risk reduction ($0.18/$m^3$/year); reduced total suspended solids ($1.44/$m^3$/year); and reduced phosphorus ($0.24/$m^3$/year). The total annual benefit from conserved natural areas was $9.23/$m^3$/year.

The benefits from all GI practices are summarized in Table 5 and Figure 1.

Table 44: Summary of benefits from GI practices.

GI practice	**Porous asphalt**	**Rain garden**	**Tree planter / pit***	**Conserve natural area**
Avoided volume	0.5856	0.5856	0.5856	0.5856
Flood risk reduction	0.1801	0.1801	0.1801	0.1801
TSS pollution	1.2678	1.4479	1.4373	1.4373
Phosphorus pollution	0.1377	0.3037	0.2401	0.2401
Amenity value	0	1.5397	0.5509	5.3184
Energy savings	0	0	1.1619	0
Air pollution reduction	0	0	0.1624	0.6004
CO_2 storage	0	0	0.3143	1.3949
Total annual benefits	**1.6442**	**3.5301**	**4.0471-11.3856**	**9.2300**

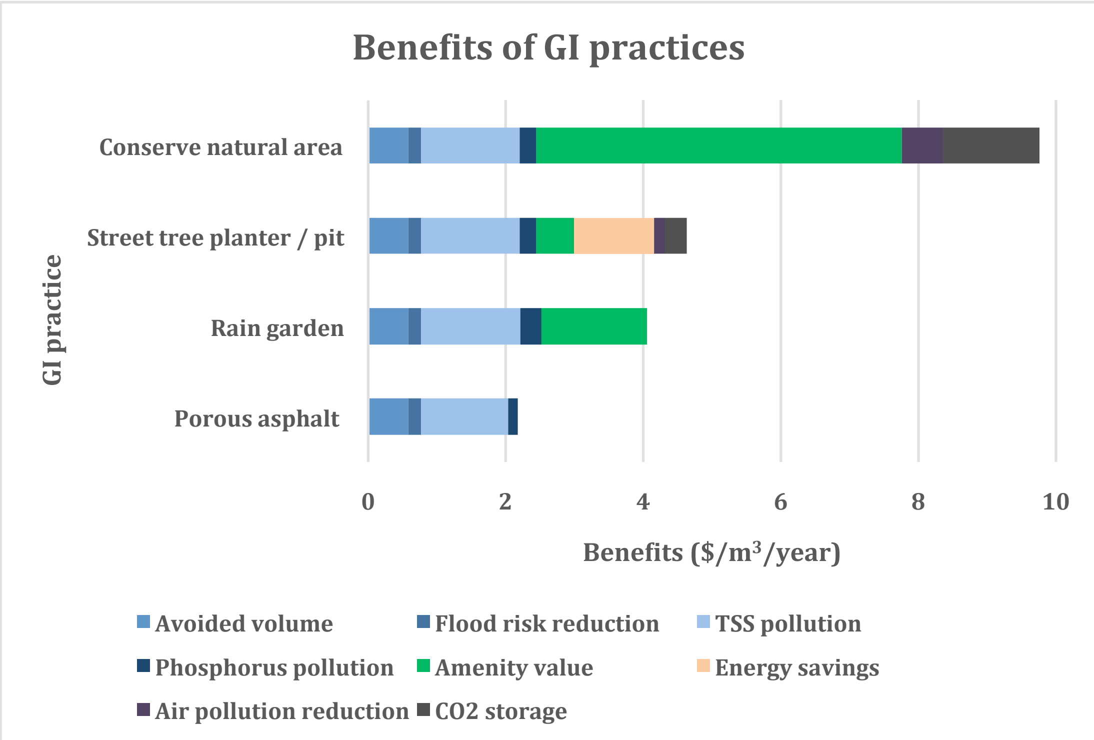


Figure 19: Benefits of GI practices ($/m^3 WQv/year).

2.6 GI costs

Green infrastructure costs were estimated using the WERF LID spreadsheet tools as a starting point and adjusted for inflation, technological advancements, and location-specific data.

2.6.1 Porous asphalt

Century West Engineering compared, side-by-side, the capital costs of conventional and porous asphalt for a 297.29 m^2 (3,200 ft^2) parking lot. The conventional asphalt lot cost $23,680 to construct ($79.65/m^2) while the porous asphalt cost $25,960 ($87.32/m^2). The comparison was conducted in Portland, Oregon in 2013. According to the US Bureau of Labor Statistics, Portland's mean construction wage is $25.64/hour and Grand Rapids' is $21.04. This ratio (0.84) was used to adjust the Portland asphalt construction costs to Grand Rapids and the costs were adjusted for inflation to 2015 using the CPI. The adjusted capital costs were $66.74/m^2 ($6.20/ft^2) for conventional asphalt and $73.09/m^2 ($6.79/ft^2) for porous asphalt. The figures were entered into the WERF LID cost model which includes 10% for engineering and planning and 20% for contingency. The total capital costs, including construction and development costs, were $88.10/m^2 ($130.64/m^3/year WQv) for conventional asphalt and $96.41/m^2 ($142.95/m^3/year WQv) for porous asphalt.

Both conventional and porous asphalt have maintenance costs. It was assumed that porous asphalt would have all the maintenance of conventional asphalt plus its own specialized maintenance. The Whitestone Facilities Maintenance and Repair Reference and the Operations Reference list recommended maintenance hours for specific tasks related to facilities management including parking lots (Abate et al. 2009). The schedule for each task is listed in the table below. The Bureau of Labor Statistics reports that the average construction wage in Grand Rapids was $19.86 in 2015. This wage was used to calculate the cost for each task (Table 6).

Table 45: Operations and maintenance costs for conventional asphalt.

O&M task	Frequency	Hours/m^2	Materials cost \$/m^2	Total cost \$/m^2	Total cost \$/m^3/year WQv
Patch and seal	5 years	0.006	0.75	0.97	1.47
Resurface	15 years	0.137	4.95	8.18	12.20
Repair	25 years	0.079	8.61	11.19	16.53
Snowplow and sweep (weekly)	Annual	-	0.32	0.32	0.53

(Houle et al. 2013) estimated the maintenance costs for porous asphalt in New Hampshire. New Hampshire's cold climate is similar to that of Grand Rapids and thus is an appropriate comparison. Houle et al. estimated that the personnel costs would be \$939/ha/year and subcontractor costs would be \$1730/ha/year. These values were adjusted to fit the Grand Rapids area by scaling them by the average construction and extraction occupation wages from the two cities as reported in the BLS's Occupational Employment Statistics. The figures were also adjusted for inflation to 2015 using the CPI. The additional maintenance costs for porous pavement were estimated at \$0.25/m^2 (\$0.38/m^3 WQv). The present value cost over fifty years comes out to \$176.22/m^3 WQv for conventional asphalt and \$189.99/m^3 WQv for porous asphalt (Table 9).

2.6.2 Rain garden

The 199.3 m^2 (2,145 ft^2) of rain gardens needed to mitigate 84.95 m^3 (3,000 ft^3) of stormwater was assumed to be spread over 11 residential homes (18.1 m^2 (195 ft^2) per rain garden). The Washington State Department of Ecology estimated the capital and maintenance costs of rain gardens (Herrera Environmental Consultants 2012). The mean of the reported low and average costs were \$193.21/m^2 (\$17.95/ft^2) and \$0.73/m^2/year (\$0.73/ft^2/year) for capital and maintenance costs, respectively. The construction wage differential between Washington and Michigan was used to adjust for location and the costs were adjusted for inflation using the CPI. The Grand Rapids costs for 2015 were \$150.66/m^2 (\$14.00/ft^2) for capital and \$6.14/m^2/year (\$0.57/ft^2/year) for maintenance. The WERF LID cost tool includes other costs, such as landscape design, first-year establishment, and periodic maintenance costs. For the 199.3 m^2 of rain garden GI practice, the total capital cost is \$32,788 plus regular maintenance costs of \$1,223/year. Periodic maintenance tasks include replacing mulch every three years (\$4,605) and tilling the soil every five years (\$3,105). It was assumed that the rain gardens would be installed professionally. Opportunity costs of land were included as described above. Capital and maintenance costs could be substantially lower if homeowners or volunteers did the work themselves. Standardized on a per m^3 WQv basis, the total first-year cost is \$14.48/m^3 WQv/year (\$0.41/ft^3/year) with a total present value cost of \$31.78/m^3 WQv (\$0.90/ft^3) (Table 9).

2.6.3 Conservation of natural areas

Conserving natural areas comes with a high opportunity cost – the land will never contain income-producing structures. This opportunity cost of open space was estimated using Thorsnes (2002) hedonic analysis of open space preservation in the Grand Rapids, Michigan area. The model included a variable for lot size. Thorsnes analyzed three developments around Grand Rapids. We based our calculations on the model for the development closest to the city in adjacent Plainfield Township. The hedonic model yielded an elasticity of 0.0031 for lot size; that is, a one percent change in lot size results in a 0.31 percent change in housing sales price. The average residential sales price in 2015 was \$129,900 and the average lot size for the northeastern portion of Grand Rapids was 849.9 m^2 (9,148 ft^2). The value of an additional square meter of lot size, therefore, was \$47.36 (\$4.40/ft^2). The annualized value at a 3.5 percent discount rate was \$2.58/m^2/year

($0.24/ft^2). Therefore conserving 0.35 ha (0.87 ac) of natural area would have an opportunity cost of $3.88/m^3 WQv/year ($0.11/ft^3/year) and a present value cost over fifty years of $92.53/m^3 WQv ($2.62/ft^3) (Table 9).

2.6.4 Tree planters / tree pits

The cost of street trees was taken directly from the Midwest Community Tree Guide which lists the costs for planting and maintaining a tree for 40 years in five year increments (McPherson et al. 2006). The costs were adjusted for inflation to 2015 dollars. The guide presents three tree size options – we chose the medium tree (red oak, *Quercus rubra*) which is common in the area. The cost of planting a tree was $200 ($244 in 2015) or $982.46/m^3 WQv ($27.82/ft^3). Total maintenance costs, which include pruning, removal and disposal, treating pests and disease, infrastructure repair, irrigation, cleanup, liability and legal costs, and administrative costs, were $15.21-33.01 per year ($18.57-40.26 per year in 2015). Standardized to WQv and in 2015 dollars, the capital cost was $982.46/m^3 WQv ($27.82/ft^3) and maintenance costs ranged from $74.87/m^3 to $162.10/m^3 WQv ($2.12/ft^3-$4.59/ft^3). Though the WERF LID cost tool includes a concrete tree vault in the default setting for street trees, the Forest Service analysis did not include a tree vault. Tree vaults, which may cost more than $1,000, were not included in our analysis. The total present value cost of the street trees over fifty years was $151.50/m3 WQv ($4.29/ft^3) (Table 7).

2.6.5 Opportunity cost of land

Porous asphalt parking lots are co-located with existing infrastructure. Rain gardens and street trees, however, replace other valuable resources such as lawn space or sidewalks. The opportunity cost needs to be accounted for. The opportunity cost was calculated using the value of a square foot of residential lot size in the Grand Rapids metropolitan area. The opportunity cost of land for rain gardens, bioretention ponds, and street trees was calculated using the same method as that for conservation of natural areas (see previous section). For the 199.28 m^2 of rain garden the opportunity cost equates to $0.212/m^3/year WQv ($0.006/ft^3/year).

Table 46: Cost for green infrastructure practices.

Infrastructure / GI type	**GI practice size (for 84.95 m^3 WQv reduction per 2.54 cm event)**	**PV cost**	**PV cost / m^3 WQv**	**PV cost / unit of GI practice**
Conventional asphalt	3,520.75 m^2	$418,462	$176.22	$118.83/m^2
Porous asphalt	3,520.75 m^2	$451,397	$189.99	$127.45/m^2
Rain garden	199.28 m^2	$75,202	$3.18	$377.39/m^2
Conserve natural areas	3,520.75 m^2	$219,883	$92.53	$62.43/m^2
Tree planter / tree pit	342 trees	$359,645	$151.50	$1,051.65/tree

3. Results and Discussion

The NPV analysis shows that five of the seven green infrastructure practices have positive net present values under the base case assumptions (Table 8, Figure 2). Conserving natural areas had the highest net benefits ($131.37/m^3 ($3.72/ft^3)) followed by rain gardens ($54.03/m^3 ($1.53/ft^3)) and street tree planters ($52.97/m^3 ($1.50/ft^3)). Porous asphalt also had a positive net present value ($26.13/m^3 ($0.74/ft^3)).

Table 47: Net present value for GI practices.

Infrastructure / GI type	**GI size (for 84.95 m^3 WQv per 2.54 cm event)**	**PV benefits ($/m^3 WQv)**	**PV cost GI ($/m^3 WQv)**	**PV cost of gray ($/m^3 WQv)**	**Net Present Value ($/m^3 WQv)**
Porous asphalt	3,520.75 m^2	$39.91	$189.99	$176.22	$26.14
Rain garden	199.28 m^2	$85.82	$31.78	-	$54.04
Conserve natural area	3,520.75 m^2	$224.25	$92.52		$131.73
Street tree planter / tree pit	342 trees	$204.47	$151.50	-	$52.97

*Not standardized to 84.95 m^3 WQv

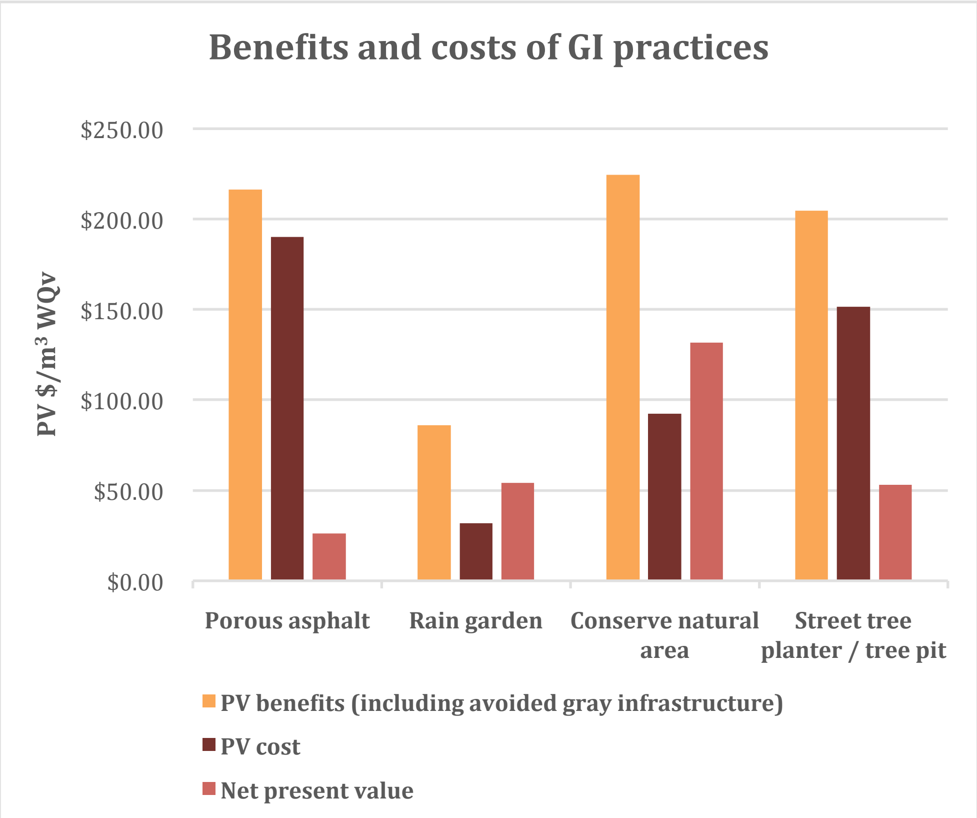


Figure 20: Benefits, costs, and NPVs of GI practices.

The GI practices showed a high degree of variability among their net present values. Conservation of natural areas owes its high NPV primarily to the amenity value it brings to a neighborhood. The scenic amenity value accounts for more than half of the total annual benefit ($5.30/m^3 ($0.15/ft^3)

out of \$9.18/m^3 (\$0.26/ft^3)). The cost of conserving natural areas comes from the opportunity cost of development. We assumed these areas would be kept in a relatively natural state without maintenance costs. While there could be some additional costs associated with this, such as deer and other wildlife eating residential garden plants, these were difficult to quantify and were not included in the analysis. The premium paid on lots adjacent to the conserved natural area, especially when combined with the suite of other ecosystem services, outweighs the opportunity cost. This suggests that low-impact development patterns that concentrate development in one area while leaving natural areas intact can be a highly cost-effective practice. It is cheaper to avoid generating stormwater runoff rather than treating it later on. This requires, however, considerable planning and long-term commitment. Natural areas are often scarce in cities like Grand Rapids so this practice may have limited potential outside of greenfield development sites.

Because of the low capital and O&M costs (\$31.78/m^3 WQv (\$0.90/ft^3)), rain gardens are an attractive GI practices for homeowners and small commercial property owners. These had the second-highest NPV of the green infrastructure practices evaluated. Our analysis assumed that the rain gardens would be professionally installed. The net benefits could be even higher if the property owners install the rain garden themselves or with volunteer help. Rain gardens are also highly scalable and can be used on large or small city lots.

Street trees were third in terms of net present value at \$52.97/m^3 WQv (\$1.50/ft^3). Street tree planters provide substantial benefits over their lifetimes. Trees, however, take time to mature and the full benefit of street trees takes decades to be realized. When using only the McPherson et al. (2006) data updated for inflation and with a 3.5 percent discount rate, the net benefits were just barely positive. Since 2006, costs for electricity and heating have increased faster than the rate of inflation. Updating the McPherson study with current costs and additional water pollution benefits shows that street trees are even more valuable than once thought. The present value costs are relatively low compared to porous asphalt. Mature trees provide a high level of benefit but it takes decades for the trees to grow. Even with a reasonable discount rate, the benefits of street trees still exceed the costs. When the McPherson et al. (2006) avoided runoff volumes were used, the NPV increased to \$53.68/m^3 WQv (\$1.52/ft^3). This all suggests that street tree planters are cost effective under a wide range of assumptions.

In our analysis, the present value costs of porous asphalt are less than ten percent higher than those of conventional asphalt. Porous asphalt has positive net benefit of \$26.13/m^3 WQv (\$0.74/ft^3). Studies from the University of New Hampshire's stormwater center showed that porous asphalt can be a cost-effective solution even in cold climates similar to that of Grand Rapids (Houle et al. 2013). Though porous asphalt is effective at reducing stormwater volumes and treating water pollution, it does not provide any amenity benefits like the other green infrastructure practices considered here.

We assumed that the entire impervious area would be paved with porous asphalt. That may not be necessary, however, as strategically placed areas of porous asphalt can effectively treat impervious areas that drain to it. This would reduce the needed area of porous asphalt and thus reduce the project cost. The City of Grand Rapids is already experimenting with strips of porous asphalt in the parking lanes of some city streets.

This benefit-cost analysis comprehensively documented the values associated with GI practices. Some values, however, are more certain than others. The amenity values for rain gardens in particular are understudied. Our literature review found one study of rain garden amenity values (Polyakov et al. 2015). Rain gardens have grown in popularity so it should be possible to see whether their presence affects housing values.

This benefit-cost analysis of green infrastructure practices has policy implications for Grand Rapids and other small to mid-size Midwestern cities. First, green infrastructure practices provide a suite of benefits including stormwater volume reduction, air and water pollution reduction, and scenic amenities. The traditional gray infrastructure provides a far more limited suite of benefits, often managing just for stormwater volumes. Therefore investments in green infrastructure practices provide far more value for each dollar invested. Second, the net benefits from green infrastructure practices, though variable, are mostly positive. Third, the benefits are largely external to the property owners. That is, the costs of green infrastructure practices are borne by the landowner but the benefits accrue to the public. This results in a market failure – fewer green infrastructure practices will be implemented than are socially optimal. There is a strong argument for public policy to provide incentives – financial, knowledge, or otherwise – for more private investment in green infrastructure practices.

A stormwater utility fee may be the most economically efficient policy to incentive green infrastructure practices. For example the City of Ann Arbor, Michigan, USA, implements a stormwater utility fee (City of Ann Arbor 2015). The advantage of a stormwater utility is that it puts a price on runoff from impervious surfaces, thus internalizing the externality. Landowners have the flexibility to either pay the fee, or reduce their runoff by investing in the most cost-effective green infrastructure practices. Pricing stormwater runoff also fosters innovation by rewarding entrepreneurs who can invent next-generation green infrastructure practices.

Policies can also overcome knowledge and institutional barriers. Barnhill and Smardon (2012) identified three major barriers that limit investment in green infrastructure: the "public good" market failure; a lack of knowledge about the true costs and benefits; and challenges in framing the issue. The market failure could be addressed by a stormwater utility. A comprehensive outreach and education program could provide more accurate, relevant, and timely information to residents and landowners about green infrastructure. Barnhill and Smardon's work suggest the outreach will be more effective if it is framed in terms of neighborhood regeneration, sustainability, and social equity. The benefit-cost analysis will be used to create a publicly available, web and mobile-based GI calculator as well as will inform a comprehensive outreach and education campaign in Grand Rapids and Muskegon, Michigan. The research team will collaborate with local government units to encourage landowners to adopt green infrastructure practices.

4. Conclusions

The benefit-cost analysis for the various green infrastructure GI practice shows that porous pavement, rain gardens, conserving natural areas, and street trees are cost-effective options. No one GI practice is appropriate for all situations. Rather the choice of GI practice will be driven by the site and budget. Porous asphalt is an attractive GI practice given that parking lots are necessary and the additional capital and O&M costs over conventional asphalt are modest. Rain gardens are low-cost and attractive options for small sites like homes and street corners. Conserving natural areas requires substantial up-front planning and a willingness to forgo immediate income. Over the thirty-year project life cycle, the benefits of the conserved areas more than make up for the opportunity cost of development. Street trees take time to fully provide the suite of stormwater mitigation and other ecosystem services, but their benefits are still greater than the lifetime costs.

With the array of options available to manage stormwater on site, municipalities like Grand Rapids are well-positioned to adopt the GI practices that are most appropriate.

References

Abate, D., Towers, M, Dotz, R., Romani, L. 2009. Whitestone Facility Maintenance and Repair Cost Reference.

Almansa, C., Martínez-Paz, J.M. 2011. What weight should be assigned to future environmental impacts? A probabilistic cost benefit analysis using recent advances on discounting. *Sci. Total Environ.* 409(7):1305–1314.

Barnhill, K., Smardon, R. 2012. Gaining Ground: Green Infrastructure Attitudes and Perceptions from Stakeholders in Syracuse, New York. *Environ. Pract.* 14(1):6–16.

Beauchamp, P., Adamowski, J. 2012. Different Methods to Assess Green Infrastructure Costs and

Benefits in Housing Development Projects. *J. Sustain. Dev.* 5(4):p2.

Center for Neighborhood Technology. 2007. Green Values Stormwater Toolbox. *Cent. Neighborhood Technol.* Available online at: http://www.cnt.org/tools/green-values-stormwater-toolbox; last accessed July 31, 2015.

Center for Neighborhood Technology. 2014. *The Economic Benefits of Green Infrastructure: A Case Study of Lancaster, PA*. Available online at: http://www.cnt.org/publications/the-economic-benefits-of-green-infrastructure-a-case-study-of-lancaster-pa; last accessed June 3, 2015.

City of Ann Arbor. 2015. Stormwater Rates and Credits. Available online at: http://www.a2gov.org/departments/systems-planning/water-resources/Stormwater/Pages/StormWaterRates.aspx; last accessed July 1, 2015.

City of Grand Rapids. 2014. Stormwater Asset Management Plan. Available online at: http://grcity.us/enterprise-services/Environment-Services/Pages/Stormwater-Asset-Management-Plan.aspx; last accessed June 12, 2015.

Debo, T. N., Reese, A. 2002. *Municipal Stormwater Management, Second Edition*. 2nd ed. CRC Press, Hoboken.

Freeman, A. M. 2003. *The Measurement of Environmental and Resource Values: Theory and Methods*. Resources for the Future. 516 p.

Herrera Environmental Consultants. 2012) *Puget Sound Stormwater BMP Cost Database*. Washington State Department of Ecology, Environmental Assessment Program, Olympia, Washington. Available online at: www.ecy.wa.gov/programs/eap/toxics/docs/PugetSoundStormwaterBMPCostDatabase.pdf; last accessed July 14, 2015.

Houle, J., Roseen, R., Ballestero, T, Puls, T, and Sherrard Jr, J. 2013. Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and Conventional Stormwater Management. *J. Environ. Eng.* 139(7):932–938.

Johnston, R. J., Rolfe, J, Rosenberger, R.S., Brouwer, R. 2015. Introduction to Benefit Transfer Methods. P. 19–59 in *Benefit Transfer of Environmental and Resource Values*, The Economics of Non-Market Goods and Resources. Johnston, R.J., J. Rolfe, R.S. Rosenberger, and R. Brouwer (eds.). Springer Netherlands. Available online at: http://link.springer.com.ezproxy.gvsu.edu/chapter/10.1007/978-94-017-9930-0_2; last accessed June 10, 2015.

Kuhns, T., Ulasir, M. (2015). First Flush Design for Stormwater. Available online at: http://www.slideshare.net/loribyron/20150226-msfa-presentation; last accessed June 14, 2015.

Landphair, H. C., McFalls, J.A., Thompson, D. 2000. *Design methods, selection, and cost effectiveness of stormwater quality structures*. Texas Transportation Institute. Available online at: http://trid.trb.org/view.aspx?id=681534; last accessed July 7, 2015.

McPherson, E.G., Simpson, J.R., Peper, P.J., Maco, S.E, Gardner, S.L., Cozad, S.K., Xiao, Q. 2006. *Midwest community tree guide: benefits, costs, and strategic planting*. Available online at: http://www.treesearch.fs.fed.us/pubs/25927; last accessed July 8, 2015.

Minnesota Stormwater Manual. 2015 Available online at: http://stormwater.pca.state.mn.us/index.php/Main_Page; last accessed June 29, 2015.

Moeller, J., Pomeroy, C.A. 2009. BMP and LID Whole Life Cost Models: Version 2.0. Available online at: http://www.werf.org/i/a/Ka/Search/ResearchProfile.aspx?ReportId=SW2R08; last accessed June 22, 2015.

NYS Dept. of Environmental Conservation. 2014. Construction Stormwater Toolbox. Available online at: http://www.dec.ny.gov/chemical/8694.html; last accessed June 3, 2015.

Polyakov, M., Iftekhar, S., Zhang, F., Fogarty, J. 2015. The amenity value of water sensitive urban infrastructures: A case study on rain gardens.

Thorsnes, P. 2002. The Value of a Suburban Forest Preserve: Estimates from Sales of Vacant Residential Building Lots. *Land Econ.* 78(3):426–441.

Weather Underground. 2016 Available online at: http://www.wunderground.com/history/airport//2016/01/23/DailyHistory.html?req_city=Grand%20Rapids&req_state=MI&reqdb.zip=49512&reqdb.magic=5&reqdb.wmo=99999; last accessed January 23, 2016.

Weimer, D. L., Vining, A. 2010. *Policy Analysis: Concepts and Practice*. 5 edition. Routledge, Boston. 496 p.

WSB & Associates. 2008. A Public Works Perspective on the Cost vs. Benefit of Various Stormwater Management Practices. Available online at: http://www.apwa.net/Documents/Meetings/Congress/2008/Handouts/; last accessed July 7, 2015.

Xian, G., Homer, C., Dewitz, J., Fry, J, Hossain, N., Wickham, J. 2011. The change of impervious surface area between 2001 and 2006 in the conterminous United States. *Photogramm. Eng. Remote Sens.* 77(8):758–762.

Collaboration and clustering in creative tourism destination management for the Alqueva dam, Alentejo region, Portugal

Idalina Dias Sardinha 1, David Ross 2, Ana Calapez Gomes 3

1 SOCIUS-Research Centre in Economic and Organizational Sociology, ISEG-Lisbon School of Economics & Management, UL-University of Lisbon, Portugal

2 Hull University Business School, United Kingdom

3 SOCIUS-Research Centre in Economic and Organizational Sociology, ISEG-Lisbon School of Economics & Management, UL-University of Lisbon, Portugal

Abstract

Creative tourism enhancement of archaeological heritage discovered during the environmental impact assessment of development projects poses special challenges and calls for cross-sectorial collaboration due to the diversity of stakeholders involved in this context. This paper focuses on the case of the Alqueva dam (Alentejo region, Portugal) to understand if these collaboration conditions are present. Semi-directed interviews were held with 38 regional actors of the tourism and heritage sectors and with the dam construction developers responsible for rescue archaeology interventions. Findings confirm the need to improve the communication and knowledge exchange among the wide range of stakeholders involved in construction, cultural heritage and tourism sectors. The conditions for the emergence of a creative tourism destination framework are identified and discussed and a model for destination management is presented which potentially contributes to increase cross-sectorial collaboration.

Keywords: destination management; creative tourism; regional cluster; Alqueva dam.

Pollution control costs of a transboundary river basin: empirical tests of cost allocation mechanisms' fairness and stability using game theory

Guang-Ming SHI

Institute of Environment Economy and Policy, Hunan Research Academy of Environmental Science, Changsha 410006, guangming0424@126.com

Abstract

Transboundary water resource and pollution conflicts tend to be common with economic growth. In transboundary water pollution conflicts, unidirectional or reciprocal externalities exist among countries/regions but no supranational organizations implement policy instruments to avoid these externalities. Meanwhile, water resource is a classic public good that has a non-excludability property. These characteristics usually pose free-ride problems that lead to the tragedy of the commons. Game theory is generally employed to study such problems because it permits the analysis of the strategy and behavior of different agents (countries) under certain behavioral assumptions. In 1989, Kilgour et al. (1989) first applied game theory using chemical oxygen demand (COD) load control as an example to analyze transboundary pollution problem. Since then, many other researchers have applied it to analyze the cost effectiveness of pollutant reduction and cost/gain allocation. Most of the studies applied game theory to analyze the cost/gain allocation of cooperation and non-cooperation for different agents. However, they ignored the analysis of the stability and fairness of gain allocation. If gain allocation is not stable, then cooperation will not persist in the end. An analysis of cooperation stability can thus be helpful to stakeholders making long-term decisions. Owing to its rapid urbanization and industrialization, China is facing increasingly serious water pollution and water scarcity problems. The discharge of pollutants into rivers has caused river quality to worsen over the years (SEPA, 2000−2012). Poor water quality has caused serious transboundary water resource and pollution conflicts, such as in the Huai River basin, which involves four provinces. Given that these conflicts always involve multiple stakeholders, coordinating the interests of the stakeholders is necessary. Accordingly, this paper seeks to establish a game-theory-based analysis model of transboundary river basin pollution. Furthermore, by using a Chinese river basin as an example, we study gain allocation mechanisms between cooperation and non-cooperation and discuss the stability of cooperation in different regions. Results demonstrated that the fully cooperative coalition yielded the highest relative gain for regions willing to cooperate if each region agreed to negotiate by transferring part of the relative gain obtained from the cooperation to cover the losses of other regions. In addition, different regions were found to have different preferences and stability for different kinds of allocation in a fully cooperative scheme.

Keywords: Cooperative game theory, Transboundary river basin pollution, Cost allocation mechanism, Cooperative stability and fairness

Saving the last wild rivers in Portugal

João Joanaz de Melo[1], Ana Brazão[2]

[1] CENSE, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, 2829-516 Caparica, Portugal; jjm@fct.unl.pt

[2] GEOTA - Grupo de Estudos de Ordenamento do Território e Ambiente, Trav. Moinho de Vento, 17-c/v drtª, 1200-727 Lisboa, Portugal; abrazao@rioslivresgeota.org

Abstract

Rivers are among the natural assets subject to greater human pressure, not only because water is essential to life support and economic activity, but also because rivers are associated with other key resources like agricultural land, biological and mineral extraction, and transport routes. Rivers are hubs of civilization and cultural identity, but also sources of conflict. Cumulative water abstraction, water pollution from domestic, industrial and agricultural sources, overfishing, dam and dyke construction, siltation from deforestation, drainage of wetlands, sand extraction, land filling, urban sprawl, have led to the degradation of natural river landscapes, and jeopardized ecosystems services provided by river basins. Portuguese rivers have been a source of welfare and cultural identity; however, this often led to over-exploitation, ultimately undermining sustainable development. Some indicators of river ecosystem use and quality in Portugal: adequate monitoring exists in only 50% of water bodies under Water Framework Directive; only 52% of inland water bodies have good ecological status; water abstraction intensity has reached over 15% of natural river flow, high for the Mediterranean region; over 80% of major rivers have been heavily modified, mostly by dams, causing deep cumulative ecosystem changes and the retention of sediments, increasing coastal erosion; natural riverbank habitats in major rivers have all but disappeared due to agricultural or urban use; some migratory species, e.g. sturgeon and salmon, have gone extinct; others, such as trout, lamprey and saramugo, are threatened; commercial fisheries, e.g. sardine, who depend on estuaries for reproduction, suffer dwindling stocks. Environmental awareness and official policies (often from the EU) have begun to invert some negative trends: e.g. urban and industrial wastewater treatment rose, from close to zero 30 years ago, to present 74%. Unfortunately, the impacts of other activities are less valued or understood, and show a negative trend: a case in point is dam construction. At present Portugal has 228 large dams with 68 hydro power plants (plus about 7000 small dams), accounting for 20% of national electricity production, 50% of water abstraction, and the irrigation of thousands of km^2 of land. Current plans for five new large dams on the Tua and Tâmega rivers, if allowed to proceed, would eliminate the largest near-natural rivers in Portugal. These state-subsidized projects, which bypassed habitat protection and water management regulations, would be used for power generation, accounting for 0.5 % of national energy consumption, at a much higher cost than available alternatives. New dams are currently the main threat to Portuguese river ecosystems, and a major blow against local sustainable development plans. Cultural heritage, natural landscapes, white water sports, mountain railways, agricultural land and other unique assets are key to both maintain environmental quality and promote local jobs (and would be severely impaired by the new dams). In the past decade, several initiatives have risen to promote local development related to natural rivers and better water management, and of need to fight new dam construction. Those movements evolved to platforms that encompass local communities, environmental NGO, wine companies and ecotourism business.

Keywords: rivers, water management, local development

1. Introduction

Rivers are among the natural assets subject to greater human pressure, not only because water is essential to life support and economic activity, but also because rivers are associated with other key resources like agricultural land, fish nurseries and fishing grounds, transport and trade routes, flat land requested for construction and mineral extraction. Rivers have long been hubs of civilization and cultural identity.

Multiple uses have often made rivers a focus of conflict. Different economic and social activities compete for what has been a scarce resource since humankind became sedentary. Cumulative water abstraction, water pollution from domestic, industrial and agricultural sources, overfishing, dam and dyke construction, siltation resulting from deforestation, drainage of wetlands, sand extraction, land filling, urban sprawl, have led to the degradation of natural river landscapes, and jeopardized ecosystems services provided by river basins. Ultimately, those multiple degradation factors reduce the availability of already scarce water resources. Current trends of climate change and loss of biodiversity compound the problem.

Water management has long been a contentious issue, and has been recognised, in many international *fora*, as one of the key environment and development challenges our society faces (UN, 1992; EEA, 2009, UN 2015). In the European Union, a key step was taken with the creation of the Water Framework Directive (WFD, Directive 2000/60/EC), which provides a comprehensive framework for water management, including criteria for chemical and ecological quality and management tools.

Portugal is a case in point in water management. Like in other countries, Portuguese rivers have been a source of welfare and cultural identity; however, this often led to over-exploitation, ultimately undermining sustainable development. The country has long possessed state-of-the-art instruments to deal with water management, at least since the early 1980s, from sanitary and environmental engineering technology to data collection equipment, laboratory facilities, know-how on mathematical simulation models and management tools. However, progress has been slow and uneven. Much attention has been given to basic sanitation, especially water supply, wastewater treatment facilities and to the distribution of water resources among major users (urban supply, agriculture, industry). Much less attention has been paid to the river ecosystems, either for their intrinsic value, or for the services provided: life support, good water quality, a variety of economic activities, social amenities. There is reasonable information on the state of the environment, but often it is not used in policy-making or management decisions. Wild rivers have become a rarity in Portugal.

The goal of this paper is to study key problems threatening Portuguese rivers, focusing on dangers that have been neglected or are worsening; and discuss approaches that have been used to deal with them. Among a general trend of improving water management practice, one particular piece of policy emerges as contradictory: the national large dam plan.

2. Methods

The research reported in this paper followed three main steps:

- Brief review of major indicators regarding water management and river quality in Portugal, with an emphasis on the ecological component and ecosystem services. Most of this information is available in official reports;
- Identification of major threats, especially those worsening over time. This was obtained from official documents, expert and stakeholder consultation;
- Discussion of approaches to deal with the increasing threats against water management, particularly the disappearance of wild rivers.

3. Results and discussion

3.1. Key indicators on river status

Some indicators of river ecosystem use and quality in Portugal:

- Adequate monitoring of water bodies under the WFD is acknowledged as insufficient.

Available information indicates that only 52% of water bodies have good or better status (APA, 2016);

- Water abstraction intensity has reached over 15% of natural river flow, high for the Mediterranean region;
- There are no updated data due to the decommissioning of hydrometric teams in governmental agencies in the past decades, and the lack of investment in monitoring networks, but it is estimated that between 80% and 90% of major rivers have been heavily modified, mostly by dams, causing deep ecosystem changes and the retention of sediments, increasing coastal erosion;
- Natural riverbank habitats in all major rivers have all but disappeared due to agricultural or urban use;
- Due to habitat fragmentation and water pollution, several migratory species, e.g. sturgeon and salmon, have gone extinct in historical times; others, such as trout, lamprey and saramugo, are threatened; commercial fisheries, e.g. sardine, who depend on estuaries for reproduction, suffer dwindling stocks.

Environmental awareness and official policies (often from the EU) have begun to invert some negative trends: urban and industrial wastewater treatment rose, from close to zero 30 years ago, to present 74% of population served; good quality public water supply rose to 98% of population served (APA, 2015). Agricultural runoff, although still a very significant problem, has been increasingly controlled by means of good practice codes, rising agro-chemicals prices, increasing use of biological agriculture and environmental measures in agriculture European subsidies. Unfortunately, the impacts of other activities are less valued or understood, and show a negative trend: a case in point is dam construction.

Water resources planning under the WFD, currently under way in Portugal, identifies all of the above pressures and dangers to water bodies (APA, 2016). Strangely, the National Water Plan, which serves as framework for the operational basin plans, neglects to identify the blatant conflict between almost every goal in the Plan, and the impacts created by projected new large dams.

3.2. Main impacts of large dams

Large dams have been marketed as the pinnacle of “good” electricity production, vital instruments for flood control and water storage, drivers of regional development and touristic promotion, and a solution to fighting climate change. These advantages are claimed by dam promoters, emphasized by governments and stated in hydro projects environmental impact assessments (McCully, 2001).

In Portugal it is no different. Enacted as upper public national interest, these constructions are promoted with public funding and shielded from consequent public participation, undermining worldwide scientific evidence of environmental and social impacts, negative externalities and investment, performance and risk indicators.

The impacts of dams depend on its physical and operational characteristics, as well as the region, climate, orography, hydrology, soil and habitats it is settled upon. Habitat destruction and reduction of biodiversity is the most visible impact. The shift from a flowing river into a reservoir, the barrier effect to fauna and the destruction of the river continuum are obstacles for transverse and longitudinal exchanges in fluvial ecosystems (Ward & Stanford, 1995). According to the National Report on Habitats Directive (ICNF, 2013), 35% of species and 66% of habitats under the Habitats Directive have an Unfavourable status, including most river habitats; 40% of protected species have unknown conservation status.

The main pressure threatening species conservation is the alteration of natural systems, namely river basin artificialization such as fragmentation by dam construction and river flow regime alteration.

One of the longitudinal functions of rivers affected is the nutrient and sediment transport. Together with flow regularization, sediment retention is responsible for diminishing the volume available for water storage in the medium and long-term. However, downstream impacts have a higher cost, as dams interrupt the sedimentary cycle and the coastal replenishment of sand. Several models have been used to assess this, and it is estimated that dams are responsible for an 80 % reduction of sand volume arriving at the Portuguese coast nowadays (GTL, 2014).

A large dam also results in water quality degradation, a phenomenon related to the retention time in the reservoir. The main effects are increased water temperatures and nutrient load, decreased turbidity and dissolved oxygen, and heavy metals and minerals concentration alterations. As water temperature increases, dissolved oxygen diminishes, jeopardizing the bacterial function to break down organic matter and thus increasing the likelihood of eutrophication. The current state of many Portuguese reservoirs is a case in point.

Another major environmental impact is the contribution of reservoirs to climate change. From the destruction of important carbon sinks (forests, wetlands, riverine ecosystems) to the construction of these major works, carbon dioxide emissions are increased. However, the most significant is methane emissions from reservoirs, a more powerful greenhouse gas that carbon dioxide. Although research on this topic is still limited, recent studies suggest that emissions from reservoirs could be responsible for 4 % of all anthropogenic global warming (IR, 2016). Estimates of methane emission in Portuguese reservoirs have never been modelled, due to lack of data and monitoring effort.

On the other hand, climate change can have a negative impact on hydroelectric production. According to the IPCC, hydroelectric production can be directly affected by changes in precipitation patterns (IPCC, 2007a/2014). In fact, hydropower potential is expected to decline from 20 to 50 % in the Mediterranean region by 2070 (IPCC, 2007b).

Dams are also advocated as regional development enhancers. Under the label of a “green” energy source and the lure of job opportunities, utilities companies mask the impacts by offering mitigation and compensation measures (often later found ineffective). Local governments hail the dam as a touristic asset for their regions, disregarding the opinions of local populations and economic agents. However, academia has repeatedly proven utilities and local governments wrong.

Available studies show that Portuguese dams such as Castelo do Bode, Alto Rabagão and Alto Lindoso have not contributed to socioeconomic development, with population decreases of 7 to 62 % since the dam construction (Velosa, 2009). The same study and others conclude that similar groundless promises of development are found in the Foz Tua Dam impact assessment process (Simão and Melo, 2011; Duarte, 2013). In the region where new large dams are being projected, Trás-os-Montes and Alto Douro, similar results were obtained in development indicators in municipalities with or without existing large dams (Bento at al. 2016). Construction works create temporary construction jobs, but the referred studies indicate that the effect on permanent jobs, if anything, is negative, affecting sectors like ecotourism and agriculture.

3.3. The Portuguese large dam program

At present Portugal has an inventory of 228 operational large dams (height over 15 m or reservoir volume over 1 000 000 m^3), plus an estimated number of 7 000 small dams. (CNPGB, 2016; RPAmb, 2016) They support 68 hydropower plants (accounting for 24% of national electricity production on an average year, 15% on a dry year, 30% on a rainy year), 50% of water abstraction, and the irrigation of 558 000 ha of land (DGADR, 2014).

Because new large dams show poor cost-effectiveness and cause such large impacts, very few projects have gone ahead in the recent past: in the last two decades only three new large dams were constructed in Portugal. The controversial Alqueva dam was conceived in the 1950s approved in 1995 and commissioned in 2002; its main goals are irrigation and the strategic control of the river Guadiana. Two other dams, Baixo Sabor and Ribeiradio-Ermida, were approved by 2007 and were recently commissioned, in the midst of a raging controversy, especially the Baixo Sabor, because it destroyed a Natura 2000 site and unique landscape. Litigation in the courts continues; the Baixo Sabor dam has been considered a case study in poor decision-making and conflict between biodiversity conservation and renewable energy policies (Melo et al. 2010, Jackson 2011).

In 2007 the Portuguese Government launched the “national program for dams with high hydropower potential”, known as PNBEPH (INAG et al. 2007). The alleged goals of the PNBEPH were to reduce greenhouse gas emissions, to improve energy import dependency, and to improve the share of renewables, but, strangely, no targets were set for these goals. The only quantitative targets were to increase national hydropower capacity to 7 000 MW and hydro pumping capacity to 2 000 MW. No evaluation of impact on electricity cost or burden on the consumers and taxpayers was performed. No alternatives other than new dams were examined.

Seven out of the ten dams in the program were eventually approved. By 2016 only one dam was under construction (Foz Tua), two had been officially discarded (Girabolhos and Alvito), one is suspended (Fridão) and three are supposed to proceed but have not yet begun construction (the Tâmega Electroproduction System or SET).

The Portuguese Government and electric companies hailed the PNBEPH as the cornerstone of energy policy regarding climate change. To the untutored eye, the near 25% increase in installed hydropower capacity seems impressive. But, beyond major environmental impacts, when we look at the economic indicators (Table 1), the new dams show an appalling performance: cost of electricity per MWh is more than twice the average cost of the existing system; actual production amounts to only 1.7% of electricity, 0.3% of primary energy and 0.4% of energy imports, despite the fact that those were the main alleged goals of the program. The best alternative — energy efficiency — is ten times more cost-effective, regarding any of the alleged goals.

Table 1 — Performance indicators of current hydropower, new dams and energy efficiency

Indicator	**Existing dams**	**Revised PNBEPH**	**Energy-saving measures equivalent to the PNBEPH**
Installed power (MW)	7 003	1 655	n.a.
Pumping power (MW)	2 439	1 140	-
Average production (TWh/year)	12.8	0.9	0.9
Use of nominal power (%)	21%	6%	n.a.
Investment (M€)	n.a.	1914	170
Average production cost (€/MWh)	50	113	10
% of national electricity production	24%	1.7%	1.7%
% of national primary energy	4.3%	0.3%	0.4%
% of national energy imports	5.2%	0.4%	0.5%

Adapted from Melo, 2012, GEOTA, 2015 and RPAmb, 2016 (n.a. = not available; - = not applicable)

We can also see that current capacity (7 003 MW total hydropower and 2 439 MW pumping, reached with the recent refitting of six existing dams) already surpasses the targets defined in the PNBEPH. This is an important point: none of the new dams are needed to reach the targets defined by the program itself.

The whole program was supposed to cost about 1 200 M€ (INAG et al. 2007), but final proposals from the concession-holders indicated twice the originally defined installed power, with almost three times the cost (Melo, 2011); this discrepancy was never officially explained. The poor performance of the new dams is related to excess capacity and low use of nominal power, 6%. The over-capacity seems to have been motivated by a promised State subsidy for “power availability”. That subsidy has been reduced, by demand of the International Monetary Fund (IMF), the European Central Bank (ECB) and the European Commission (EC), due to the economic crisis and the recognition that subsidies to the electric companies are already excessive. This has prompted the electric companies to give up on several projects, despite having paid a total of 624 M€ for the concessions.

3.4. The early campaigns against dams

Of all large constructions works, few encompass as many stakeholders as large dams do. The irreversibility and high magnitude of impacts caused by dams change the lives of thousands directly, and millions indirectly. The negative nature of these impacts is often ignored in favour of the benefits gained by a few. These struggles have gained weight worldwide and in Portugal.

Opposition to large dams is an old phenomenon in Portugal, but for many years it was restricted to affected local inhabitants or environmental groups; in the XX century it rarely gained national, let alone international attention.

The first such debate to gain real public notoriety, even passion, was about the Alqueva mega-project: a large dam creating a 25 000 ha reservoir to irrigate 110 000 ha of land. The debate went on through the whole second half of the XX century. Alqueva was eventually approved despite substantial negative impacts, as it did have some benefits regarding geostrategic and development issues (Melo & Janeiro, 2005). Most critics of the project fought for impact mitigation and better practice rather than a full opposing campaign. Decisions on Alqueva were debatable, often bad, but understandable in their context.

The newer crop of dams, beginning with Foz Coa, then Cela, Baixo Sabor, Ribeiradio-Ermida and finally the PNBEPH, had very different stories, because they possessed scant or no public interest to begin with.

The campaign against the Foz Coa dam on the river Coa (Douro basin), 1992-1995, was run mostly by archaeologists protesting the destruction of unique Palaeolithic rock engravings, with large support from the international community. They capitalized on a very favourable political context, with a change in Government that promised more attention to cultural issues. The dam was stopped in 1995, after construction had already begun.

The campaign against the Cela dam on the river Minho happened in the early 2000s, involving municipalities, wine producers and environmental NGO. The project was reproved in 2005 due to the strong public opposition both in Portugal and in Galicia (Spain).

The Ribeiradio-Ermida project suffered harsh criticism but no full-blown campaign.

3.5. The “save the rivers” campaigns

The campaign against the Baixo Sabor dam began in 2004, run by the environmental coalition Plataforma Sabor Livre, focused on the ecological value of the Sabor valley Natura 2000 site. There was early success in the media and the courts, but the campaign neglected to involve local populations and economic agents. The Baixo Sabor dam was supported by heavy lobbying by EDP before the municipalities, the Portuguese Government and the European Commission. Ultimately, the pro-river campaign was defeated by the weak local opposition and the passivity of both Portuguese and European authorities (Melo et al, 2010).

The launching of the environmentally devastating large dam program in 2007, right before the Water Framework Directive came into force, prompted the Portuguese environmental movement to pay more attention to the “green energy” cause. In 2008, a group of NGO submitted a formal complaint to the European Commission against the dam program, proving infringements of important legislations such as WFD. The complaint was closed in 2010 based on false information provided by the Portuguese Government.

Meanwhile, several NGO and many other stakeholders participated in the public consultation of these dams under the environmental impact assessment process. In cases such as Foz Tua, Fridão and the Sistema Electroprodutor do Tâmega, heavy criticism by environmental authorities and participants in the public consultation were completely dismissed and neglected in the political decisions. Upon the issuing of the licenses to construct those dams, several local movements were created to fight against each particular dam.

After the destruction of the lower course of the river Sabor by the Baixo Sabor dam, the Tua and the Tâmega are the largest Portuguese rivers close to their natural state (among the very few in

Europe). All three rivers are tributaries of the Douro, the second-longest Iberian river. The cumulative impacts of six new dams (including the Baixo Sabor) in the Douro basin (water quality degradation, habitat fragmentation, sediment retention) were never studied.

The one dam of the PNBEPH currently under construction, Foz Tua, is located on the Tua river, a tributary of the right bank of the Douro River, about 1 km from the confluence. The dam is a concrete arch 108 m height and 280 m wide. It will submerge 420 ha of vineyards, olive and cork oak groves, agricultural land, plus one of the most beautiful landscapes in Portugal and a unique 140-year-old mountain railway, the last in Portugal. The new dam stands within a UNESCO World Heritage (WH) Site, the Alto Douro Wine Region (ADWR), where the worldwide famous Porto Wine is produced. The dam is being built a few meters from the WH core zone, and the whole reservoir will be within the buffer zone. According to a mission report form ICOMOS to UNESCO in 2011, "the area intervened affects fully the WH property" (ICOMOS, 2011). However, in 2012 the World Heritage Committee was misled into admitting compatibility between the dam and the ADWR, as long as a list of impact mitigation measures would be met by concessionary and the Portuguese State (WHC/ICOMOS/IUCN, 2012). The investment for the construction of the dam and power plant is estimated at 370 M€ (that will increase to at least 410 M€ with the power line and ineffective mitigation measures). The concession holder is EDP – the largest Portuguese electricity company, whose main stockholder happens to be China Three Gorges.

In the river Tâmega, already impacted by the strongly eutrophycated reservoir of the Torrão dam, and threatened with four new large dams, NGO such as ProTâmega started acting against the Fridão Dam, and submitted a legal complaint in Portuguese courts based on the risk of building a large dam 6 km upstream of a riverside city, Amarante.

Urged by the outstanding values of the Tua and Sabor valleys, GEOTA, on behalf of a coalition of NGO, presented two formal complaints to the European Commission in 2012. None has ever received a reply, nor was any action taken by the Commission to prevent further degradation while investigating both cases. The Baixo Sabor Dam was concluded in 2015, still lacking the implementation of mitigation measures.

In order to stop the Foz Tua dam, several environmental NGO and local associations, canoeing/rafting clubs and wine producers have created Platform Save the Tua (PST) in 2013. PST has repeatedly presented evidence to UNESCO, European and Portuguese authorities, that key demands have not been and almost certainly are not going to be met (PST, 2014). The promised mobility plan has been delayed and does not comply with mandatory specifications; and in October 2014, the Portuguese State approved an aerial high voltage power line connecting the hydropower plant to the national electrical grid across the ADWR property or buffer zone: two blatant infringements regarding specific conditions of the Foz Tua dam environmental impact declaration.

Several raising awareness actions have been developed under the PST campaign “Save the Tua, Protect the Douro”, reaching national and international media (PST, 2016a). Simultaneously, three legal actions were presented in the Portuguese courts between 2013 and 2015, still pending (PST, 2016b).

In 2014, the environmental organization GEOTA launched a project to preserve the last wild rivers in Portugal and halt the implementation of the Dam Program. The Rios Livres Project has adopted a methodology based on failures and victories of these past experiences: (1) Analyzing relevant documentation concerning river status and the dams EIA in order to gather data; (2) visiting the places and consulting all relevant stakeholders; (3) closely monitoring all developments (legal and *in loco*); (4) developing campaign materials that answer FAQ (5) raising awareness campaigns that embrace all stakeholders and (6) acting at a judicial and policy lobbying level.

The organization of “Caravana do Tâmega: de Chaves a Amarante” took place in November 2015 and aimed to raise awareness regarding all dams projected for the Tâmega River. The caravan spent one week following the river stream, from the highland city of Chaves to the downstream riverside city of Amarante. The caravan organized actions everyday with local associations and movements (including ProTâmega), passing through several affected villages, and ended with a kayak action and a large debate concerning the future of the valley and the region. Thousands of people were reached and the matter regained media attention in the area, relaunching a subject dormant due to years of delay in the projects (GEOTA, 2016).

More recently, PST and one of its members, the wine producer Esporão® have launched a national and international campaign, called "The Last Days of Tua", aimed at raising awareness to public in general and urge them to sign a letter pressuring UNESCO to take action. The campaign is based on the website with four small documentaries showing what four people will lose forever if the dam is concluded (PST, 2016c). So far, results demonstrate that having a good campaign product, together with a clear Call for Action, is key to target the audience. Moreover, showing the impacts on people, and not just the financial equilibrium or nature destruction, has certainly broadened the type of audience.

4. Conclusion

Our society got used to exploit resources to the point that they are no longer renewable or available. Among other important resources, water and river ecosystems have been strongly affected. We risk losing not only essential assets for our survival and comfort, but also a unique heritage in biodiversity, landscape and culture. This paper reflects on the threats and actions to save the rivers. Particular attention was paid to the campaigns against large dams, because dams were found to be the largest threat for the last wild rivers in Portugal.

The fact that the Foz Tua dam jeopardizes historical and cultural heritage, just as in the Foz Coa dam case, generated a stronger reaction from many people. Another key aspect is the increased strength of having a multi-stakeholder platform instead of divided forces, enabling to reach a wider audience. This approach was not taken in the Baixo Sabor campaign, run by environmental organizations and focused mostly on biodiversity loss.

The Rios Livres (Free Rivers) project at GEOTA has also came to the conclusion that tackling dams on a multi-disciplinary basis and embracing local movements allows much better knowledge of the issues at hand, and better effectiveness of the campaign. Simultaneously, joining geographically dispersed movements enables to widen the message, pressure local decision and opinion makers and getting a national reach in the media.

Sadly, one of the main conclusions of the struggle against dams in Portugal is the unreliability of national and European Union's institutions and legal instruments to defend objective public interest, and act before irreversible damage is made. Decision-makers often define policies and promote harmful projects in the face of contrary scientific evidence and public participation. Information available has reached the point that local inhabitants, as well as public opinion at large, when faced with the Pros and Cons of these dams, do not want them and recognize the existence of better alternatives: financially, environmentally, but mostly, socially.

Acknowledgements

The authors would like to thank: colleagues and students at the School of Science and Technology of the New University of Lisbon (FCT-UNL), where much of the research referred in this paper was performed; activists and staff at GEOTA, Platform Save the Tua, and its member organizations, for their hard work on behalf of our rivers, often on a voluntary basis; to Esporão, sponsor of The Last Days of Tua campaign, and to MAVA Foundation, sponsor of the Rios Livres project.

References

APA, 2015, Relatório do Estado do Ambiente 2015. Agência Portuguesa do Ambiente. Lisboa.

APA, 2016. Plano Nacional da Água. Março 2016. Agência Portuguesa do Ambiente. Lisboa.

Bento, A.R., Brazão, A., Melo, J.J. (2016). Avaliação estratégica de uma rede de turismo para o desenvolvimento regional em Trás os Montes e Alto Douro. 6ª Conferência Nacional de Avaliação de Impactes (CNAI´16). APAI, Évora, 19-21 Maio 2016.

CNPGB, 2016. Barragens de Portugal. http://cnpgb.apambiente.pt/gr_barragens/gbportugal/ (accessed 2016.03.23)

DGADR, 2014. Estratrégia para o Regadio Público 2014-2020, Direção-Geral de Agricultura e Desenvolvimento Rural, Portugal.

Duarte, A.F., 2013. Barragens e Albufeiras em Portugal: Usos da Água, Preocupações Ambientais e Ordenamento do Território. Dissertação de Mestrado em Gestão do Território, FCSH-UNL.

EEA, 2009. Water resources across Europe — confronting water scarcity and drought. European Environment Agency, Report No 2/2009. ISSN 1725-9177

GEOTA, 2016. Rios Livres GEOTA website - Caravana pelo Tâmega – 1 a 8 de novembro. http://rioslivresgeota.org/caravana-pelo-tamega-chaves-a-amarante-1-a-8-de-novembro/

GTL, 2014. Gestão da Zona Costeira O Desafio da Mudança. Relatório do Grupo de Trabalho do Litoral. Lisboa. (accessed 2016.05.19) http://sniamb.apambiente.pt/infos/geoportaldocs/docs/Relatorio_Final_GTL2015.pdf

ICNF, 2013. Rede Natura 2000 – 3º Relatório Nacional de Aplicação da Diretiva Habitats (2007-2012). Instituto de Conservação da Natureza e Florestas (accessed 2016.05.19) http://www.icnf.pt/portal/naturaclas/rn2000/dir-ave-habit/rel-nac/rel-nac-07-12

ICOMOS, 2011. World Heritage List: Advisory mission to ALTO DOURO WINE REGION (PORTUGAL) to consider the impacts of the proposed Hydro-electric Foz Tua Dam Project, UNESCO. Paris.

INAG, DGEG, REN, 2007. Programa Nacional de Barragens com Elevado Potencial Hidroeléctrico (PNBEPH). Instituto da Água, Direcção Geral de Energia e Geologia, Redes Energéticas Nacionais.

IPCC, 2007a. IPCC Fourth Assessment Report: Climate Change 2007, Intergovernmental Panel on Climate Change. https://www.ipcc.ch/publications_and_data/ar4/syr/en/spms3.html (accessed 2016.05.19)

IPCC, 2007b. IPCC Fourth Assessment Report: Climate Change 2007, Intergovernmental Panel on Climate Change - TS.4.2 Regional impacts, adaptation and vulnerability. https://www.ipcc.ch/publications_and_data/ar4/wg2/en/tssts-4-2.html (accessed 2016.05.19)

IPCC, 2014. Climate Change 2014. Mitigation of Climate Change Report, Intergovernmental Panel on Climate Change, UN. pp 442.

IR, 2016. Wrong Climate for Big Dams: Fact Sheet. Destroying Rivers Will Worsen Climate Crisis. International Rivers- https://www.internationalrivers.org/resources/wrong-climate-for-big-dams-fact-sheet-3373 (accessed 2016.05.19)

Jackson, A.L.R. (2011). Renewable energy vs. biodiversity: Policy conflicts and the future of nature conservation. Global Environmental Change, 21 (4), 1195–1208. Elsevier

MARP, 2016. Revisão do Programa Nacional de Barragens. Visão integrada da utilização, renaturalização e proteção dos rios. Ministério do Ambiente da República Portuguesa, Lisboa.

McCully, P., 2001. Rivers No More: The Environmental Effects of Dams, in: McCully, P., Silenced Rivers – The Ecology and Politics of Large Dams. Zed Books, London & New York, pp. 29-64.

Melo, J,J,, Chainho, P., Fráguas, B., Santos, P.T., Patacho, D., 2010. A barragem do Baixo Sabor: um caso de má aplicação da avaliação de impactes ambientais. 4ª Conferência Nacional de Avaliação de Impactes (CNAI´10). APAI/UTAD, Vila Real, 20-22 Outubro 2010.

Melo, J.J. (2012). Not sustainable: the sad business of Portuguese new dams. IAIA 2012 —Annual conference of IAIA: Energy future — the role of impact assessment. Porto, Portugal, 27 May-1 June 2012. (published booklet of short abstracts; full papers published on-line:

www.iaia.org/conferences/iaia12)

Melo, J.J., Chainho, P., Fráguas, B., Santos. P.T., Patacho, D., 2010. A barragem do Baixo Sabor: um caso de má aplicação da avaliação de impactes ambientais. 4ª Conferência Nacional de Avaliação de Impactes (CNAI´10). APAI/UTAD, Vila Real, 20-22 Outubro 2010

Melo, J.J., Janeiro, C., 2005. Alqueva dam and irrigation project: hard lessons learned from good and bad assessment practice. IAIA´05 – Proc. International Association for Impact Assessment annual meeting. Cambridge, Massachusets, USA, 31 May-3 June 2005.

PORDATA, 2016. Produção bruta de energia elétrica: total e por tipo de produção de energia elétrica – Portugal (accessed 2016.05.19) http://www.pordata.pt/Portugal/Produ%C3%A7%C3%A3o+bruta+de+energia+el%C3%A9ctrica+total+e+por+tipo+de+produ%C3%A7%C3%A3o+de+energia+el%C3%A9ctrica-1126

PST, 2014. Report on non-compliance of commitments by EDP and the Portuguese State on the Alto Douro Wine Region and Foz Tua dam. Plataforma Salvar o Tua. Portugal.

PST, 2016a. Platform Save the Tua / Press. http://www.salvarotua.org/en/press/ (accessed 2016.05.19)

PST, 2016b. Platform Save the Tua / Legal Actions. http://www.salvarotua.org/en/judicial-processes/ (accessed 2016.05.19)

PST, 2016c. Platform Save the Tua /Last Days of Tua. http://lastdaysoftua.com/ (accessed 2016.05.19)

RPAmbiente, 2016. Revisão do Programa Nacional de Barragens. República Portuguesa, Ministério do Ambiente (52 p.)

Simão, J.V., Melo, J.J. (2011). Impact of nature and cultural tourism in the Tua Valley. IAIA 2011 – International Association for Impact Assessment annual meeting. Puebla, Mexico, 28 May-4 June 2011. (published booklet of short abstracts; papers published on-line: www.iaia.org/conferences/iaia11/

UN, 1992. Report of the United Nations Conference on Environment and Development, UN. Rio de Janeiro.

UN, 2015. The Millennium Development Goals Report 2015, United Nations.

Velosa, J., 2009. Os efeitos das grandes barragens no desenvolvimento local. Dissertação para obtenção do Grau de Mestre em: Engenharia Civil, Instituto Superior Técnico da Universidade de Lisboa. Lisboa.

Ward, J.V., Stanford, J.A. 1995. Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation. Regulated Rivers: Research and Management, 11, pp 105-119.

WHC/ICOMOS/IUCN UNESCO, 2012. Report of the joint World Heritage Centre/ ICOMOS /IUCN reactive monitoring mission to Alto Douro Wine Region (Portugal), 30 July – 3 August 2012. UNESCO. Paris.

Theme 2 posters

Application of different composting techniques in the treatment of waste from restaurants

Maria Cristina Rizk[1], Adriano da Silva Yokoya[2], Marcelo de Melo Bernini Conte[3]

[1,2,3] Universidade Estadual Paulista "Júlio de Mesquita Filho" – Faculdade de Ciências e Tecnologia, campus de Presidente Prudente – São Paulo – Brasil, [1]mc_rizk@yahoo.com.br, [2]adriano_yokoya@hotmail.com,[3]marcelo_conte_93@hotmail.com

Abstract

Composting is one of the methods recommended for the treatment of organic solid waste, since it transforms the waste that would be discarded without any usefulness in the environment into organic fertilizers, which can often be used as soil conditioner. Besides, the compost it is interesting because is a low investment technique and easy to install. Thus, this study aimed to evaluate different methods of composting for the treatment of organic waste generated in a restaurant. Three different methods of composting were studied: the aerated pile technique with manual revolving every five days; the mechanized composting reactor with a daily injection of air by a compressor; and the vermicomposting with manual revolving initially and after the temperature stabilization with the addition of worms. The three techniques used 50% of organic waste from a restaurant and 50% of grass cutting waste. The parameters analyzed were temperature, pH, moisture content, organic matter, total ash, organic carbon, total nitrogen, and C/N ratio. The results had showed suitable for using the treated waste as soil conditioner. In the composting in pile the final pH was 7.62, the moisture content was 81.95% and the C/N ratio was 9.84. In the composting in vessel, these parameters were, respectively, 7.25; 37.65% and 9.68 and in the vermicomposting process, it was, respectively, 7.89; 9.10 and 69.76%. In the techniques studied, the best result was obtained in the reactor, which reached stabilization parameters in less time than the other techniques and with the highest concentration of organic matter, which is positive for the soil application. Thus, composting can be an option for the proper disposal of organic waste, which before would be discarded without treatment and could cause environmental impacts and public health problems. In addition to these factors, composting can add to your product economic value and can provide income generation.

Keywords: organic waste; aerate pile; reactor; vermicomposting

1. Introduction

Food and kitchen waste from households, restaurants, caterers and retail premises, and similar waste from food processing plants are considered major contributors to bio-wastes. Waste management options for kitchen wastes, as part of biowastes, include, in addition to prevention at source, collection (separately or with mixed waste), anaerobic digestion (AD) and composting, incineration, and landfilling (Vavouraki et al., 2014).

Life cycle assessment studies have found composting to be more advantageous than other organic waste disposal scenarios, such as landfill and incineration, causing less environmental impacts (Saer et al., 2013).

Based in many studies Chan et al. (2016) related that food waste is a suitable substrate for composting because it is rich in organic matter with little concerns about heavy metals and pathogens. However, the specific characteristics of food wastes such as high moisture, acidity, high oil content, and high salinity may retard the decomposition process.

Composting consists of two narrowly linked processes, degradation and humification: a part of compost organic matter is aerobically mineralized by microorganisms, whereas the partially decomposed or undegraded part leads to the formation of humic substances. The final product, compost, is a soil amendment, an efficient tool for bioremediation processes or soil restoration, and has capability for improving soil's physical, chemical and biological properties (Benlboukht et al., 2016).

Composting is a biological process in which organic matter (OM) can be utilized by aerobic thermophilic and mesophilic microorganisms as substrate and mainly converted into mineralized products (CO_2, H_2O, NH_4^+) or stabilized OM (mostly as humic substances) (Qian et al., 2014).

There are few main factors which may able to affecting the composting process; temperature, carbon to nitrogen ratio, aeration (percentage of oxygen), moisture content, porosity and pH. The acceptable range are: temperature 54-60ºC; C:N 25-30:1; aeration (percentage of oxygen) >5%; moisture content 50-60%; porosity 30-36%; and pH 6.5-7.5 (Shafawati and Siddiquee, 2013).

Different methods for controlling the effective aerobic composting are: physical turning (mechanical and non-mechanical) of the mass, natural convection, and forced aeration (positive and negative modes) (Jolanun and Towprayoon, 2010).

Similar to composting, the vermicomposting is the biological decomposition of organic waste to produce stabilized organic fertilizer. The vermicomposting process involves interactions between earthworms and microorganisms to biodegrade organic waste at a faster rate. The earthworms act as the main drivers in the decomposition of organic waste by fragmenting and conditioning the substrate (Lim et al., 2016).

Thus, the aim of this work was to evaluate the composting and the vermicomposting in the treatment of food waste from a restaurant, in terms of physical/chemical parameters.

2. Methods

2.1 Collected waste

The organic wastes used in this study were collected at FCT/UNESP University, Brazil. The food waste was collected in the University Restaurant. The menu composition of the restaurant consists in a base plate (rice/beans), main course, trim, salad, dessert and juice. So, the waste generated composition is associated to the menu of the restaurant. Another waste used in the composting was the grass cutting wastes, which was collected in the green areas in the campus.

2.2 Composting in pile

A windrow constituted with 50% of food waste (FW) and 50% of grass cutting (GC), in mass, was composted during 117 days.

The manual aeration pile was developed above a plastic tarp, in which the food waste and the grass cutting were intercalated. The open windrow was covered when there was a possibility of rain to not interfere in the process.

The size of the windrow was 2 meters wide x 2 meters long and about 1.5 meters high. The total weight of the pile was 100 kg.

During the composting process, the pile was manually mixed with shovels. At the beginning of the composting, the pile was every day mixed during the first 15 days. After, the pile was manually mixed every 4 days and later, with 50 days of composting, the pile was manually mixed every week until the 117th day of composting.

The samples were collected every 15 days for the determination of the designed parameters. The composite samples were homogenized and representative samples were taken of the composting substrate by the quartage method (ABNT, 2004).

The pH of the raw material or the compost samples was detected by a pH meter (portable pH meter HANNA, model HI-221). The moisture content of the sample was obtained by drying at 105°C in an oven for 24 h; the organic matter (OM) and total ash (TA) were determined by the sample ignition at 550°C for 1 h; the organic carbon (OC) was found by the values of OM per 1.8, according to the procedures described by Kiehl (1985). Total nitrogen (TN) was determined in accordance to the method of IAL (1985).

The pile temperature was measured by a digital thermometer (NOVUS) with a probe of 3 m at five different points in pile. Firstly, the measurements were done daily; after 15 days of composting, the measurements were done every 4 days; and with 50 days of composting, the measurements were done weekly. The temperature measurements were done before the pile mixing.

The obtained results were compared to the Normative Instruction (NI) 25/2009 from the Ministry of Agriculture, Livestock and Supply of Brazil (Brasil, 2009), which establishes the reference values to commercialize organic compost from waste treated.

2.3 Composting in vessel

The in-vessel composting system was constituted by a cylindrical plastic reactor, with a working volume of 200 L. The reactor was perforated in many depths around the vessel to enable the air inflow. Beyond the natural air to enter the vessel composting, the system was aerated by an air compressor. Air was evenly distributed to the waste mixture through the perforated holes. The mechanical aeration was developed daily during 15 minutes.

The reactor of composting was constituted by 50% of food waste and 50% of grass cutting, in mass. The total weight of the reactor was 30 kg in which the food waste and the grass cutting were intercalated at the system. The composting lasted 60 days.

In the same manner as in pile composting, the samples were collected every 15 days to the determination of the pH, moisture content, organic matter, total ash, organic carbon and total nitrogen, according to the procedures above described. Also, it was taken homogenized and representative samples.

The temperature was measured by a digital thermometer (NOVUS) with a probe of 3 m at five different points in reactor. Firstly, the measurements were done daily; after 15 days of composting, the measurements were done every 4 days; and with 50 days of composting, the measurements were done weekly.

The obtained results were compared to the Normative Instruction 25/2009 to observe the quality of the produced organic compost.

2.4 Vermicomposting

Vermicomposting was carried out in a wooden vermibin measuring 1 meter x 1 meter x 0.8 meter (Length x Width x Depth). Inside the vermibin it was put a plastic tarp in order to prevent the escape of worms, because the vermibin presented cracks in its structure. At the top of vermibin it was placed a protection to prevent birds or other animals could feed the worms.

The vermicomposting system was constituted by 50% of food waste and 50% of grass cutting, in mass. The total weight was 100 kg in which the food waste and the grass cutting were intercalated at the system. The vermicomposting lasted 60 days.

The vermicomposting followed all the steps of the conventional composting in pile until the temperature stabilization in the 27th day. The acclimated earthworms (*Eisenia foetida*) were inoculated into the system when the temperature reached a mean value in a range of 20 – 28°C as per requirement for the worms. The worms were handled with care and were added at the centre, covered with the compost as this type of worms lived in darkness and are prone to light.

An optimal of 2 g live weight of worms per 1 liter of substrate (Modesto Filho, 1998), which corresponded in this study to 1 kg of worms, was used in order to obtain the maximum bioconversion of the feedstock into earthworm biomass.

Also mentioned above, the homogenized and representative samples were collected every 15 days to the determination of the pH, moisture content, organic matter, total ash, organic carbon and total nitrogen, according to the procedures before described.

The temperature was measured by a digital thermometer (NOVUS) with a probe of 3 m at five different points in vermibin. Firstly, the measurements were done daily; after 15 days of composting, the measurements were done every 4 days; and with 50 days of composting, the measurements were done weekly.

The obtained results were compared to the Normative Instruction 25/2009 to observe the quality of the produced vermicompost.

3. Results and Discussion

3.1 Composting in pile

The Table 1 shows the results obtained in the initial characterization of organic waste and the grass cutting waste, used in composting.

Table 1. Initial characterization of the waste for composting in pile.

Parameters	Food waste	Grass cutting waste
pH	6.32	6.11
Moisture Content (%)	71.35	7.50
Organic Matter (%)	92.32	89.58
Total Ash (%)	7.68	10.42
Organic Carbon (%)	51.29	49.76
Total Nitrogen (%)	1.82	1.74
C/N ratio	28.10	28.59

The pH of both waste was within an acceptable range, somewhat lower than 7, but that does not compromise the biological activity of the microorganisms in the composting process (Bernal et al., 1998).

The moisture content of the food waste was high (71.35%), unlike the grass cutting waste was quite dry (7.50%).

The high concentrations of organic matter in 92.32 and 89.58% of the food and grass cutting wastes, respectively, indicated that the wastes can be decomposed by biological processes.

The total ash (7.68% for food waste and 10.42% for grass cutting waste) indicated a low amount of ash present in the wastes, due to the high amount of organic material present therein.

The C/N ratio showed values close to the ideal for the beginning of composting. According to D' Almeida and Vilhena (2000) the appropriate value of C/N ratio is 30/1. The found values were 28.10/1 and 28.59/1, respectively, for the food waste and trimming / weeding for grass cutting waste.

An et al. (2012) obtained during the characterization of a composite of food waste the following values: pH 5.79, moisture content 62.35%, ash content 1.74%, organic content 35.91%, carbon 45.12%, nitrogen 1.39% and C/N ratio 32.46. The parameters pH, moisture content, carbon, nitrogen and C/N ratio were closed to the values obtained in this study.

Gabhane et al. (2012) characterized the green waste consisting of vegetable waste and garden biomass in equal (1:1) ratio. It contained 50.92% of organic carbon, 2.91% of total nitrogen, 16.17% of protein, 47.49% of cellulose, 19.5% of lignin, and 16.12% of hemicellulose. The initial C/N ratio of green waste was 17.49. The organic carbon was closed to the value obtained in this study, but the total nitrogen and C/N ratio weren't similar.

The Table 2 shows the values obtained in the initial and final characterization of the waste mixture in the composting in pile.

Table 2. Initial and final characterization of the waste mixture during the composting in pile.

Parameters	Initial	Final	N. I. 25/2009 Class A
pH	6.24	7.62	Minimum 6
Moisture Content (%)	45.60	81.95	Maximum 50%
Organic Matter (%)	93.01	57.73	---
Total Ash (%)	6.99	42.27	---
Organic Carbon (%)	51.67	32.07	Minimum 15%
Total Nitrogen (%)	1.86	3.26	Minimum 0.5%
C/N ratio	27.78	9.84	Maximum 20/1

It can be observed that the mixture of the waste fit the most parameters for the beginning of composting.

The moisture content that was very high for food waste and very low for grass cutting waste became proper after the mixture of the waste for the composting, around 45%. The high moisture content at the final of composting in pile can be justified due to the strong influence of the rains and the water entrance in the pile. Even with coverage in the days when there was precipitation, unfortunately it had been water incorporation to the compost.

In the initial of the composting, the C/N ratio in the pile system was close to the optimum value (27.78), indicating its fit for composting.

One of the most important parameters in composting is the final C/N ratio. It's responsible for characterizing the quality of the compost and to determine whether it is matured or not.

The C/N ratio for the compost application in agriculture must not exceed the ratio of 18/1 (semi-cured compost). The ratio below to 12/1 classifies the compost as cured (D' Almeida and Vilhena, 2000). So, in the studied treatment, the final C/N was 9.84/1, which classifies the compost as a final product cured and ready for use on the soil.

The pH behavior had an increase during the composting that can be explained by the occurrence of hydrolysis of proteins and also the ammonium release. Thus, the pH level increased until its stabilization. The final pH in composting should be at least 6 and the final value is in accordance to law for using the organic compost, because of the final value was 7.62.

Observing the Table 3, it can see that the only parameter that doesn't fit within the levels required by law is the moisture content, since the maximum is 50%. This parameter needs to be adjusted to suit the law by drying the compost.

3.2 Composting in vessel

The Table 3 shows the results obtained in the initial characterization of organic waste and the grass cutting waste used in composting in vessel and in vermicomposting.

The pH of the wastes is in a desirable range for biological activity, 7.22 for food waste and 7.04 for grass cutting waste.

The moisture content of food waste was 75.81% and 43.51% for grass cutting waste, due to the composition of each waste.

The C/N ratio of the food waste was 23.37/1 and 21.95/1 for grass cutting waste, being lower for composting.

Table 3. Initial characterization of the waste for composting in vessel and vermicomposting.

Parameters	Food waste	Grass cutting waste
pH	7.22	7.04
Moisture Content (%)	75.81	43.51
Organic Matter (%)	89.60	80.62
Total Ash (%)	10.39	19.38
Organic Carbon (%)	49.78	44.79
Total Nitrogen (%)	2.13	2.04
C/N ratio	23.37	21.95

The Table 4 shows the values obtained in the initial and final characterization of the waste mixture in the composting in vessel.

Table 4. Initial and final characterization of the waste mixture during the composting in vessel.

Parameters	Initial	Final	N. I. 25/2009 Class A
pH	7.43	7.25	Minimum 6
Moisture Content (%)	73.43	37.65	Maximum 50%
Organic Matter (%)	85.97	64.25	---
Total Ash (%)	14.03	35.74	---
Organic Carbon (%)	47.76	35.69	Minimum 15%
Total Nitrogen (%)	2.02	3.68	Minimum 0.5%
C/N ratio	23.64	9.68	Maximum 20/1

The initial pH of the waste mixture didn't differ much from the pH of each separated waste. The initial pH was 7.43, suitable for the biological activities of microorganisms. The pH behavior in vessel was similar to in pile, in which it had a considerable increased to 8 during the phase characterized as thermophila, thus indicating a high rate of hydrolysis of proteins and high microbial activity. After an initial growth phase, the pH was decreasing until it reached its stabilization at the end of the process in 7.25. The final pH was in accordance the law, because it was superior 6.

The moisture content in the reactor was slightly above the ideal value of 60%, but not prejudicial for the beginning of composting. As the reactor was covered, there wasn't rain influences in the moisture content. Thus, the final compost was much drier than in its initial state. This fact reveals the importance for special care of pile composting exposed to rain. The Normative Instruction allows a maximum of 50% of moisture content, and in the reactor it was 37.65%.

The C/N ratio at the beginning of composting was still a little far from ideal that is 30/1. During composting the C/N had a decay profile, reaching values in accordance the law. At the end of the process, the C/N in the reactor was 9.68/1. Thus, the reactor produced a compost considered cured, with a C/N less than 12/1.

It can be conclude that all the parameters required by the Normative Instruction for commercializing organic waste had been met, so the compost is recommendable for using. Besides that, the composting in vessel lasted 60 days for the stabilization of the majority of monitored parameters.

3.3 Vermicomposting

The wastes used in vermicomposting were the same used in reactor. Thus, the initial characterization of these wastes was previously presented in Table 3.

The Table 5 shows the values obtained in the initial and final characterization of the waste mixture in the vermicomposting.

Table 5. Initial and final characterization of the waste mixture during the vermicomposting

Parameters	Initial	Final	I. N. 25/2009 Vermicompost Class A, B, C and D
pH	7.61	7.89	Minimum 6
Moisture Content (%)	65.83	69.76	Maximum 50%
Organic Matter (%)	83.02	41.64	---
Total Ash (%)	16.97	58.35	---
Organic Carbon (%)	46.12	23.13	Minimum 10%
Total Nitrogen (%)	4.69	2.54	Minimum 0.5%
C/N ratio	9.83	9.10	Maximum 14/1

The pH was maintained suitable for the treatment after the waste mixture. The moisture content that was high for food waste, in the mixture reached a fit value (65.83%) at the beginning of the process. Nitrogen has reached a high value in the mixture, with values of 4.69%, making the C/N ratio reached low value for the beginning of the composting process (9.83/1).

The pH profile in vermicomposting process doesn't vary with such intensity during the treatment. In the first days, there was a slight increase, behavior similar to pH in pile and in reactor, but with less intensity. At the end of the vermicomposting process, the pH value was 7.89, above the minimum proposed by the Normative Instruction.

Such as in pile, the vermibin was conducted open air, vulnerable to the action of rain, even with all the care to avoided the incorporation of water. The moisture content was high since the beginning of the process and in addition to rain water incorporation; the worms metabolism also can contribute to the increase of moisture content. The final moisture content, as in pile, was above the law (50%), which was 69.79%. The parameter can be corrected by drying the compost.

In the treatment of municipal solid waste, Soobhany et al. (2015) selected to suitability for vermicomposting some wastes: food waste, grass clippings, dry leaves and small branches, market waste, office shredded paper and newspaper, and cow dung. It was done moisture adjustments by adding water to the vermibin and the moisture content, in the different experiments, was around 80%, just before the addition of the worms. After the moisture content peaks, it happened a decreasing trend in moisture content in the experiments, reaching a range of approximately 50–55% at the end of the experiments, differently of the results observed in this study.

The C/N ratio had a slight decline, since the beginning of the process. The vermicomposting reached final value of 9.10, considerably being quite satisfactory. The final C/N was within the required law standards (14/1). This means that the compost is classified as matured and can be used in soil.

It's concluded that the only parameter that doesn't fit within the levels required by law was the moisture content, since the maximum is 50%. This parameter needs to be adjusted to suit the law by drying the compost.

4. Conclusions

It can be concluded, by the obtained results in this study, that the composting in vessel produced a cured compost and respected all parameters required by the Normative Instruction 25/2009 in a shortest amount of time (60 days), being the best option for the waste treatment.

The results obtained in the other treatments showed that the produced compost were in accordance to the Normative Instruction 25/2009, except the moisture content parameter, which can be easily adjusted. Thus, both composting in pile, in vessel and vermicomposting are indicated to be applied in the treatment of organic solid waste.

The production of compost from food waste from restaurants could close the life cycle of the food production chain, with its application in soil for the production of new food that could be purchased by the restaurant itself, benefiting the environment, besides being able to generate income from the sale of organic compost and stimulate the sustainable food production.

References

ABNT. Associação Brasileira de Normas Técnicas, 2004. Norma NBR 10.007 – Amostragem de resíduos sólidos. Rio de Janeiro. 63 p.

An, C-J., Huang, G-H., Yao, Y., Sun, W., An, K., 2012. Performance of in-vessel composting of food waste in the presence of coal ash and uric acid. Journal of Hazardous Materials, v. 203-204, pp. 38-45.

Benlboukht, F., Lemee, L., Amir, S., Ambles, A., Hafidi, M., 2016. Biotransformation of organic matter during composting of solid wastes from traditional tanneries by thermochemolysis coupled with gas chromatography and mass spectrometry. Ecological Engineering, v. 90, pp. 87-95.

Bernal, M. P., Sànchez-Monedero, M. A., Paredes, C., et al., 1998. Carbon mineralization from organic wastes at different composting stages during their incubation with soil. Agriculture Ecosystems & Environment, v. 69, pp. 175-189.

Brasil. Ministério da Agricultura, Pecuária e Abastecimento, 2009. Secretaria de Defesa Agropecuária. Instrução Normativa n° 25, de 23 de julho de 2009. Diário Oficial da República Federativa do Brasil. Poder Executivo, Brasília, DF.

Chan, M. T., Selvam, A., Wong, J. W. C., 2016. Reducing nitrogen loss and salinity during 'struvite' food waste composting by zeolite amendment. Bioresource Technology, v. 200, pp. 838-844.

D' Almeida, M. L. O., Vilhena, A., 2000. Lixo Municipal: Manual de Gerenciamento de Resíduos. 2a edição. IPT/CEMPRE: São Paulo.

Gabhane, J., William, SPM. P., Bidyadhar, R., Bhilawe, P., Anand, D., Vaidya, A. N., Wate, S. R., 2012. Additives aided composting of green waste: Effects on organic matter degradation, compost maturity, and quality of the finished compost. Bioresource Technology, v. 114, pp. 382-388.

Jolanun, B., Towprayoon, S., 2010. Novel bulking agent from clay residue for food waste composting. Bioresource Technology, v. 101, pp. 4484-4490.

IAL. Normas Analíticas do Instituto Adolfo Lutz, 1985. Métodos químicos e físicos para análises de alimentos. 3. ed. São Paulo: Editoração Débora D. Estrella Rebocho.

Kiehl, E. J., 1985. Fertilizantes orgânicos. Agronômica Ceres. Piracicaba. 492 p.

Lim, S. L., Lee, L. H., Ta Yeong Wu, T. Y., 2016. Sustainability of using composting and vermicomposting technologies for organic solid waste biotransformation: recent overview, greenhouse gases emissions and economic analysis. Journal of Cleaner Production, v. 111, pp. 262-278.

Qian, X., Shen, G., Wang, Z., Guo, C., Liu, Y., Lei, Z., Zhang, Z., 2014. Co-composting of livestock manure with rice straw: Characterization and establishment of maturity evaluation system. Waste Management, v. 34, pp. 530-535.

Saer, A., Lansing, S., Davitt, N. H., Graves, R. E., 2013. Life cycle assessment of a food waste composting system: environmental impact hotspots. Journal of Cleaner Production, v. 52, pp. 234-244.

Shafawati, S. N., Siddiquee, S., 2013. Composting of oil palm fibres and Trichoderma spp. as the biological control agent: A review. International Biodeterioration & Biodegradation, v. 85, pp. 243-253.

Soobhany, N., Mohee, R., Garg, V. K., 2015. Comparative assessment of heavy metals content during the composting and vermicomposting of Municipal Solid Waste employing *Eudrilus eugeniae*. Waste Management, v. 39, pp. 130-145.

Vavouraki, A. I., Volioti, V., Kornaros, M. E., 2014. Optimization of thermo-chemical pretreatment and enzymatic hydrolysis of kitchen wastes. Waste Management, v. 34, pp. 167-173.

Acknowledgements

The authors would like to thank PIBIC (Programa de Iniciação Científica da UNESP) Processes n. 31440/2014 and n. 34315/2015 for financial support. The authors would like to thank the grant 2016/07583-0, São Paulo Research Foundation (FAPESP) for financial support.

Destination of by-products in the citrus industry in Brazil

Márcia Aparecida Andreazzi 1, Maria de Los Angeles Perez Lizama 2, Adriano Rogério Mendes 3, Isabele Picada Emanuelli 4, Queila Turcheto 5, Karina Volpe de Oliveira 6, Rafaela Herrera 7

1 UNICESUMAR

2 PPGTL/ UNICESUMAR

3 PPGTL/ UNICESUMAR

4 PPGTL/ UNICESUMAR

5 PPGTL/ UNICESUMAR

6 IC/ UNICESUMAR

7 IC/ UNICESUMAR)

Abstract

The cultivation of orange is considerated the main activity in the fruitculture in Paraná State, 4th place as Brazilian producer. According to data from official agencies, the state produced in 2015 about 1 million tons of oranges, mainly in the North and the Northwest regions in its orchards. This fruit is transformed in juice, with focus on exportation for the European Union, Middle East countries, United States of America, Australia and Canada. This high production is associated with a great generation of by-products, comprising approximately 50% of the total fruit. An alternative to disposal of these by-products its use in animal feed, as an alternative to commonly used cereal grains, thereby decreasing animal production costs and eliminating waste with environmental pollution potential. The main forms of use of citrus by-products include wet pulp, dehydrated pulp, the pulp pellets and silage. The objective of this survey was to determine the allocation of by-products generated by existing citrus industries in the north and northwest region of Paraná state. According to the survey, all the by-products produced are offered in animal feed, especially for beef cattle herds and milk in the state. Due to the need for adequate equipment which would result in higher cost of by-product, the dehydrated pulp and pelletized pulp are not employed, so the major forms of adoption consist in providing the wet pulp or silage, which do not require large technical and/or investments for the producer. The main problem related to the supply of wet pulp is that it has only 15-20% dry matter, encumber the transport and increasing the possibility of deterioration, so for it to be economically viable use, the property must be close to the citrus industry. In addition to these facts, the producer should consider that the by-product composition may swing and depends on the type of orange, method of extraction and time of production. Animal feed expenses reach 70% of total costs of production, so the adoption of this practice results in the environmentally adequated destination of these by-products, reducing costs on animal feed However, the producer must establish the economic benefits, nutritional and environmental for the use of this practice, aiming the ribest outcomes possible to the milk production chain.

Keywords: orange peel, milk cows, agro-industrial waste, alternative food

Environmental health: use of fish parasites as bioindicators of environmental quality in Brazil.

Maria de los Angeles Perez Lizama[1,2]; Marcia Aparecida Andreazzi[1]; Eliane da Silva Fernandes[2]; Ricardo Massato Takemoto[2,3]

[1]Programa de Pós-graduação em Tecnologias Limpas, Unicesumar, Maringá, Paraná, Brasil *Author for correspondence. e-mail: maria.lizama@pq.cnpq.br

[2]Programa de Pós-graduação em Ecologia de Ambientes Aquáticos Continentais, Universidade Estadual de Maringá, Maringá, Paraná, Brasil.

[3]Núcleo de Pesquisas em Limnologia, Ictiologia e Aqüicultura, Universidade Estadual de Maringá, Maringá, Paraná, Brasil.

Abstract

The increase in the consumption of water, and high use for agricultural and industrial production was a result of demographic and industrial expansion. The anthropogenic interference resulting from this expansion, directly or indirectly affects both organisms and the water quality along the river. In Brazil, different organisms are used to standardize biological tests in the monitoring of water quality. However, studies using fish parasites as bioindicators are still scarce. This study aims to define the species of parasites with potential to be used as bioindicators of environmental quality in aquatic ecosystem. Both, ecological and diversity studies in parasites are used for this purpose. This study correlated the parasites of *Hypostomus ancistroides*, a fish of the Siluriformes order, with the water quality in the Pirapó river. The Pirapó river is an important river where water extraction is made for population of Maringá city consumption, Parana State, Brazil. Sampled stations were distributed along the river according to the level of human interference. Twenty specimens of *H. ancistroides* were collected from each sample station (Upstream-preserved; Intermediate-anthropized and Downstream- sewage dump in the period from December 2012 to July 2013, in the Pirapó river. Where registered 843 parasites that belong to 4 **taxa** (Monogenean, Digenean, Nematode and Acanthocephala). Only the nematodes presented prevalence above 10%, (*Rhaphidascaris* sp. and Nematoda sp2) and only *Rhaphidascaris* sp. presented significative difference between the sample station ($H= 13.2608$, $p= 0.0013$), indicated that the fishes collected in the intermediate station are more parasitized. Significant differences in the abundance of parasites between the sampling stations were observed ($H = 6.2415$, $p = 0.004$), being more abundant in Intermediate and Downstream stations. The Pirapó river in several sections, receives liquid effluents of industrial and domestic origin, such as organic load of a fridge, detergents of various industries, rainwater contaminated with industrial waste, in addition to being silted, due the lack of riparian forest. These sources of pollution are responsible for causing irreparable damage to the ecosystem, causing both loss of biodiversity, and the adaptation of other species for their survival. The highest incidence of nematodes in the most polluted locals may indicate that these parasites can be resistant to similar environments in detriment of other parasites species most sensitives to environmental pollution, as is the case of ectoparasites that live in contact direct with the environment. It is know that there is a close relationship between nematode parasitism and the presence of Hg in fish, for example, as well as the nematode alter the host capability to bioaccumulate pollutants, among many other effects and this is extremely important when it comes to environments that are heavily impacted by pollution of the river from industrial development. Thus, when the search for the sustainable development of a region, one should take into account environmental health, reducing pollution, monitoring the environment and reducing the loss of biological biodiversity

Keywords: environmental control, ecology, biodiversity

Financial Support: CNPq and CAPES.

Influence of treated effluent discharged in Ribeirão Montalvão, city of Alfredo Marcondes / SP – Brazil

Renata Ribeiro de Araujo[1], Raul Selverio Fuso[2], Maria Cristina Rizk[3]

[1,2,3] Universidade Estadual Paulista "Júlio de Mesquita Filho" – Faculdade de Ciências e Tecnologia, campus de Presidente Prudente – São Paulo – Brasil, [1]reribeiro@fct.unesp.br, [2]raulfuso@hotmail.com, [3]mc_rizk@yahoo.com.br

Abstract

The quality of water in river channels is directly influenced by how they are managed. In Brazil, many water bodies are used as final disposal of treated sewage, causing an imbalance of its natural conditions, which affect the fauna and flora of the water body. This situation can be observed in the city of Alfredo Marcondes/São Paulo, Brazil where the treated domestic sewage is discharged in Ribeirão Montalvão. This water body is used for various purposes such as watering livestock. It is very important to identify the possible environmental changes caused by this practice, so that it can develop a sustainable management through decision making for environmental management. Therefore, this study aimed to carry out a limnological monitoring in some sections of Ribeirão Montalvão, which is a widely used tool to monitor and analyse changes in the water quality conditions over time and space. To achieve this goal it was realized the limnological monitoring into four sections in the main channel of Ribeirão Montalvão, in two sections on two of its tributaries and in the wastewater treatment plant (WWTP). The variables evaluated were temperature, electrical conductivity, turbidity, pH, ammoniacal nitrogen and dissolved oxygen. For this, it was used a parametric Multiprobe brand Hanna, model HI 9829. It was also evaluated the flow according to Palhares et al. (2007). In laboratory, it was determined the dissolved phosphorus, soluble reactive phosphorus and total phosphorus according to Mackereth et al. (1978) and chemical oxygen demand according to APHA (1998). The results demonstrated that the variables analysed showed variations after the treated domestic sewage discharge, especially the total phosphorus. The total phosphorus results were above the value set by law. These results indicate that the appropriation by humans of the canals of the watershed of Ribeirão Montalvão has led to impacts on water quality, compromising its various uses. Face to this context, it is proposed that managers and users of water resources of Ribeirão Montalvão pursue conservation actions and environmental preservation, such as improving the efficiency of the treatment of domestic sewage, use of soil conservation techniques and restoration of Permanent Preservation Areas.

Keywords: Alfredo Marcondes, Ribeirão Montalvão, Limnological Monitoring, Treated Sewage

1. Introduction

Today, although the strategic importance of fresh water is universally recognized more than ever before, and although issues concerning sustainable water management can be found almost in every scientific, social, or political agenda all over the world, water resources seem to face severe quantitative and qualitative threats. The pollution increase, industrialization and rapid economic development, impose severe risks to availability and quality of water resources, in many areas worldwide (Abdel-Raouf et al., 2012).

Pollution is a man-made phenomenon, arising either when the concentrations of naturally occurring substances are increased or when non-natural synthetic compounds are discharged into the environment. Organic and inorganic substances which are discharged into the environment as a result of domestic, agricultural and industrial water activities lead to organic and inorganic pollution (Lim et al., 2010).

One of the major sources of water pollution is the uncontrolled discharge of human wastes, while some countries have made massive investment in water supply projects there has been an overall under-investment in appropriate sanitation systems, which has resulted in harmful contamination of water resources, increased flooding and reduced health benefits from water investments (Abdel-Raouf et al., 2012).

The human wastes, according to Chagas (2000) may come from various types of water use, such as household, commercial, hospital, and others.

According to Miguel et al. (2004) domestic sewage comes from houses with bathroom facilities, laundries, and kitchens, among others, being composed by urine, feces, paper, food waste, soap and detergents. The industrial wastewater is from industrial processes having a variable composition. The storm water is due to the collection of atmospheric precipitation and sidewalks washing.

If the domestic sewage has no proper treatment, it induces the deterioration of water bodies that receives this domestic sewage, which would remove the aquatic life and damaging the water users (Netto et al., 2002).

According to Paula (2011), the impact of the discharge of sewage is determined by the efficiency of the treatment, the allocation of pollutant loads and especially the behavior of the watercourse receiver due to the intervention.

Krama (2008) used the sewage treatment as a subtheme of the environmental indicators for measuring the sustainable development. The author considered this indicator for the basic characterization of the population's quality of life and the activities of water users receiving sewage.

Various wastewater treatment technologies are developed with the primary concern of natural water bodies. Therefore, there are various types of sewage treatment.

Abdel-Raouf et al. (2012) sets out some of them, as the preliminary treatment that removes large solid materials delivered by sewers that could obstruct flow through the plant or damage equipment; the primary treatment, in which the sewage passes to sedimentation tanks, which aim to remove the settleable solids by gravity; the secondary treatment, that aims to reduce the biochemical oxygen demand exerted by reducing organic matter and the tertiary treatment, that aims to remove all organic ions.

Even with the use of these types of treatment, it isn’t correct to say that the water body will not be impacted by the discharge of treated domestic sewage. After the discharge, the receiving body will go into self-purification process, which, according to Heindenwag et al. (2001) is the assimilation of organic matter and dissolved nutrients in the water by bacteria, plants and animals, and it would also include processes of dilution and mixture of organic matter and nutrients.

This self-purification is, according to Dzyuban (2003) and Parkyn et al. (2003) the key aspect of the river dynamics, which allows the establishment of the magnitude of treatment effects in time and distance.

Smith and Smith (2002) maintains that streams can self-depurate in a natural way, by decomposing organic matter through bacterial activity, and the time required will depend on the degree of pollution and stream characteristics.

Braga et al. (2015) mentioned that over time and the longitudinal profile of the watercourses, it is possible to identify the ecological succession of stages associated with four different areas, known as depuration zones.

The first zone is known as degradation zone, and is defined by Mota (1995) as being the location downstream of the discharge point of sewage, in which the water contains dark aspect, but also have high nutrient content.

The active decomposition zone is the further zone of the degradation zone. According to Faria (2008), it is in this area where the level of degradation reaches the apex, having the lowest values of dissolved oxygen.

The third zone is the recovery zone, which, according Mota (2003), presents water with lighter aspect and more stabilized organic matter.

Finally, there is the area of clean water, described by Andrade (2010) as the area in which the water returns to satisfactory conditions regarding the initial conditions of oxygen and biochemical oxygen demand.

The Ribeirão Montalvão, located in Alfredo Marcondes – São Paulo, Brazil isn't an exception, because it passes through the self-depuration process, considering it receives the treated domestic sewage from the wastewater treatment plant of the municipality.

Thus, this study aimed to analyze how the discharge of treated domestic sewage on the Ribeirão Montalvão can change its physical and chemical characteristics.

2. Methods

For the development of the present study it was performed the limnological monitoring in four sections of Ribeirão Montalvão, in two sections on two of its tributaries and in the Wastewater Treatment Plant (WWTP) located at Alfredo Marcondes.

The monitored sections were S1 (Section 1) located in Ribeirão Montalvão, coordinates 21°58'33.10" S / 51°24'13.35" W; S2 (Section 2) located on Tributary 1, coordinates 21°57'56.70" S / 51°23'47.59" W; S3 (Section 3) located in Ribeirão Montalvão, coordinates 21°57'14.57" S / 51°24'15.96" W; S4 (Section 4), coordinates 21°57'09.46" S / 51°24'17.73" W; S5 (Section 5) located in Ribeirão Montalvão, coordinates 21°57'07.62" S / 51°24'16.55" W; S6 (Section 6) located in the Tributary 2, coordinates 21°57'07.75" S / 51°24'19.85" W and S7 (Section 7) located in Ribeirão Montalvão, coordinates 21°57'01.09" S / 51°24'19.49" W, as shown in Figure 1.

In field, it was analyzed, by a parametric Multiprobe brand Hanna, model HI 9829, the following limnological variables: temperature, electrical conductivity (EC), turbidity, pH, dissolved oxygen (DO) and ammoniacal nitrogen.

To calculate the flow it was used the float method by Palhares et al. (2007), according to equation 1.

$$Flow = A \; x \; L \; x \; C \, / \, T \quad (m3/\,s) \qquad \text{(Equation 1)}$$

In which:

A= average area of the river (the distance between the edges multiplied by the depth of the river).

L= the measurement area length (using the length of 6.0 m).

C= correction factor (0.8 to rivers with stony background or 0.9 to rivers with muddy bottom). It allows the correction due to the fact the water move faster on the surface than in the river bottom. Multiplying the speed of the surface by the correction coefficient it will have a better measure of the speed of water.

T= time, in seconds, that the float takes to move the length L.

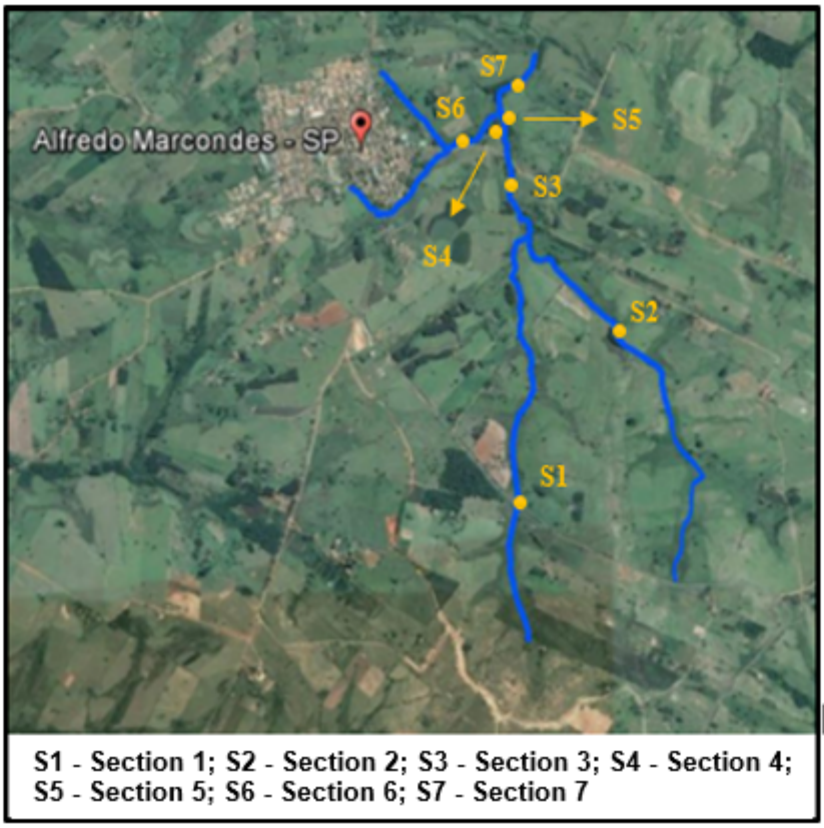


Figure 1. Ribeirão Montalvão and tributaries with its respective sampled sections.

For the development of laboratory protocols, water samples were collected at sampling sections, preserved in polyethylene bottles (5 L) and refrigerated with ice.

To determine the chemical oxygen demand (COD) it was used an oxidizing solution, a catalysis solution and a standard, using a reactor (COD - REACTOR HACH) at 150 ° C for two hours and spectrophotometric reading at 620 nm (APHA, 1998).

In laboratory, water samples were filtered on Whatman GF/C membranes. The filtered water was preserved in a freezer at -20 °C in polyethylene bottles (500 ml), for subsequent determination of the dissolved phosphorus and soluble reactive phosphorus. Likewise, the unfiltered water was preserved in a freezer at -20 ° C in polyethylene bottles (500 ml) for subsequent determination of total phosphorus concentration.

The total phosphorus fractions and dissolved phosphorus were quantified after digestion in the presence of a catalyst in an autoclave and subsequent reaction with the addition of a mixed reagent (molybdate of ammonium, antimony potassium tartrate and ascorbic acid) and read in a spectrophotometer at 882 nm (Mackereth et al., 1978).

The reactive phosphorus soluble or orthophosphate was also obtained after reaction with ammonium molybdate, antimony potassium tartrate and ascorbic acid and subsequent reading in a spectrophotometer at 882 nm (Mackereth et al., 1978).

The results of Ribeirão Montalvão variables were compared with the reference values set in CONAMA Resolution n° 357/2005, altered by CONAMA Resolutions n° 410/2009 and n° 430/2011, which provides for the classification of water bodies and environmental guidelines for its framework and establishes the conditions and standards of effluent discharge, and other measures.

The results of the variables related to wastewater treatment plant were compared with reference values set in CONAMA Resolution n° 430/2011, which establishes the conditions and standards of effluent discharge.

The variable electrical conductivity isn't mentioned in CONAMA Resolution. Due its importance, it was used a report about environmental and health significance of water quality variables developed by CETESB – Environmental Company of the State of São Paulo, in which this variable is described.

3. Results and Discussion

The descriptive analysis shown in Table 1 identifies the amplitude variations of the obtained results. It has been seen that the greatest changes occurred to the electrical conductivity, ranged from 171 to 739.1 µS/cm and to the chemical oxygen demand, ranged from 8.69 to 211.58 mg/L.

Table 1. Descriptive statistics of the limnological variables sampled in the sections of Ribeirão Montalvão, presented the number of cases (N), average, minimum and maximum values and standard deviation.

Variables	N	Average	Minimum value	Maximum value	Standard deviation
Temperature (°C)	7	25.76	24.500	26.90	0.32
EC (µS/cm)	7	288.23	171.000	739.10	76.91
Turbidity (NTU)	7	39.43	9.385	99.35	11.33
pH	7	7.17	6.830	7.38	0.07
DO (mg/L)	7	7.76	1.800	9.20	1.00
Flow (L/s)	7	60.80	9.740	146.50	18.05
COD (mg/L)	7	51,78	8.690	211.58	27.12
Ammoniacal Nitrogen (mg/L)	7	3,38	0.007	20.02	7.48
ORTHO (mg/L)	7	0.24	0.001	1.35	0.50
DP (mg/L)	7	0.30	0.003	1.79	0.73
TP (mg/L)	7	0.42	0.011	2.47	0.92

EC – electrical conductivity; DO – dissolved oxygen; COD – chemical oxygen demand; ORTHO – orthophosphate; DP – dissolved phosphorus; TP – total phosphorus (TP).

It was observed that 45% of limnological variables had a high standard deviation, especially, as mentioned, the electrical conductivity and chemical oxygen demand.

This high standard deviation was given by the discharge of treated domestic sewage, which showed high values for the variables analyzed, as it can be observed in the electrical conductivity, as shown in Figure 2.

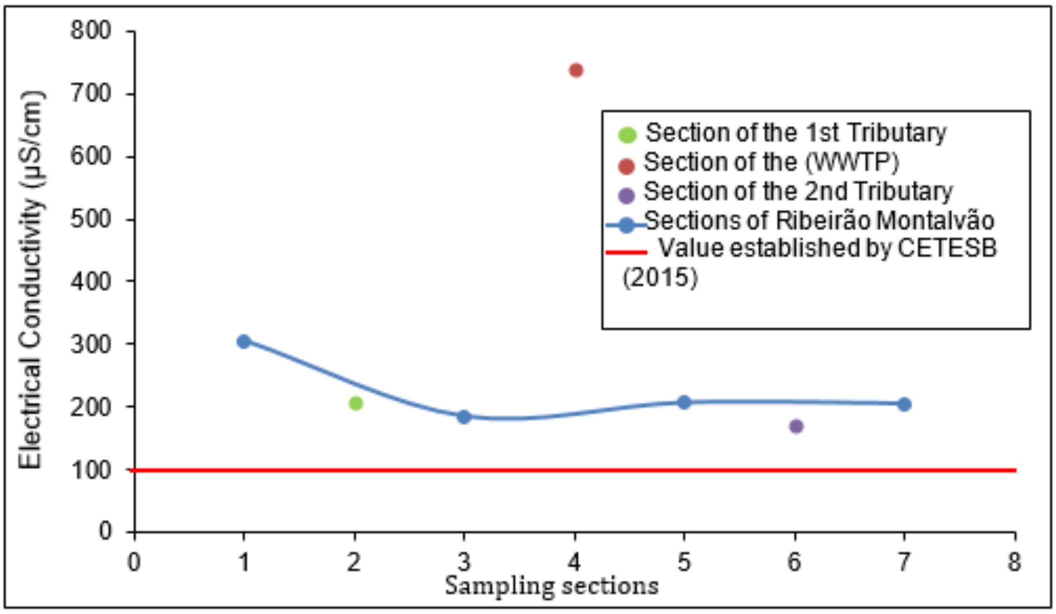


Figure 2. Electrical conductivity in the different sampled sections.

Electrical conductivity describes the ability of an aqueous solution to carry an electric current (APHA et al., 1998). The amount of ions or total dissolved salts in water is an indicator of conductivity; the conductivity increases as the concentration of ions increases (Tchobanoglous and Schroeder, 1985). Solutions with mostly inorganic compounds tend to be better conductors while solutions with organic compounds don't conduct currents well (APHA et al., 1998). The type of rock and soil within the hidrografic basin affects conductivity.

Ions that are directly responsible for electrical conductivity include potassium, sodium, calcium, carbonates, carbides, sulfates and chlorides. Electrical conductivity doesn't provide information on which specific ions are present in a water sample, rather it is an indicator of the overall quantity of ions in the sample. The parameter indicates possible environmental impacts on the hydrographic basin, caused by discharge of industrial and mining wastes and other effluents (Steffens et al., 2015)

In water bodies polluted by domestic sewage, the electrical conductivity is related to the organic matter from food, fecal and waste in general that incorporate water-salts (Blundi, 1988). The highest values found for the variable refer to sections 1 and 4.

In the Section 4, the treated sewage is discharged in the receiving body, which can justify the high value of electrical conductivity. The high electrical conductivity of the treated sewage caused higher values of the electrical conductivity in the sections downstream the sewage discharge, compared with the sections upstream the discharge.

In the study carried out by Abraham (2006) in Riacho Mussuré – Paraiba, Brazil, it was also found the negative influence of domestic sewage dump on a water body, which showed wide variations after the discharge.

Jonnalagadda and Mhere (2001) also found a longitudinal variation of the electrical conductivity in Rio Odzi, Zimbabwe, resulting from the domestic sewage supply in water body.

According to CETESB (2015) values above 100 µS/cm indicate environmental impacts. It can be seen that all sections of Ribeirão Montalvão were affected, because there's no section with values below this level.

Another variable that showed high variation along the continuum of the river was the chemical oxygen demand, as shown in Figure 3.

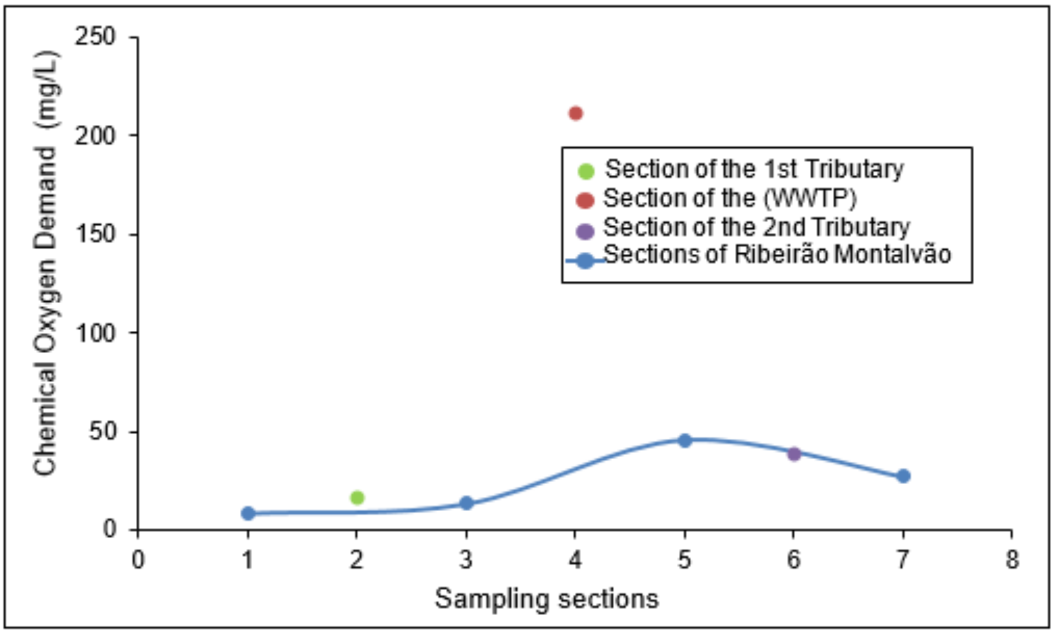


Figure 3. Chemical oxygen demand in the different sampled sections.

Chemical oxygen demand is commonly applied for wastewater control and water quality monitoring. Considering the biodegradation process, the organic matter is assimilated by microorganisms under appropriate conditions, with the presence of nutrients such as nitrogen, phosphorous, and mineral nutrients, and converted into microbial biomass, eventual transformation products derived from the initial organic matter, CO_2 and H_2O (Jouanneau et al., 2014). COD is normally and systematically used for organic matter monitoring, especially in wastewater treatment plants (Knapik, 2014)

Upstream of the discharge of treated domestic sewage, the water body had a COD of 13.4 mg/L, and after the discharge, the river presented 45.725 mg/L of COD, and section 7 presented the value of 27.25 mg/L.

These values follow a dynamic known as self-depuration, which a water body tends to return to its initial characteristics with the time. So, after the discharge of treated domestic sewage, the value of COD increased and subsequently it was declining.

This dynamic can be observed when analyzing the values of dissolved oxygen, as shown in Figure 4.

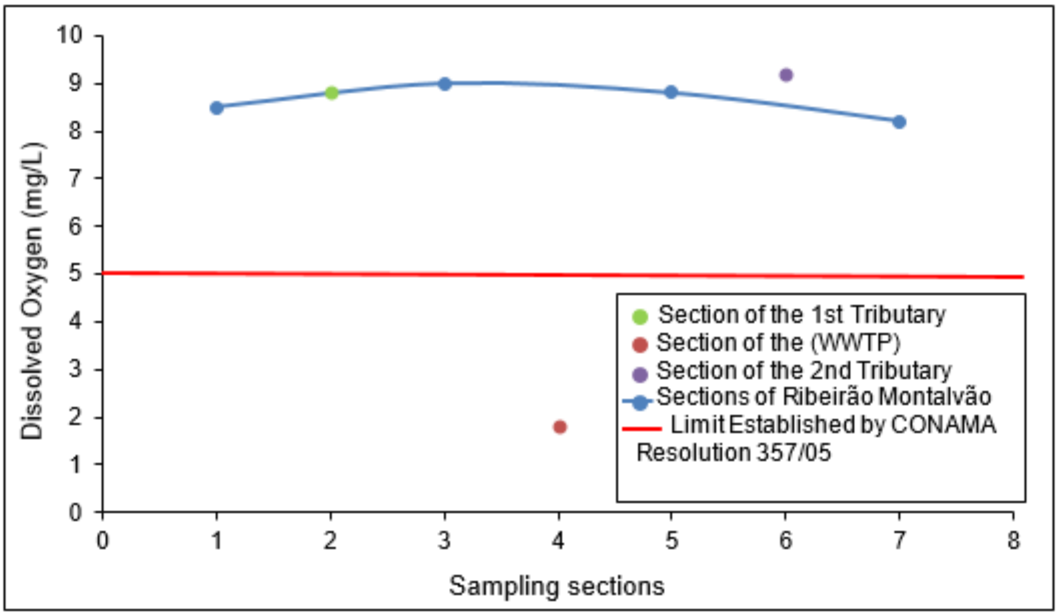


Figure 4. Dissolved oxygen in the different sampled sections.

The dissolved oxygen is a measurement of the amount of oxygen gas dissolved in water, and available for using by plant and aquatic species. Oxygen gas naturally mixes with water through surface interaction. Fast moving waters typically have a higher DO due to the mixing with the air when the water hits obstacles such as rocks and logs (Vigil, 2003).

The accurate determination of dissolved oxygen is highly important in water-quality studies because oxygen is indispensable to fishes and other aquatic organisms (Ellis, 1946).

The dissolved oxygen can be depleted by the demand of the organic decomposition and by the use in plant and animal respiration. Aquatic populations exposed to low dissolved oxygen concentrations may be more susceptible to adverse effects of other stressors such as disease or effects of toxic substances (Aull, 2005).

The DO depletion was observed in the sections 4, 5 and 7, because after the discharge of the treated domestic sewage (1.8 mg/L of DO), it happened the depletion of oxygen in the stream, since the load of the organic matter presented in the treated domestic sewage was being oxidized, and this oxidation occurred at the expense of dissolved oxygen.

According to CONAMA Resolution n° 357/05, the minimum value for the variable dissolved oxygen in a water body Class 2, in which the Ribeirão Montalvão fits, is 5 mg/L, so the obtained values were in compliance with current legislation.

The turbidity values are shown in Figure 5.

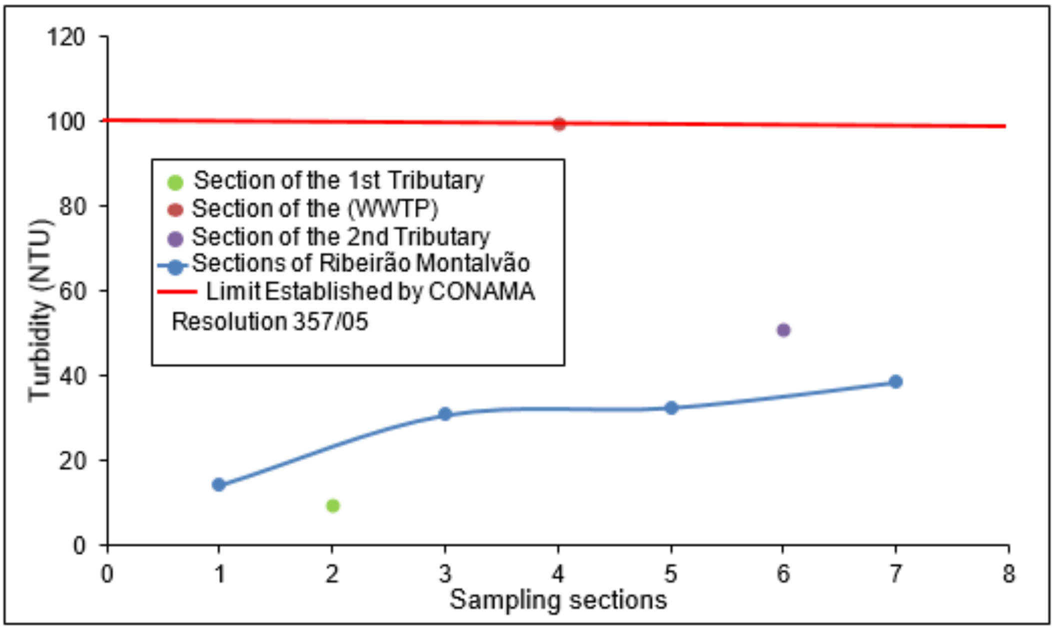


Figure 5. Turbidity in the different sampled sections.

The turbidity is an aggregate measure of water clarity based on the amount of particles within the sample. The composition of materials that contribute to turbidity are suspended and colloidal matter including clay, silt, finely divided organic matter, plankton, and other microscopic organisms (APHA et al., 1998).

Particulate matter found in water can affect the aesthetics of water by decreasing clarity and also by contributing to tastes and odors. Turbid water can affect the water treatment processes, including disinfection and coagulation, as well as adding costs to treatment from the extra demand for removal of the particles. In addition, solids can be harmful to aquatic species, as turbid waters inhibit respiratory processes and reduce visibility (Vigil, 2003).

Steffens et al. (2015) observed that the turbidity has considerable increase due to very heavy rainfall, which can cause erosion along the river, since this is a phenomenon that increases turbidity.

The highest values of the turbidity were observed after the section 4, which comprises the downstream sections of the discharge of treated domestic sewage. The highest turbidity found in section 4 refers to the highest concentrations of solids in suspension presented at the treated sewage. The sections 5 and 7 were influenced by these concentrations.

The section 6 is located after the confluence of two tributaries bordering the urban area of the municipality of Alfredo Marcondes, and it is believed that this proximity may have caused this increase of suspended material in the water bodies through runoff. It is worth mentioning that in this region of the hydrographic basin, the soil cover is grassy and in some places there is no riparian vegetation, which facilitates the carrying of allochthonous sediment to the water.

According to CONAMA Resolution n° 357/05, the maximum value to the turbidity in a water body Class 2 is 100 NTU, a value that has not been achieved in any section of the river, which shows that it is in compliance with current legislation.

The flow values in are shown in Figure 6.

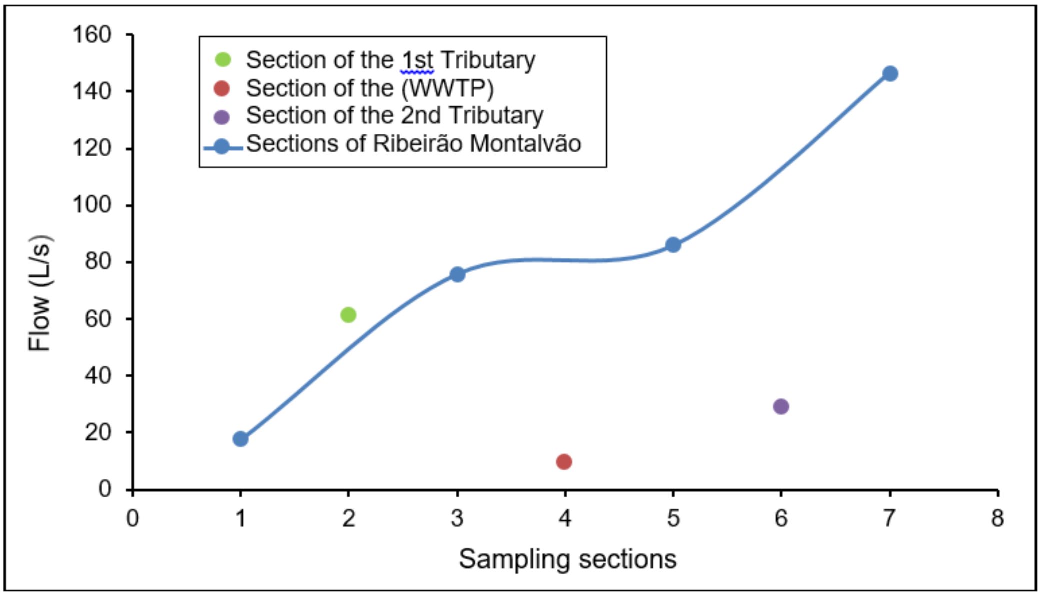


Figure 6. Flow in the different sampled sections.

Studies carried out by Tucci (2002) pointed out that precipitation shows relative impact on the flow of the hydrographic basin. According to the author, in the wetter years, the increase of precipitation produces a larger increase in flow, since infiltration increases slightly and the potential evapotranspiration decreases by the increased of water availability. In periods of drought, the reduced rainfall and the increase in evapotranspiration decreases significantly the flow.

The flow were in agreement with the expected, considering that the flow increases after the confluence of a tributary, as observed between sections 1 and 3 and sections 5 and 7.

It can be noticed that this increase wasn't always proportional to the input of water from the tributaries, and it may be related to hiporrêica zone, which is a connecting ecotone between the surface and groundwater (Mugnai et al., 2015), being constituted by the interstitial spaces between the particles of the riverbed (Valet, 1996).

In this way, these differences are related to water flows between the interstices of the sediments in the area.

The ammoniacal nitrogen results can be seen in Figure 7.

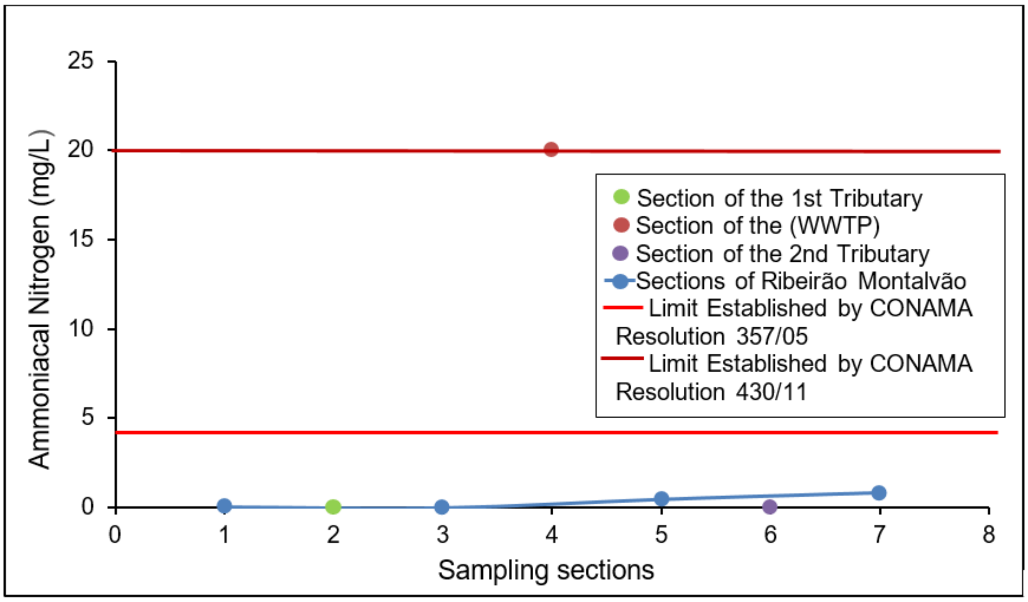


Figure 7. Ammonia nitrogen in the different sampled sections.

Ammonia shows interest in water quality studies, because ammonium compounds are generally detrimental or lethal if more than 2,5 ppm of ammonia are presented. More than 1 ppm of ammonia in natural waters usually points to organic pollution, and many of the lower plants and bacteria that are involved in the superior food chain, which fishes depend, can utilize ammonia as a source of nitrogen (Ellis, 1946).

The usual sources of ammonia in natural water are disintegrating plant or animal material, sewage or other organic wastes (Ellis, 1946; Paula, 2011).

The ammoniacal nitrogen, found in wastewater, originates from the bacterial mineralization of protein and urea, which is the main constituent of the hydrolysis of urea, biological degradation of amino acids and also by the use of disinfectants ammonium base (Mendonça, 2009; Oliz et al., 2010).

According to CONAMA Resolution n° 357/05, the maximum value to ammoniacal nitrogen in a water body Class 2 is 3,7 mg/L to a pH below 7.5, which is the case of Ribeirão Montalvão. The obtained values not exceeded the reference value in any section of the stream, which shows that the stream is in compliance with current legislation.

According to CONAMA Resolution n° 430/11, the amount of ammoniacal nitrogen in effluent should not exceed 20 mg/L, however, the treated domestic sewage discharged in Ribeirão Montalvão had 22.02 mg/L, not in compliance with current legislation.

The phosphorus fractions are shown in Figure 8.

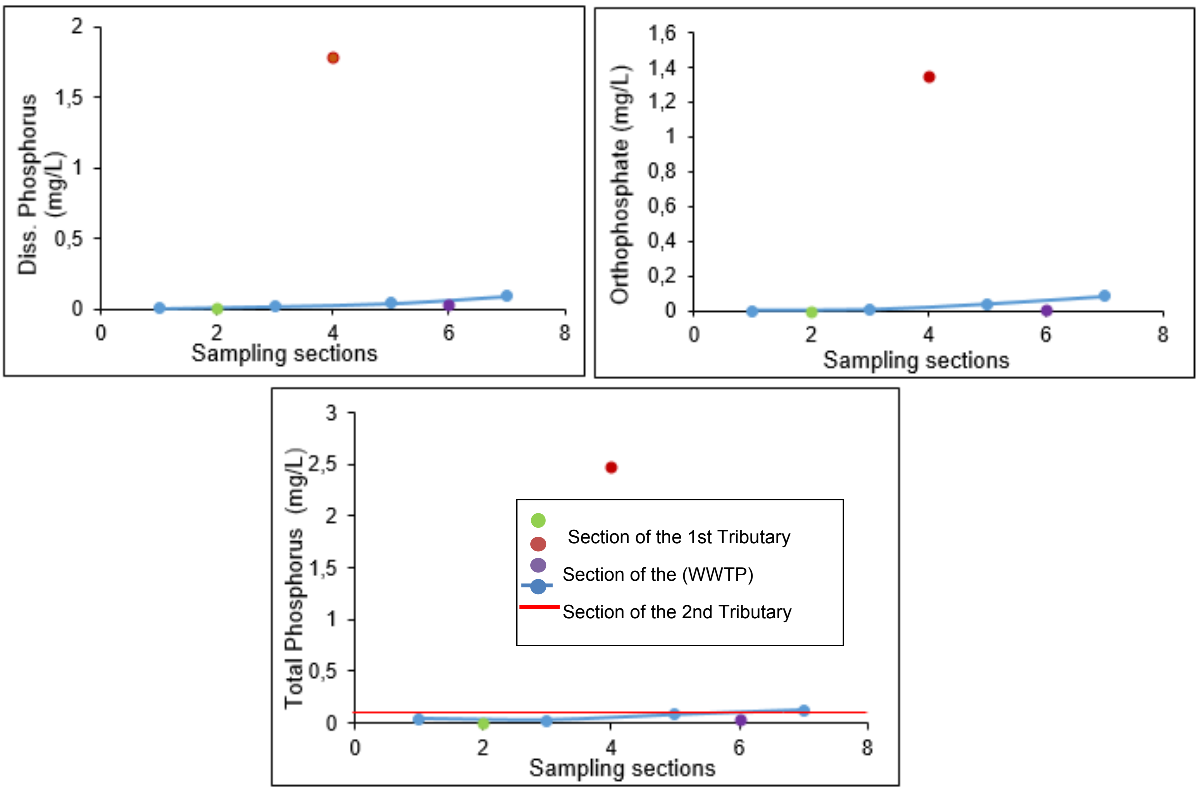


Figure 8. Different phosphorus fractions in the different sampled sections.

Phosphorus is an essential nutrient for the growth of the microorganisms responsible for the stabilization of organic matter, but in high concentrations is responsible for the eutrophication process, because it is necessary for algal growth (Paula, 2011).

High levels of phosphorus in water bodies may be associated with entrainment of sediment of fertilized agricultural land or dumping of sewage (Reis et al., 2009). It can also be associated to detergents superphosphate used in household cleaning, in addition to own fecal matter, which is rich in protein (Oliz et al., 2010).

Studies carried out by Paula (2011) obtained values of total phosphorus in the stream Brejo Alegre in Araguaia – Minas Gerais, Brazil, was similar to those found in Ribeirão Montalvão after the discharge of treated domestic sewage.

Kings (2009) found the greatest phosphorus record in Stream Recanto in Americana – São Paulo, Brazil, after the discharge of effluent from a manhole upstream of the analyzed section.

According to CONAMA Resolution n° 357/05, the maximum value to total phosphorus in a water body Class 2 is 0.1 mg/L, value that was exceeded in section 7 of the river, downstream of the discharge of treated domestic sewage, not being in compliance with current legislation.

The pH values can be observed in Figure 9.

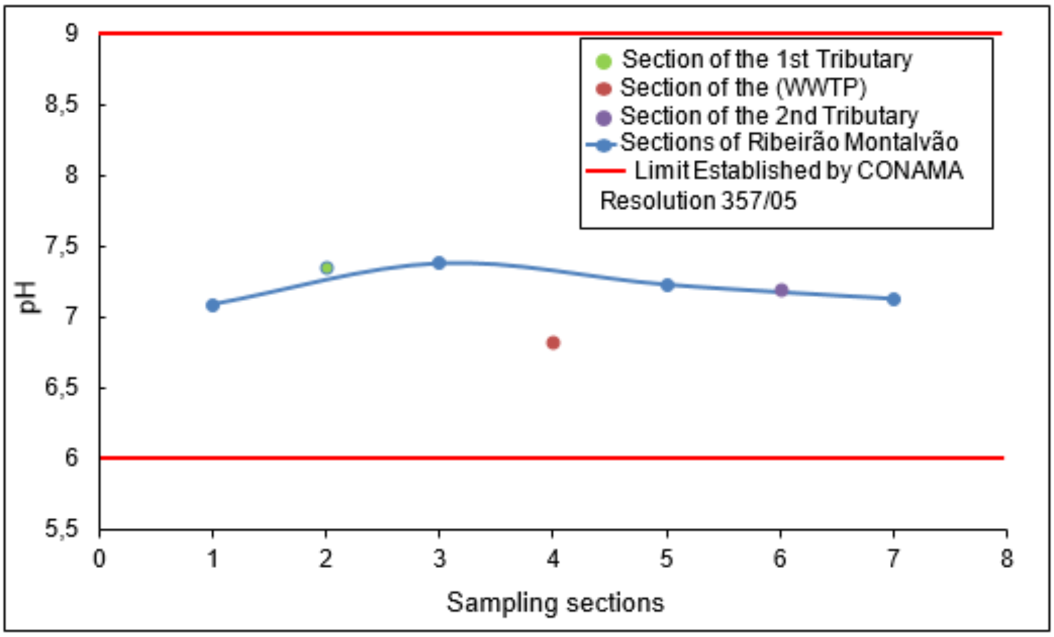


Figure 9. pH in the different sampled sections.

The pH level is a quantitative measure of the hydrogen ions, representing the acidity or alkalinity of a solution. The acidic solution has more free hydrogen ions and the alkaline solution has fewer free hydrogen ions. Any substance with lower pH level is an acid and any substance with high pH level is a base (Barber, 2012).

According to Aull (2005), several factors can be affected by the water pH, including biological availability and solubility of elements in water. The ability of water to resist to changes in pH is based on the buffering capacity of the water body.

In most natural waters, the water pH is influenced by the concentration of H ions originating from the dissociation of carbonic acid that generates low pH. It can also vary by human action, such as the launch of domestic and industrial effluents (Manoel, 2013; Ortega, 2011).

The lower pH was found in section 4, in the point of discharge of treated domestic sewage, being 6.83. The value and can be associated, as enunciated by Farias (2006), to the high levels of organic matter, which, when decomposed, generate a large amount of acid, such as humic acid.

According to CONAMA Resolution n° 357/05, water bodies Class 2 must have a pH value between 6 and 9, and, as can be seen in Figure 8, all the values are within this range.

The pH limits for effluents, according to CONAMA Resolution n° 430/11 should be between 5 and 9, therefore, the treated domestic sewage is also in compliance with the current legislation.

The temperature results can be seen in Figure 10.

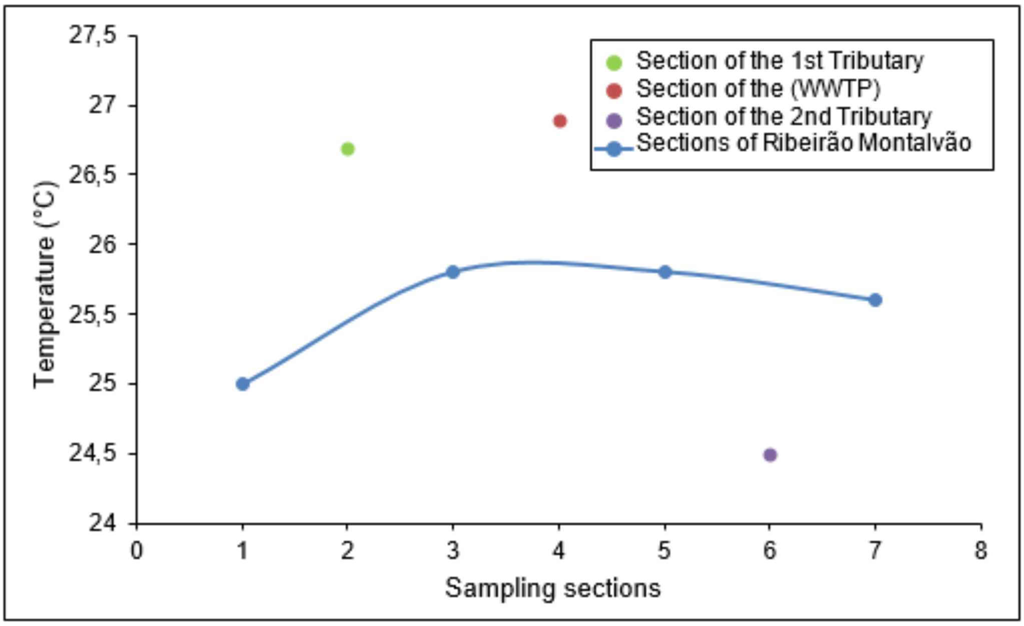


Figure 10. Temperature in the different sampled sections.

Changes in temperature largely affect the chemical characteristics of water. Overall increased temperatures in water bodies can cause increased chemical and biological reaction rates, mineral solubility, and growth of aquatic organisms. Higher temperatures also decrease gas solubility and respiration rates (Tchobanoglous and Schroeder, 1985).

Warmer waters have lower dissolved oxygen solubility. Low DO levels negatively affect plant and aquatic species within the water and change the character of a water body (Kailasam and Sivakami, 2004).

In riparian areas, waterbodies can be protected from the temperature changes from shading cause by plant life on the edges of the water body. Other causes of temperature changes are due to seasonal variations and daily temperature changes (Aull, 2005).

The highest value found for the temperature was in the treated domestic sewage, being 26.9 °C, a value that is in accordance to CONAMA Resolution n° 430/11, which limits a maximum temperature of 40 °C.

The lowest value was found in the section 6, being 24.5 °C, which is located in one of the tributaries of the river. This section is widely wooded, which, as stated by Aull (2005), helps to decrease the temperature of the water through the shades provided by the vegetation.

Thus, as it could be seen, the treated domestic sewage discharged in the Ribeirão Montalvão caused changes in the analyzed variables, forbidden the uses of the water body. In accordance to the CONAMA Resolution n. 357/05, the water body class 2 may be destined to the supply for human consumption after conventional treatment; the protection of aquatic communities; recreation for primary contact; irrigation; aquaculture and fishing activity.

Ribeirão Montalvão is a tributary of Peixe's river, responsible for supplying water to Presidente Prudente and other medium-sized cities. So, the discharge of treated domestic sewage in Ribeirão Montalvão and, consecutively, in Peixe's river causes an increase in the costs for the water treatment.

4. Conclusions

With the development of this work, it was possible to identify the influence of the treated domestic sewage on the Ribeirão Montalvão, especially regarding the self-depuration process that the water body presents.

It was found that the treated domestic sewage discharge interfered with increased in the turbidity, COD and conductivity in the downstream sections after the discharge. However, only one of the variables wasn't in compliance with the current legislation, which was the total phosphorus. This variable is one of the major causes of uncontrolled growth of aquatic plants, as noted in Ribeirão Montalvão, which can promote the emergence of vectors, representing a risk to health.

One of the solutions could be the implementation of a specific process for phosphorus removal, and the development of technologies for the preservation of water quality of Ribeirão Montalvão.

This research demonstrated that it should be implemented a system to improve the domestic sewage treatment, accessible to the reality of the city that has 4,000 inhabitants.

If such measures were taken, it would be possible to use the water of Ribeirão Montalvão for numerous activities, such as fishing, irrigation, production processes and recreation, practice that was held before, but isn't observed nowadays.

With the implementation of a more sustainable system, many advantages could be identified, because with a better water quality, it would not be necessary to invest in further techniques for detection and removal of certain pollutants.

Thus, it is fundamental that the responsible authorities take actions in relation to the quality and quantity of the treated domestic sewage discharged in Ribeirão Montalvão considering the legislation, so that there is sustainable management of this water body and a better utilization by the population that has it as a resource.

Acknowledgment

The authors would like to thank the Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP) for the financial support through process number 2014/06702-0.

References

Abdel-Raouf, N.; Al-Homaidan, A.A.; Ibraheem, I.B.M., 2012. Microalgae and wastewater treatment. Saudi Journal of Biological Sciences. v. 19, n. 3, p. 257-275.

American Public Health Association (APHA), American Water Works Association, Water Pollution Control Federation 1998. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington, D.C.

Andrade, L. N. 2010. Autodepuração dos corpos d'água. http://www.ib.usp.br/revista/node/45 (accessed 03.04.2016).

Aull, M. E. Water quality indicators in watershed subbasins with multiple land uses. 2005. 122 p. Dissertation (Master in Environmental Engineering) - Worcester Polytechnic Institute.

Barber, J. 2012. pH paranoia: understanding alkaline water claims. http://www.watertechonline.com/ph-paranoia-understanding-alkaline-water-claims/ (accesses 06.04.2016).

Blundi, C. E., 1988. 229 p Aplicação de métodos alternativos para determinação de matéria orgânica e biomassa em águas residuárias. Thesis (Doctorate in Agronomy), Universidade Federal de São Carlos, São Carlos.

Braga, B. et al., 2015. Introdução a engenharia ambiental: o desafio do desenvolvimento sustentável. 2nd ed. Pearson Prentice Hall, São Paulo.

BRASIL. Resolução nº 357 de 17 de março de 2005. Dispõe sobre a classificação dos corpos de água e diretrizes ambientais para o seu enquadramento e dá outras providências. http://www.mma.gov.br/port/conama/res/res05/res35705.pdf (accessed 04.04.2016).

BRASIL. Resolução nº 357 de 17 de março de 2005. Dispõe sobre as condições e padrões de lançamento de efluentes, complementa e altera a Resolução n° 357, de 17 de março de 2005, do

Conselho Nacional do Meio Ambiente - CONAMA.. http://www.mma.gov.br/port/conama/legiabre.cfm?codlegi=646 (accessed 04.04.2016).

CETESB (São Paulo). 2015. Qualidade das águas superficiais no estado de São Paulo 2014. http://aguasinteriores.cetesb.sp.gov.br/wp-content/uploads/sites/32/2013/11/Ap%C3%AAndi

ce-D-Significado-Ambiental-e-Sanit%C3%A1rio-das-Vari%C3%A1veis-de-Qualidade.pdf (accessed 04.04.2016).

Chagas, W. F., 2000. 89 p. Estudo de patógenos e metais em lodo digeridos bruto e higienizado para fins agrícolas, das estações de tratamento de esgoto da Ilha do Governador e da Penha no Estado do Rio de Janeiro. Dissertation (Master of Public Health) – Programa da Fundação Oswaldo Cruz. Escola Nacional de Saúde Pública, Rio de Janeiro.Dahm, C.N.;

Dzyuban, A.N. 2003. Bacteriobenthos of the upper Volga Reservoirs as a characteristic of their environmental state. Water Resources. v. 30, n. 6, p. 680 – 688.

Ellis, M. M. 1946. Determination of water quality. Washington: Government Printing Office. http://babel.hathitrust.org/cgi/pt?id=mdp.39015086579425;view=1up;seq=9 (accesses 05.04.2016).

Faria, D. S. 2008. Capacidade de autodepuração do Ribeirão Anicuns/GO, um estudo de caso. Goiânia. http://www.pucgoias.edu.br/ucg/prope/cpgss/ArquivosUpload/36/file/CAPACI

DADE%20DE%20AUTODEPURA%C3%87%C3%83O%20DO%20RIBEIR%C3%83O%20ANICUNS-GO%20-%20UM%20ESTUDO%20DE%20CASO.pdf (accessed 03.04.2016).

Farias, M.S.S., 2006. 152 p. Monitoramento da qualidade da água na bacia hidrográfica do Rio Cabelo. Thesis (Doctorate in Agricultural Engineering)- Centro de Tecnologia e Recursos Naturais, Universidade Federal de Campina Grande, Campina Grande.

Jacobi, P. 2003. Educação ambiental, cidadania e sustentabilidade. Cadernos de Pesquisa, n. 118, p. 189-205.

Jonnalagadda, S.B; Mhere, G., 2001. Water quality of the Odzi River in the eastern highlands of Zimbabwe. Water Research. v.35, n. 10, p. 71-76.

Jouanneau, S.; Recoules, L.; Durand, M.J.; Boukabache, A.; Picot, V; Primault, Y.; Lakel, A.; Sengelin, M.; Barillon, B.; Thouand, G., 2014. Methods for assessing biochemical oxygen demand (BOD): A review. Water Research, v. 49, p. 62-82.

Lim, S.; Chu, W.; Phang, S., 2010. Use of Chlorella vulgaris for bioremediation of textile wastewater. J. Bioresour. Technol. v.101, n. 19, p. 7314–7322.

Mackereth, F.Y.H.; Heron, J.; Talling, J.F., 1978. Water analysis: some revised methods for limnologists. Freshwater Biological Association, Ambleside.

Manoel, L.O., 2013. 167 p. Avaliação e monitoramento da qualidade da água na microbacia do Córrego Caçula no município de Ilha Solteira – SP. Dissertation (Master in Civil Engineering) – Universidade Estadual Paulista "Júlio de Mesquita Filho" Campus de Ilha Solteira, Ilha Solteira.

Mendonça, A.S.F., 2009. Análise técnica dos novos padrões brasileiros para amônia em efluentes e corpos d'água. Eng. Sanit. Ambient. v.14, n. 3, p. 353 – 362.

Miguel, A.R.; Bevilacqua, N.; Guerra, P.A.D.V; Baptistelli, S.C., 2004. Tratamento de águas residuárias domésticas, in: Romero et al. Panorama ambiental da metrópole de São Paulo. Signus, São Paulo pp. 77-87, 96-103.

Mota, S., 1995. Preservação e conservação de recursos hídricos. 2nd ed. ABES, Rio de Janeiro.

MOTA, S., 2003. Introdução à engenharia ambiental. 3rd ed. ABES, Rio de Janeiro.

Mugnai, R.; Messana, G.; Di Lorenzo, T., 2015. The hypoheic zone and its functions: revision and research status in Neotropical regions. Braz. J. Biol. v. 75, n. 3, p. 524-534.

Netto, O.M.C.; Soares, S.R.A; Bernardes, R.S., 2002. Relações entre saneamento, saúde pública e meio ambiente: elementos para formulação de um modelo de planejamento em saneamento. Cad. Saúde Pública. v. 16, n. 6, p. 1713-1724.

Oliz, C.M.; Isoldi, L.A.; Souza, R.C., 2010. Tratamento de esgoto doméstico por filtro anaeróbio com recheio de bambu. 2010. Vetor. v. 20, n. 2, p. 5-19.

Ortega, D.J.P., 2011. 151 p. Avaliação dos efeitos das atividades antrópicas na bacia hidrográfica do Córrego do Ipê, município de Ilha Solteira – SP. 151 p. 2011. Dissertation (Master in Civil Engineering). – Universidade Estadual Paulista "Júlio de Mesquita Filho" Campus de Ilha Solteira, Ilha Solteira.

Palhares, J.C.P.; Ramos, C.; Klein, J.B.; Lima, J.C.M.M.; Muller, S. Cestonaro, T. 2007. Medição da Vazão em Rios pelo Método do Flutuador. Comunicado Técnico, Concórdia: Embrapa Suínos e Aves. http://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/443939 (accessed 04.04.2016).

Parkyn, S.M.; Davies-Colley, R.J.; Halliday, N.J.; Croker, G.F. 2003. Planted riparian buffer zones in New Zealand: do they live up to expectations? Restoration Ecology v. 11, n. 4, p. 436 – 447.

Paula, L.M., 2011. 196 p. Avaliação da qualidade da água e autodepuração do Rio Jordão, Araguari (MG). Dissertation (Master in Civil Engineering) - Faculdade de Engenharia Civil da Universidade Federal de Uberlândia, Uberlândia.

Reis, F.A.G.V.; Simionato, R.; Archanjo, P.; Medeiros, G.A., 2009. Diagnóstico da qualidade da água na microbacia do córrego Recanto, em Americana, no estado de São Paulo. Geociências. v. 28, n. 2, p. 181-191.

Smith, R. L.; Smith, T. M. (2002). Ecología. Pearson Educación S.A. Editora, Madrid.

Steffens, C.; Klauck, C.R.; Benvenuti, T.; Silva, L.B.; Rodrigues, M.A.S., 2015. Water quality assessment of the Sinos River – RS, Brazil. Braz. J. Biol. v. 75, n. 4, p. 62-67.

Tchobanoglous, G.; Schroeder, E.D. 1985. Water Quality. Addison Wesley, New York.

Tucci, C.E.M. 2002. Impactos da variabilidade climática e uso do solo sobre os recursos hídricos. http://www.cepal.org/samtac/noticias/documentosdetrabajo/6/23336/InBr02902.pdf (accesses 05.04.2016).

Knapik, H. C. Organic matter characterization and modeling in polluted rivers for water quality planning and managment. 2014. 318 f. Thesis (Doctor in Water Resources and Environmental Engineering) Federal University of Paraná, Curitiba.

Valet, H.M., 1996. Hyporheic zones, in Hauer, F.R., Lamberti, G.A. (Eds.). Methods in stream ecology. Academic Press, San Diego, pp. 107-119.

Vigil, K. M., 2003. Clean water : an introduction to water quality and water pollution control. 2nd ed. Oregon State University Press, Oregon.

Kailasam, M.; Sivakami, S., 2004. Effect of thermal effluent discharge on benthic fauna off Tuticorin bay, south east coast of India. Indian Journal of Marine Sciences. v.33, n. 2, p. 194-201.

Krama, M.R., 2008. 185 p. Análise dos Indicadores de desenvolvimento sustentável no Brasil, usando ferramenta painel de sustentabilidade. 2008. 185 f. Dissertation (Master in Industrial and Systems Engineering) - Pontifícia Universidade Católica do Paraná, Curitiba.

Interaction between copper and five selected organic amendments to use them to remediate polluted soils

B. Mayans[1], C. Escolástico*[1], M.A. García[1], E. Eymar[2] y A. Masaguer[3]

[1]Dpto. Química Orgánica y Bio-Orgánica. Facultad de Ciencias, UNED.

[2]Dpto. Química Agrícola y Bromatología, UAM.

[3]Dpto. Edafología. ETSI Agrónomos, UPM.

*Correspondence author email: cescolastico@ccia.uned.es

Abstract

Copper is an essential micronutrient for living organisms in natural ecosystems but it is a toxic pollutant as well when its concentration is high. Soil is the major source of metals reaching food chain, so that, it is very important to develop techniques to remediate polluted soils to avoid metals to enter the food chain and natural ecosystems. Organic amendments from organic wastes could be a good option to immobilize metals and make them less bioavailable. Five organic amendments, Humic Acids (HA), sheep and horse Manure compost (M), Vermicompost (VC), Pine Bark compost (PB) and Pruning Waste compost (PW), were selected to study their interactions with copper using ^{13}C CPMAS NMR and FT-IR techniques in order to clarify the mechanism of metal interaction and the functional groups involved. The study was performed using two different pH (2.5 and 5) and different copper concentrations were studied (10, 25, 50, 100, 250, 500 and 1000 mg/L of Cu). The experimental procedure itself was tested in order to know whether it could affect the chemical structure of the amendments and thus their capacity to interact with Cu (II). *Materials and Methods: Organic amendments* (Horse and sheep composted manure (M), Pine bark composted (wood fiber and peat) (PB), Humic Acids of leonardita HUMITEC (HA), Vermicompost (VC), Pruning waste compost (PW); *Spectroscopy technique (*^{13}CPMAS NMR spectra were carried out on a Bruker WB-400; FT-IR spectra were done on a FTIR Bruker IFS66v spectrometer.r. *Results.* Humic acids (HA) and Vermicompost (VC) seem to be the most suitable amendments to immobilize Cu (II) probably due to their higher content in carboxylic and phenolic groups. Both ^{13}CPMAS NMR and FT-IR spectra showed higher interaction between all the amendments and copper at pH 5. The experimental procedure affected the structure of every amendment included the functional groups involved in copper interaction like carboxylic and phenolic groups at both pH: 2.5 and 5. *Conclusions*. Humic Acids and Vermicompost could be a good option to be used in assisted phytoremediation to restore copper polluted soils and any natural ecosystem. It is concluded that the peculiar chemical composition of HA and the presence of some functional groups show that the combination with different plant species could be a very useful tool to phytoremediate polluted soils with high metal concentration due to their likely great immobilization capacity .

Keywords: organic amendments, phytoremediation, heavy metals polluted soils, copper,^{13}CPMAS NMR, FT-IR.

Process of urbanization and appropriation of fluvial channels: a case study in the Macacos Stream, Alvares Machado / SP – Brazil

Renata Ribeiro de Araújo[1], Bruna de Souza Silva[2], Maria Cristina Rizk[3]

[1,2,3] Universidade Estadual Paulista "Júlio de Mesquita Filho" – Faculdade de Ciências e Tecnologia, campus de Presidente Prudente – São Paulo – Brasil, [1]reribeiro@fct.unesp.br, [2]brunnasouzasilva@hotmail.com, [3]mc_rizk@yahoo.com.br

Abstract

In Brazil, the intense urbanization process and the lack of adoption of conservation practices on river channels have contributed considerably in increasing environmental degradation of these resources. In this context, the headwaters of the watershed of the Macacos Stream, in the municipality of Alvares Machado, located in the state of São Paulo/Brazil, present many environmental problems caused by human occupation. Therefore, the present study aimed to analyse how the use and coverage of the watershed can influence the water quality through the limnological monitoring sections of a stretch on the upper reaches of the Macacos stream. For this, it was elaborated a map of use and coverage land in the software ArcGIS 10.3 for scanning screen, using high-resolution aerial orthophoto. In addition, semi-annual samplings were carried out in five sections and the variables monitored in the field were: water temperature (T), electrical conductivity (EC), turbidity (Turb), pH, dissolved oxygen (DO), all of them through portable digital devices. Also in the field, the width, depth and speed of water runoff values were monitored to calculate the flow of the sample sections, as described by Palhares et al. (2007). In laboratory, it was analysed the dissolved phosphorus (DP), soluble reactive phosphorus (P ortho), total phosphorus (TP), according to Mackereth et al. (1978); and ammonia according to Koroleff (1976). It was used the Principal Component Analysis (PCA) to check possible behaviours and patterns of the variables, the spatial and temporal dimensions. The results showed that in the studied watershed the predominant land use are grasslands and urban areas, representing together 93% of the entire land use of the hydrographic basin, indicating that the area has come under intense human intervention. The exploratory analysis revealed an organization of results in relation to seasonal periods, allowing discrimination between the rainy season and the dry season. Analysis of the results also revealed that the determining factor, for the characterization of water quality along the sections, is the land use and cover, especially due to the anthropogenic interference in the drainage network. Other studies using the exploratory analysis also showed the same type of pattern, because of the human activities, such as high soil sealing in the areas of the hydrographic basin, removal of riparian vegetation, pollution and siltation of water bodies, among others, lead to several changes in water quality. In this sense, the appropriation of the channel due to the urbanization process occurs in the sense that the stream functions as a receiving body of all the water that runs through the watershed, getting all kinds of contaminants that alter the ecological dynamics and water quality, compromising its use in a sustainable manner.

Keywords: Macacos stream, Watershed, Limnological Monitoring, Land Use and Cover.

1. Introduction

Water is an essential natural resource for the survival of all living beings and its availability is crucial to characterize the life's quality of some populations. However, how the water resources are used and managed influence the environmental degradation and the risk of water shortages that compromise the life's quality of future generations (Ferreira and Cunha, 2005).

According to Kreischer et al. (2012) since the last century, urban development began to create patterns of urban concentration. In big cities, there was a process of urban decentralization towards the periphery, leaving the downtown depopulated and degraded cities. In Brazil, in some regions, the population in irregular or informal area reaches 50% (MMA 2000).

The large Brazilian urban concentrations present critical sustainability conditions due to excessive loads of domestic and industrial pollution and the occurrence of urban flooding that contaminate water sources, besides the strong water demand (Tucci, 2005). Such factors lead to an impending reduction in water availability. A deterioration in the life's quality is consequently potentiated in population with the worsening of emerging and re-emerging waterborne diseases and the collapse of commercial and industrial activities (Pesce, 2000).

The rivers and streams are very sensitive to human occupation in urban areas as in rural areas, reflecting such effects on physicochemical and biological quality water. According to Tundisi (2008), the rivers are submitted permanently to impacts of human activities, which have several levels of magnitude, from the construction of canals and deforestation of many galleries to the discharge heavy metals, herbicides, pesticides and a large number of organic substances that will be dissolved in water.

The water quality study is an interesting way to diagnose the main problems associated with human activities that affect the natural dynamics of the water body. According to Campos (1999), besides the anthropic presence, the water quality of a hydrographic basin can be influenced by several factors; among them are climate, vegetation, topography, geology, as well as the type, use and management of the hydrographic basin.

In the municipality of Álvares Machado – SP/Brazil, the urban area is on an interfluve and its expansion occurs toward the slopes. The lack of an adequate environmental planning is reflected in the environmental situation of watersheds that are present mostly in the degradation process.

The headwaters of the Apes Stream, located in the northern part of the municipality of Álvares Machado, have many environmental problems resulting from the forthcoming urban presence of its banks. According to Pereira (2010), these impacts are mainly caused by the removal of vegetation, soil sealing and occupations close to the valleys.

Thus, the objective of this research was to understand how the use and coverage of the watershed influence the water quality through the limnological monitoring at the Macacos stream, in order to identify patterns and trends spatiotemporal regarding the behaviour of physical, chemical and biological variables, and understand how the anthropic presence interferes with the quality and sustainable use of water resources.

2. Methods

The map of land use and coverage was generated using an aerial orthophoto, with spatial resolution of 1 m in ArcGIS 10.3. The thematic information were defined with the aid of the Technical Manual of Land Use (IBGE, 2013).

In the vector editing software module it was performed the vectorization on screen for each of the classes. The areas of each class of use were obtained through the Calculate Geometry tool in ArgGis, and percentages were calculated in Excel 2013.

The monitoring was carried out through two work field, the first on September 19th 2015, the second on February 28th 2016. Table 1 and Figure 1 show the geographical location of the sampling sections.

Table 1 – Geographic location of the sampled sections.

Sections	Latitude	Longitude	Altitude (m)
S1	22° 4'31.47"S	51°28'15.12"O	464
S2	22° 4'18.29"S	51°28'3.24"O	434
S3	22° 3'59.25"S	51°27'55.18"O	412

S4	22° 3'57.27"S	51°27'56.88"O	412
S5	22° 3'55.37"S	51°27'53.71"O	412

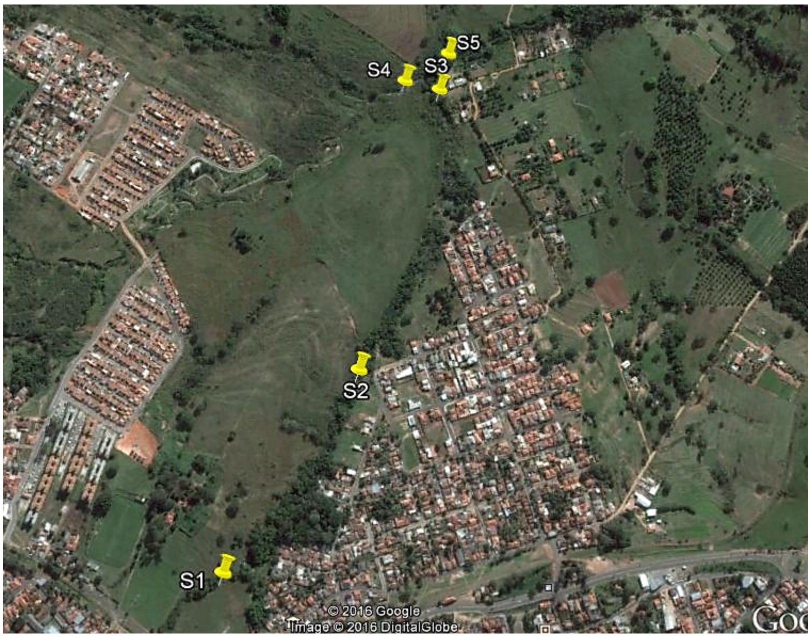


Figure 1. Geographic location of the sampled sections.

The measures flow velocity, width and depth of the sampled sections were made in field to determine the flow. The calculation was done in two steps: firstly, it was determinate the width and the average depth, through a bathymetry of the channel sections, to calculate the area.

In the second step, the flow velocity was determined at various points of the section. For this, a distance of 1 meter was measured with a measuring tape, and then a floating material was positioned at its zero point. With a chronometer, the time that the floating material took to go through the distance proposal was recorded three times to make the average.

The flow of the river was determined by the equation 1:

$$Q = A.\ Vm \qquad \text{(Equation 1)}$$

In which:

Q: average flow of the river

A: cross-sectional area of the river in the measurement section

Vm: average velocity in the section

The variables pH, temperature, turbidity, conductivity and dissolved oxygen were obtained in field with portable digital devices. The analysis of orthophosphate, dissolved phosphorus and total phosphorus were made in laboratory according to Mackereth et al. (1978), and ammonia analysis according to Koroleff (1976).

The results were tabulated in Microsoft Excel 2013 and later in the Statistica software version 13.0. The principal component analysis (PCA) (Gauch, 1994) was applied in order to reduce the dimensionality of the data and evaluate patterns in the spatial ordering. The values of the limnological parameters, except the pH, were log transformed (base ten), to linearize the relationship and reduce the effect of high values. The model of "broken-stick" was used to evaluate the axes to be retained for interpretation (Jackson, 1993).

3. Results

Figure 2 shows the forms of land use and coverage in the hydrographic basin of the Macacos Stream with the following use classes: Urbanized Area, Permanent Culture, Temporary Culture, Forest, Grassland and Forestry.

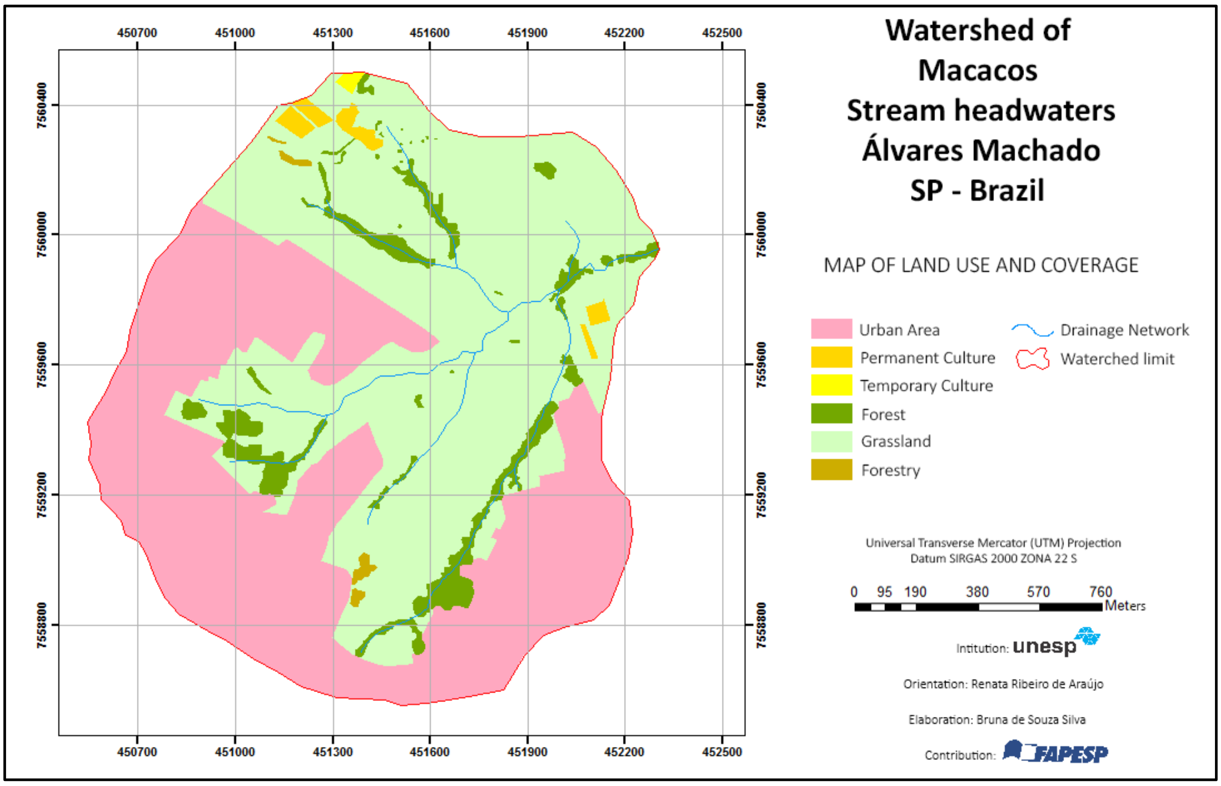


Figure 2. Map of land use coverage in the hydrographic basin of Macacos Stream.

Table 2 – Classes of use and coverage and respective areas (hectares (ha) and percentages).

Classes	Area (ha)	Percentage (%)
Urban Area	106,8	43,3
Permanent Culture	2,5	1,0
Temporary Culture	0,3	0,1
Forest	13,5	5,5
Forestry	0,8	0,3
Grassland	122,5	49,7
Total	246,4	100

Figure 2 and Table 2 show that the hydrographic basin is characterized by two distinct uses and coverage: one more urbanized and densely populated and other with lower density, which there is a predominance of grasslands and undergrowth in general. Together, these two classes account 93% of all uses and coverage of the studied hydrographic basin, showing the intense human intervention suffered in the area.

Regarding the results of the water quality monitoring, the principal component analysis (PCA) summarized all the environmental variables chosen for the study. Using the model of "broken-stick", the principal components 1 and 2 were significant and retained for the interpretation of limnology and hydrodynamic data. These two components explained 85.0% (= 58.2% PC1 and PC2 = 26.8%) of the total variability of the data. The derived structure coefficients of the principal components analysis applied to limnologic data are shown in Table 3. These coefficients express the Pearson correlations between the variables and the principal component (PC1, PC2). The above values of 0.65 (in module) identify the structure coefficients more correlated with the principal components 1 and 2.

Table 3. Derived structure coefficients of the principal component analysis applied to limnology and hydrodynamic data.

Variables	PC1	PC2
pH	**0,856113**	0,405397
Dissolved Oxygen	**0,842472**	-0,504793
Electric conductivity	0,600120	**0,652215**
Turbidity	**-0,816918**	-0,531375
Temperature	**-0,835177**	-0,433218
Ammonia	-0,415081	**0,685549**
Orthophosphate	**-0,926881**	0,223626
Dissolved Phosphorus	**-0,889926**	0,284523
Total Phosphorus	**-0,902565**	0,281850
Flow rate	0,132499	**-0,827754**

The variables positively correlated with the principal component 1 were pH and dissolved oxygen, while the variables turbidity, temperature, orthophosphate, dissolved phosphorus and total phosphorus were negatively correlated. In relation to the main component 2, the variable electrical conductivity and ammonia were positively correlated, and the flow variable, was negatively correlated.

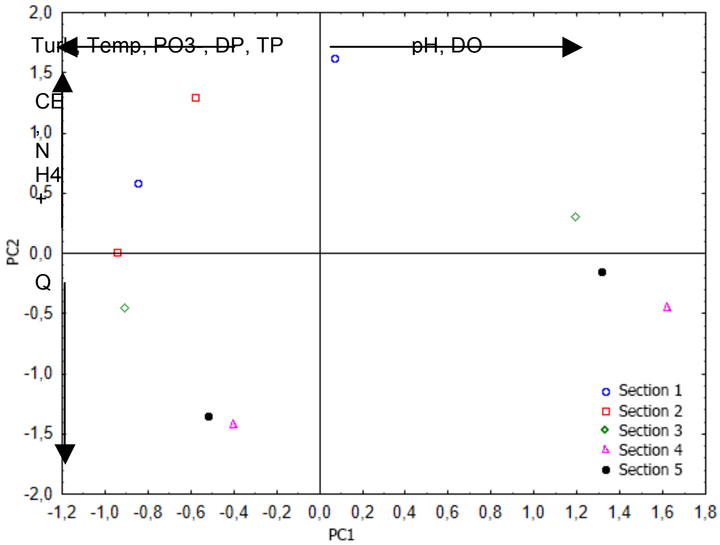


Figure 3. Table of spatial trends.

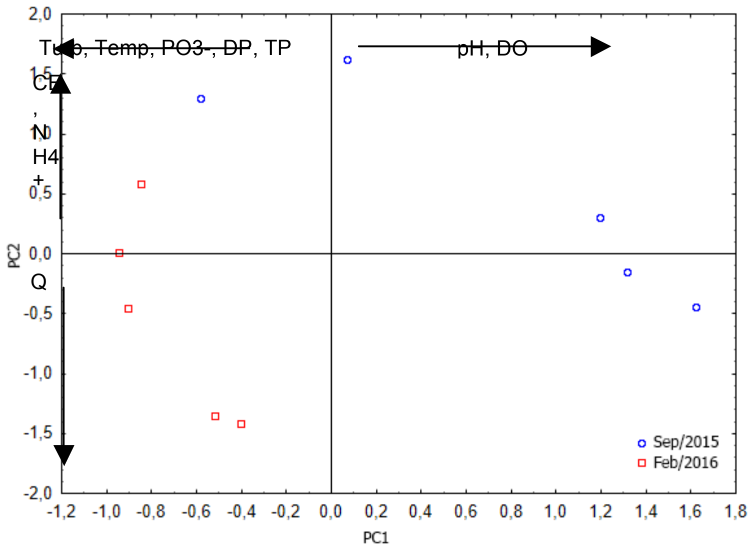


Figure 4. Table of temporal trends

Regarding the spatial trends in Figure 3, it's possible to notice that the diagram separated the section 1 and 2 on the bright side of PC2, and the sections 4 and 5 in the negative part. The section 3 shows a more dispersed behaviour in relation to this axis. In relation to PC1, the variables also exhibited a more complex behaviour. Thus, the spatial trend that can be verified in Figure 3 is that the sections 1 and 2 showed higher electrical conductivities and ammonia, while Sections 4 and 5 showed higher flow rates.

Regarding the temporal pattern, Figure 4 shows a tendency of organization the results on the PC1. Samplings of September 2015 showed grouping on the bright side of this axis, while samplings of February 2016 showed grouping in the negative part of this axis. Regarding PC2, samplings of February were distributed predominantly in the negative part of the axis, while September on the bright side.

Therefore, by the observed temporal ordering, in September the water showed higher pH, dissolved oxygen, ammonia and conductivity, while in February the water showed higher turbidity, temperature, orthophosphate, dissolved phosphorus, total phosphorus and flow.

4. Discussion

The studied region has some forest fragments surrounded by totally disfigured areas of its original vegetation. According to Boin (2000), this fact is due to western of São Paulo State has suffered intense anthropogenic changes that were caused by the action of grabbers and land speculators, and it has been occupied by farmers and still crossed by railways and major wood consumers. Therefore, the region has had its natural vegetation, predominantly forests quickly extinguished and replaced by crops and pastures.

Forest cover provides protection to the soil from the direct impact of raindrops, slowing the velocity of runoff and promoting water infiltration into the soil (Vaeza et al., 2010). From an ecological point of view, the strong reduction in regional forest cover has implications on the composition and distribution of plant and animal species, a process that usually leads to a reduction of gene flow between populations, thereby increasing the chances of local extinction (Primack and Rodrigues, 2001).

In addition, the region is characterized by urban area occupation. According to Tucci (2002) the urban development alters the vegetation and causes changes in the natural water cycle, because the original vegetation is replaced by impervious areas and is introduced conduits for storm water runoff. Schneider et al. (2011) also report that once the streets have little or no barrier to the flow, the water tends to concentrate and flow rapidly to the drainage systems, leading the water to the rivers.

The exploratory analysis of the obtained data from the water quality monitoring reveals that the rains potentiate the urbanization impacts on streams. Brazil has a marked seasonality, with dry and rainy season at different times of the year according to the geographic location (Figueroa and Nobre, 1989). Usually rainy season occurs between the months of November to March and the dry season from May to September. In the rainiest month, February 2016, the concentrations of phosphorus, nitrogen and turbidity were higher due to increased surface runoff water that runs through the city streets, carrying more contaminants to the water body.

From the spatial analysis, the sections 1 and 2, located on the outskirts of the urban area and in direct contact with the storm sewers, had a higher electrical conductivity values. Normally, this variable is related to mineral composition of rocks present in the region, such as carbonates. However, according to Tundisi (1988), the lack of riparian vegetation can contribute to increase this value, as it has a powerful effect on the absorption of dissolved ions.

Arroio Junior at al. (2011) used the exploratory analysis to explain the spatial and temporal behaviour of the variables in Rio Santo Anastácio – São Paulo, Brazil, and revealed the same behaviour. The main finding of theirs study was that the observed responses in Rio Santo Anastácio might be inter-related to human activities, such as high soil sealing in the areas of the hydrographic basin, the absence of measures to contain the erosive processes, the removal of riparian vegetation, pollution and siltation of water bodies and the disorderly occupation of the land.

In this regard, it's noted that the use and coverage of the land in the hydrographic basin, which has suffered intense human intervention leading to the shortage of riparian vegetation, is a key factor in maintaining the water's quality. The behaviour of the limnologic variables in space and time showed how such factors directly influence the physicochemical characterization of the water.

In the studied area, the stream is used primarily for watering livestock and irrigation. Depending on the intensity of the environmental impact caused by the presence of the urban area close to the stream margins, the use of water resources is compromised. So, it's necessary to preserve and conserve the vegetation of the surroundings, which is primarily responsible for ensuring the sustainable use of stream water.

5. Conclusions

The study of the behaviour of physical and chemical variables to understand the limnologic dynamics of a water body can be an important tool for making-decision involving environmental planning of hydrographic basin.

The appropriation of the channel, due to the urbanization process, occurs so the receiving body of storm sewers and runoff receives all kinds of contaminants and solid waste that modify the ecological dynamics and the water quality, compromising its use.

To search an environmental sustainable solution it's needed the integrated management in urban infrastructure, starting with the definition of the land use with preservation of natural functions as the infiltration and natural network flow. The principles of sustainable development in storm water involve: recovery or maintenance of natural functions of storm water runoff and infiltration, natural ravine developed by the flow and reduction of diffuse sources of pollution such as contamination.

The greatest difficulty for the implementation of an integrated planning is due to the limited institutional capacity of the municipalities to solve complex and interdisciplinary problems and the sectorial way that municipal management is organized. Public policies that involve environmental education and encouraging people to dispose of waste properly and the preservation of riparian vegetation within the limits established by law are some of the measures that guarantee the sustainable development of the community and the conservation of water resources.

Acknowledgements

The authors would like to thank the Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP) for the financial support through process number 2014/02875-7.

References

Arroio Junior, P. P.; Araújo, R. R.; Souza, A, 2011. Monitoramento da Qualidade da Água no Manancial do Rio Santo Anastácio. Colloquium Exactarum. v. 3, n. 1, pp.10 - 17.

Boin, M. N, 2000. Chuvas e erosões no oeste paulista: uma análise aplicada. 281 f. Tese (Doutorado) - Curso de Geociências e Meio Ambiente, Universidade Estadual Paulista - Unesp, Rio Claro.

Campos, J. R, 1999. Tratamento de esgotos sanitários por processo anaeróbico e disposição controlada no solo. Abes/Prosat, Rio de Janeiro, 435p.

Ferreira, A., Cunha, C, 2005. Sustentabilidade ambiental da água consumida no Município do Rio de Janeiro, Brasil. Rev Panam Salud Publica, v.18, n. 1, pp 93 – 99.

Figueroa, S.N.; Nobre, C.A, 1989. Precipitation distribution over Central and Western tropical South America. Climanalise, pp. 36-45,

Gauch, H.G., 1994. Multivariate analysis in community ecology. Cambridge: Cambridge University Press, pp 298.

Jackson, D., 1993. Stopping rules in principal component analysis: a comparison of euristical and statistical approaches. Ecology, 74, 2204-2214.

Koroleff, F, 1976. Determination of nutrients. In: Grasshoff, K. (Ed.). Methods of sea water analysis. Weinheim: Verlag Chemie,

Kreischer, T. C. V.; Gonçalves, D. M. M.; Valentini, C. M. A, 2012. Aspectos Hidroambientais do Córrego Barbado em Cuiabá-MT. Holos, Cuiabá, v. 1, n. 28, pp 86-109.

Mackereth, F.Y.H., Heron, J.G.; Talling, J., 1978. Water analysis: some revised methods for limnologists. Fresh. biological associat. publ. 36, 120p.

MMA, 2000. Cidades sustentáveis: subsídios à elaboração da Agenda 21 Brasileira. Ministério de Meio Ambiente, Brasília, 155p.

Pereira, D. M, 2010. Diagnóstico Ambiental das Nascentes do Córrego dos Macacos – Município de Álvares Machado/SP. Monografia (Especialização) - Curso de Geografia, Universidade Estadual Paulista, Presidente Prudente, 90p.

Pesce S. F., Wunderlin D. A., 2000 Use of water quality indices to verify the impact of Cordoba City (Argentina) on Suquia River. Water Res, v. 34, n.11, pp 2915–26.

Primack, R. B.; Rodrigues, E, 2001. Biologia da Conservação. Londrina: Ed. Planta, 328p.

Schneider, R. M. et al, 2011 Estudo da influência do uso e ocupação de solo na qualidade da água de dois córregos da Bacia hidrográfica do rio Pirapó. Acta Scientiarum. Technology, Maringá, v. 33, n. 3, pp.295-303.

Tucci C. E. M., Hespanhol I, Cordeiro Netto O. M, 2000 A gestão da água no Brasil: uma primeira avaliação da situação atual e das perspectivas para 2025 [relatório]. Global Water Partnership:

Tucci, C. E. M. Água no meio urbano, 2002. In: Rebouças, A.; Braga, B.; Tundisi, J. G. Uso e conservação. 2. ed. São Paulo: Academia Brasileira de Ciências, Instituto de Estudos Avançados, USP, pp. 473-506.

Tundisi, J. G.; Matsumura T, 2008. Limnologia. Oficina de Textos. São Paulo

Vaeza R. F, Oliveira-Filho P. C, Disperati A. A., Maia A. G, 2008 Uso e ocupação do solo a partir de imagens orbitais de alta resolução para estudo em bacia hidrográfica em área urbana. In: Anais do XIX Seminário de Pesquisa; Anais da XIV Semana de Iniciação Científica; 2008; Irati. Universidade Estadual do Centro-Oeste – UNICENTRO, Irati.

Strategy environmentally sustainable: Use of graphene for the removal of textile dyes

Eveline Haiana Costa de Oliveira[1], Ana Maria Salgueiro Bapstistella [2], Helder de Barros Guimarães[3], Marcos Gomes Ghislandi[4], Marilda Nascimento Carvalho[5], Maurício Alves da Motta Sobrinho[6]

[1,5,6] Universidade Federal de Pernambuco, Av. Prof. Moraes Rego, 1235 - Cidade Universitária, Recife - Pernambuco - Brazil CEP: 50670-901. email: eveline.coliveira@ufpe.br[1], marildacarv@gmail.com[5], mottas@ufpe.br[6]

[2]Universidade Federal da Paraíba, Campus Universitário I, João Pessoa – Paraíba - Brasil CEP: 58051-900 anabapmaria@gmail.com

[3]Instituto Federal de Pernambuco, Av. Prof. Luís Freire, 500 - Cidade Universitária, Recife - PE, 50740-540 helder.prof@gmail.com

[4]Universidade Federal Rural de Pernambuco, Condomínio Logístico Cone Suape Multimodal, BR 101 Sul, n° 5225, Ponte dos Carvalhos, Cabo de Santo Agostinho – PE – Brazil, ghislandi@gmail.com

Abstract

The textile industries are so important in the world economy and one of the main inputs used by this sector is water, which is largely employed. It is estimated that in order to produce 1 kg of fabric it takes about 80 L of water. The waste water from these industries are potential contaminants of water bodies because the dyes used during the dyeing process are mostly consisting of complex chemical structures, making it difficult to identify the contaminant compounds and their proper removal. There are over 100,000 brands of commercial dyes that produce annually about 700 tons of the product. The treatment of wastewater containing dyes derived from the textile industry has been a major challenge. However, as there is the possibility of non-use of water, many companies are investing in technologies with the purpose of reusing, hence the need of searching for new technological alternatives, in particular the adsorption techniques. The adsorption process has been highlighted to be a separation technique that has in its process feature a high selectivity at the molecular level as well as being effective and economical. It is known that nanotechnology has revolutionized the scientific and technological world in recent years, whose object of study involves creating and building structures and new materials from atoms. Among these, carbon nanomaterials: carbon nanotubes, fullerenes and graphene including graphene. Graphene is perhaps the newest of the carbon nanomaterials and expected to be a very active field of study. The 'isolation' of graphene in 2004 brought the attention of the chemistry, materials and physics communities to this nanomaterial. Despite the adsorption studies of the graphene been in an initial stage, recent results have shown it as a promising adsorbent due to its high surface area and te possibility of regeneration and reusing. In the present study it was evaluated the graphene XGNP adsorption capacity for the anionic dyes Reactive Red 120 and Direct Red 80. The data, obtained from experimental tests showed a high dye removal rate. It was investigated the variables that influence in the process. The results indicate the efficiency of the adsorbent.

Keywords: graphene, dyes, textile industry, adsorption process

1. Introduction

Colored dyes are widely used in various industries such as textile, printing, plastic, food, pharmaceutical, and cosmetic to color the final product. The dyes can be considered one of the most dangerous environmental contaminants despite the different types of environmental pollutants from industries, reaching represent 15% of industrial waste released into the environment annually (Rong et al 2014). Their discharge into water body can cause environmental pollutions because many of the used dyes are toxic, excessive exposure to dye cam causes skin irritation, respiratory problems, or even some are considered carcinogenic for human health (Luo, 2010). Furthermore, the presence of dyes in wastewater also contributes to high chemical oxidation demand and causes foul odor (Moradi et al, 2015). Thus, it is of extreme importance to remove dyes from wastewater effectively to ensure safe discharge of treated liquid effluent into watercourses. (Tan et al 2015) There are currently about 100,000 brands of commercial dyes producing in a year the range of 700 000 tons of dyes (Crini et al, 2006). The most of them used in textile industry.

In Brazil, the textile industry is quite representative with more than 33,000 companies around the country that produce on average, including garments, bed and bath, an average of 6 billion pieces (ABIT, 2014). Treatment of wastewater containing dyes derived from the textile industry is complicated due to the complex composition of the products used in processing tissue, coming therefore the need to search for new alternative technologies such as adsorption techniques (Yagub et al 2014). Different physical and chemical process such as degration, chemical oxidations, biological or enzymatic treatment, coagulation, flocculation, ion exchange, membrane filtration, electrochemical oxidation and catalytic ozonation have been used for the treatment of wastewater containing dyes. However, these technologies are limited due to restricted efficiency (Du et al, 2014). Thus, adsorption techniques stand out mainly by the simplicity of operation and effective removal in low concentrations. When it comes to alternative technologies, in recent years, nanotechnology and nanoscience have been considered areas of great importance to scientific development. The materials at the nanoscale have new properties, and the chemical elements manifest different reactivity patterns (Martinez et al, 2013). With the development of nanoscience and nanotechnology, so as to improve the adsorption efficiency, many nanomaterials, which have large special surface areas to increase the loading amount of dye have been used for the adsorption of dyes and achieved good results. Nevertheless, there are still growing demands for the development of efficient and cost-effective treatment technologies for the removal of such dyes. (Liu et al, 2015).

Among nanomaterials, derivatives of carbon stand out as fullerenes, nanotubes and graphene, the latter being first synthesized in 2004 by Novoselov and Gein winners of the physics Nobel Prize in 2010 for the important milestone in nanotechnological development. Graphene is the basic structural element of some carbon allotropes. Therefore, its structure is considered the basis for other allotropes of carbon, being formed by a graphite monolayer consisting of a hexagonal structure of carbon atoms with sp2 hybridization and distance between the carbons of approximately 1,42ºA (Geim and Novoselov , 2007). One of the most

important features of graphene to be taken into account for its potential use in wastewater treatment, and other adsorption processes, is its great specific surface (2630 m2/g) and flat geometry (González et al 2015, Moradi et. al., 2015; Robati et.al, 2015 ; Srikanth et.al. 2014).

Recent studies have shown graphene for the adsorption of dyes in aqueous solutions as a promising adsorbent, despite of the initial stage of research, due to its outstanding properties such as high surface area and abundance of functional groups (Xu et al, 2013).

In the present study, we evaluated the XGNP graphene adsorption capacity for anionic dyes Direct Red 80 (VD) and Reactive Red 120 (VR). The data obtained from experimental tests showed a good rate of removal of dyes. The variables that influence the adsorptive process, and the results indicated the adsorbent efficiency analyzed for the removal of dyes

2. Methods

2.1. Adsorbent

The graphene used in the adsorptive tests was a commercial one acquired from XG Sciences (USA), presented in the form of nanoplatelet (xGnP® category M - 25 microns). According to the information on the manufacturer's data sheet the adsorbent was produced by microwave expansion at high temperature, containing less than 1% oxygen by weight remained as a functional group (carboxylic acid, ether and hydroxyl) attached to the surface of the sheet. Platelets have an average thickness of 6 to 8 nm and an average diameter of 25 micrometers. As the adsorbent was commercially obtained, it was not made any larger preparations or modifications before its use. It was only determined the point zero charge of the adsorbent and the identification of the crystalline phases.

The identification of crystalline phases was carried out from the X-ray diffraction (XRD), equipment with Bruker brand (D8 advance). The analyzes were performed with CuKα radiation (λ = 1.5406) in the angular range 2 to 80 °. The identification of the crystal phase was carried out by comparison with the standards of the Joint Committee on Power Diffraction Standards (JCPDS) for graphene (PDF - 75-1621) (HU 2005).

To determine the zero charge point of the adsorbent it were placed 0.05g of the adsorbent in contact with 20 ml of a sodium chloride solution (NaCl) 0.05 mol L-1, at different initial pH conditions (2, 3, 4, 5, 6, 7, 8, 9 and 10). For the initial adjustment of pH using a solution of hydrochloric acid (HCl) 0.1 mol L-1 and a sodium hydroxide (NaOH) at 0,1mol.L-1. The sample was left under agitation for 24 hours to reach equilibrium conditions, and then final pH values were measured. For the tests, the samples were kept under agitation of 150 rpm at 25 ° C. The determination of the zero charge point was made through the construction of graph final pH versus initial pH.

2.2. Adsorbates – Direct Red 80 (DR) and Reactive Red 120 (RR) dyes

The selected dyes were obtained commercially from the company Sigma - Aldrich®. Their structure is shown in the Figures 1 and 2.

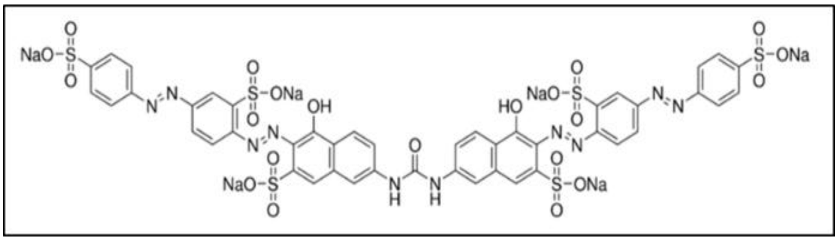


Figure 1. Molecular structure of the dye Direct Red 80. Source: Sigma - Aldrich®.

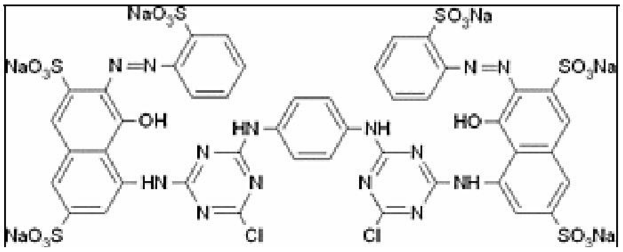


Figure 2. Molecular structure of the dye RR 120. Source: Sigma - Aldrich®.

2.3. Adsorbent characterization

The techniques employed for the characterization of adsorbent material were the X-ray diffraction and the zero charge point (pHpcz).

In general, the identification of crystalline phases was carried out from the X-ray diffraction (XRD) equipment with Bruker brand (D8 advance). The analyzes were performed with CuKα radiation (λ = 1.5406) in the angular range 2 to 80 °. The crystalline phase was identified by comparison with standard by the Joint Committee on Power Diffraction Standards (JCPDS) for graphene (PDF - 75-1621) (HU 2005). This characterization was carried out in the northeast of Strategic Technology Center (CETENE).

To determine the adsorbent zero charge point 0.05g of the adsorbent are placed in contact with 20ml sodium chloride solution (NaCl - 0,05 mol.L-1) under 9 different initial pH conditions (2.3, 4,5,6,7,8,9 and 10). The initial pH was adjusted using hydrochloric acid (HCl - 0,1 mol.L-1) and

sodium hydroxide (NaOH - 0,1mol.L-1). It was stirred for 24h until it reached equilibrium conditions. Subsequently the solutions were filtered using a syringe with hydrophobic PTFE membrane filter of 0.22 uM pore, and then the final pH values were measured. The test conditions were kept on a shaker table with stirring of 150 rpm at 25 ° C.

The determination of the zero charge point was made by graphing final pH versus initial pH, which value can be estimated.

2.3. pH test

To check the influence of the pH it was varied the range from 1.0 to 12.0 and it were used 0.01 M HCl and 0.1 M NaOH to adjust the values. Aliquots of 100 ml of dyes were then prepared 50 ml/g and adjusted to pH concerned, placed, subsequently, in contact with the mass of adsorbent in an agitation 150 rpm for 120 min.

2.4. Mass test

To evaluate the influence of the sorbent mass in the adsorption process for the RR masses 120 grams of 0.010; 0.030; 0.050; 0.070; 0.105; 0.110; 0.130; 0.150; 0.170 and 0.200 graphene were used. For the dye DR 80 it was evaluated the influence of the mass in the process. The endpoints (0.01 g and 0.2 g) and the central point 0,105g were evaluated. Hence rates of 50 mL of the dye were then prepared 50 mL / g and placed in contact with the graphene in a stirring 150 rpm for 120 min.

2.5 Estimating the maximum adsorptive capacity

The adsorbed amount was calculated according to Equation 1:

$$q = \frac{(Ci - Cf)}{M} . V \qquad (1)$$

in which q is the maximum adsorption capacity, Ci is the initial concentration Cf final dye concentration in mg / L, M the mass of the adsorbent and adsorbate g and V the volume in L

Equation (2) was used to verify the removal efficiency:

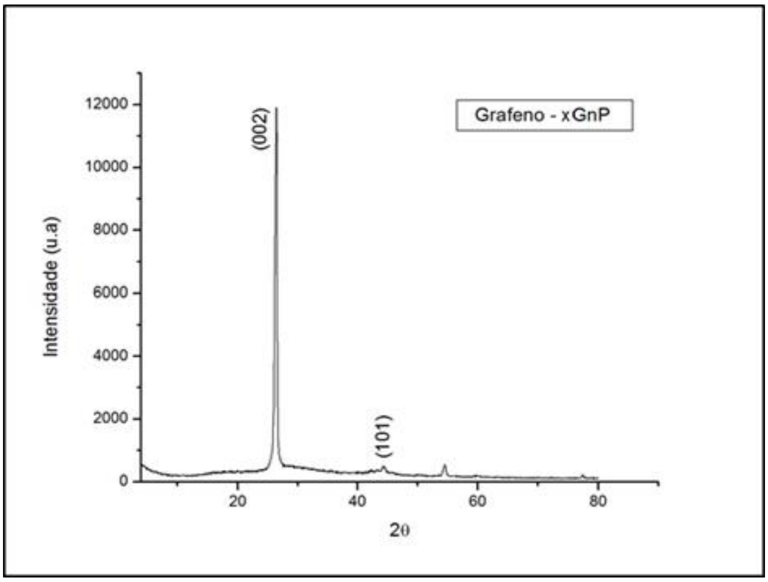
$$e = \frac{Ci - Cf}{Ci} x100 \qquad (2)$$

where e is the efficiency of the process, Ci is the initial concentration Cf and the final concentration of the dye.

3. Results and Discussion

3.1. Potential of zero charge (PZC) and X-ray diffraction pattern of the sample of graphene xGnP®

The pH affects the surface charge of the adsorbent. Because of that the influence of pH on the adsorption process is one of the most important variables to be studied. The pHpcz indicates the pH in which the number of positive charges equals the number of negative charges when the system reaches equilibrium, and the adsorbent behaves as a buffer. It was found that this constant pH occurred in a final pH values between 3.6 to 3.9, obtaining an average of 3.78, which will be the pHpcz of the analyzed graphene.



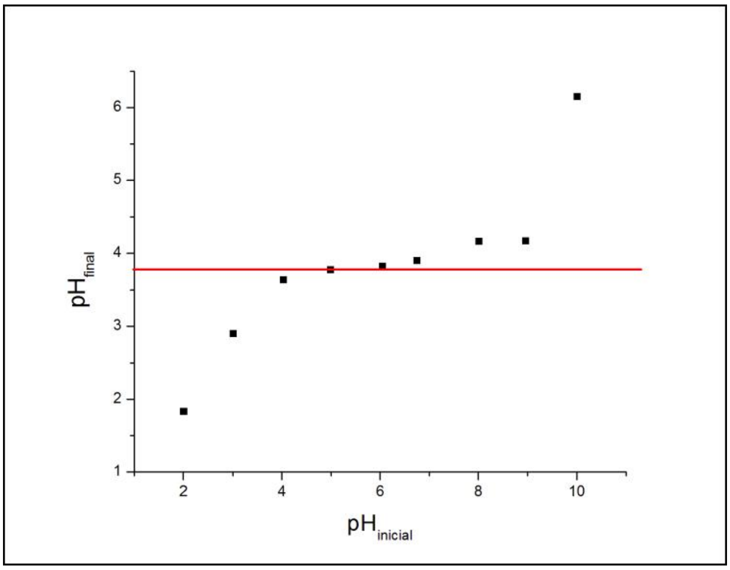


Figure 3. Zero charge point (pHpcz) of XGNP graphene

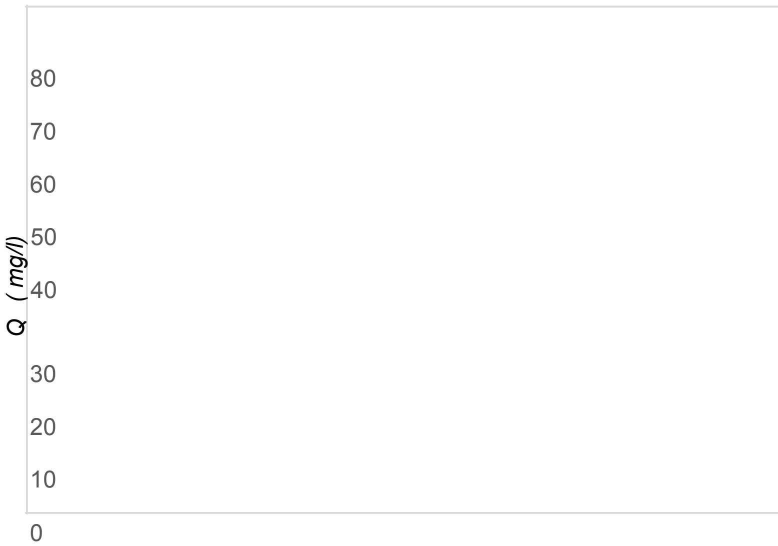
Figure 4. X-ray diffractogram of sample of graphene

It is observed that when the pH is less than pHpcz, the surface of the graphene will be positively charged, this fact favors the adsorption of anionic dyes, such as the VR 120 and the DR 80.

The X-ray diffractogram of sample of graphene, Figure 4 shows, by means of the peak at 2Θ equal to 26.48 and 44.34, characteristic diffraction planes of graphite (002) and (101) respectively.

3.2 Study of pH effect on the adsorption process of dyes on graphene

For the initial evaluation, it was found the maximum absorption wavelength determined by spectral scanning of the dye in the visible region. Then, the initial pH testing was performed on each dye using a mass 0:05 g of graphene. The results are shown in Figures 5 and 6.



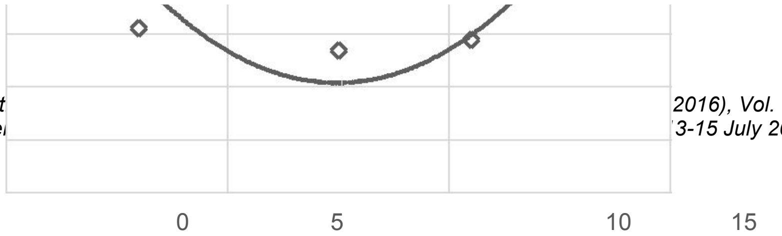


Figure 05 : Effect of pH in the of VR 120 adsorption process

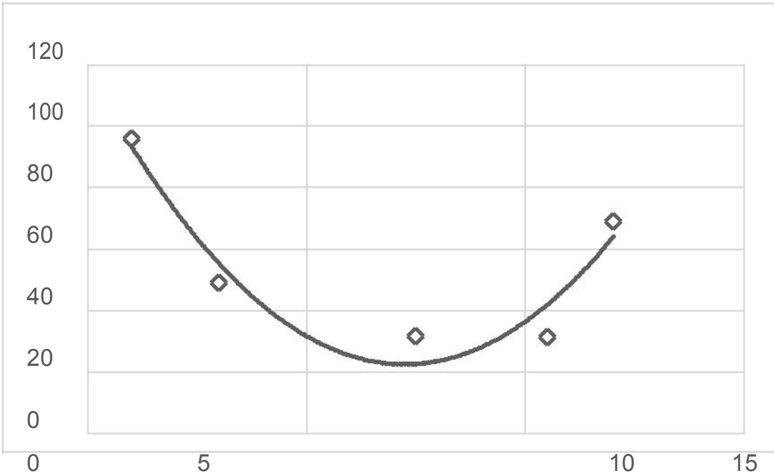
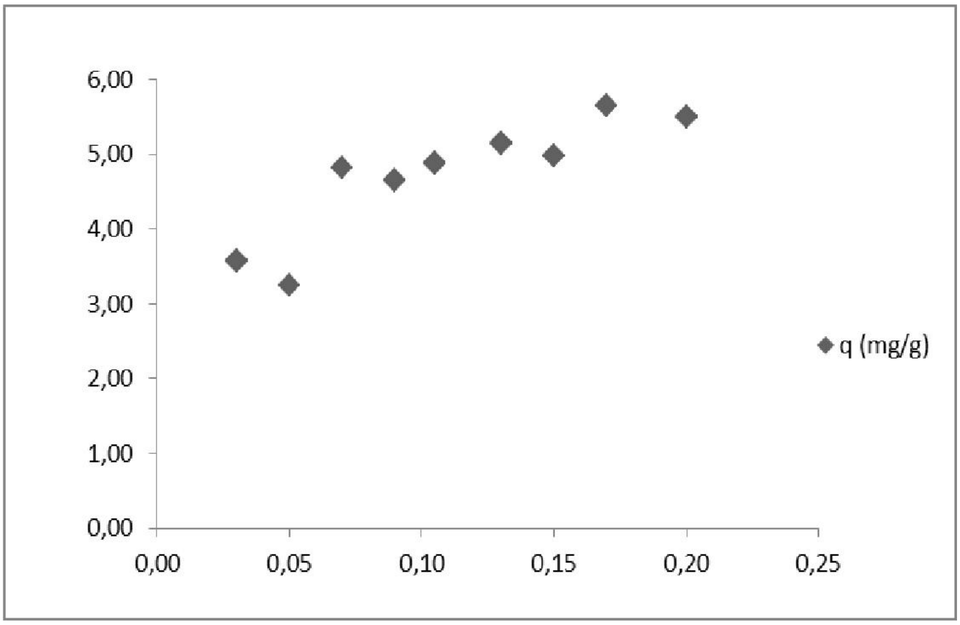


Figure 06: Effect of pH in the of DR 80 adsorption process

Effect of solution pH The pH of the dye solution has a significant effect on the surface charge of Graphene, the degree of ionization of the materials, the dissociation of functional groups on the active sites of the adsorbents surface, and the structure of the dye molecule. (Moradi 2015). For the studied dyes it was observed that at lower pH values, the removal was more pronounced. Ramesha (2011) explained that this type of behavior is associated with anionic character of the dye, which interacts sharply with the negatively charged groups of the graphene surface by means of van der Waals forces. It has been found through the study of the pH to the percentage of removal of the RR 120 was approximately 63% and the DR 80 dye was approximately 96%.

3.3 Mass Effect Study on the adsorption of the dye on graphene

It was found that the maximum adsorption capacity was obtained with 0.170 g. It was examined a variation in mass of 0.01g to 0.2g of graphene. It was observed that the adsorptive capacity grows to 0.170 g, and from this point it decreases. Whereas, from 0.170g of adsorbent happens to decrease the active sites are free for adsorption.



m (g)

Figure 07: Effect of mass changing in the RR 120 adsorption process

In the case of the dye DR 80 the mass that was most suitable for use in the process was 0,01 g. Showing that for a removal of significant amounts of coloring agents it is just needed only a small aliquot of graphene.

4. Conclusions

The results of this study indicate that the adsorption process on graphene xGnP® is an excellent alternative for removal of dyes RR 120 and DR 80. The optimized mass and pH in which occurred the maximum adsorptive capacity were respectively 0.170 g for RR 120 and 0.01 g for the DR 80, both at pH 3. Considering the results obtained it can be concluded that graphene is an excellent technology strategy for the removal of dyes due to its regenerative properties and reuse.

5. References

ABIT – Associação Brasileira da Industrial Têxtil e de Confecção. São Paulo, 2014.

- CRINI G. Non-conventional low-cost adsorbents for dye removal: A review. Bioresour Technol. 2006;97(9):1061-85.

DU 2014- DU, Q.; SUM,J.;LI,Y.; YANG, X.; WANG, X; WANG, Z.; XIA, L. Highly enhanced adsorption of congo red onto graphene oxide/chitosan fibers by wet-chemical etching off sílica nanoparticles. *Chem. Eng. J.*, 245, p 99-106, 2014

GEIM AK, NOVOSELOV KS. The rise of graphene. *Nat Mater.* 2007;6(3):183-91.

GONZÁLEZ, J. A.; VILLANUEVA, M. E.; PIEHL L. L.; COPELLO, G. J. 2015. Development of a chitin/graphene oxide hybrid composite for the removal of pollutant dyes: Adsorption and desorption study, Chemical Engineering Journal vol 280 pag 41–48.

LIU, K.; LI, H.; WANG Y.; GOU, X.; DUAN Y. 2015. Adsorption and removal of rhodamine B from aqueous solution bytannic acid functionalized graphene. *Colloids and Surfaces A: Physicochem. Eng. Aspects* vol 477 pag 35–41.

LUO, P.; ZHAO, Y.F.; ZHANG B., LIU, J.D.; YANG, Y.; LIU, J.F.; 2010 Study on the adsorption of Neutral Red from aqueous solution onto halloysite nanotubes, Water Res. 44 1489–1497.

MARTINEZ, L.M.P., TORRES, S.M., GOMES, H.T., SILVA, A. M.T. 2013. Nanotubos e grafeno: os primos mais jovens da família do carbono! *Quim, 128*, p 21-27

MORADI, O.; GUPTA V.K.; AGARWAL S.; TYAGI, I.; ASIF, M; MAKHLOUF, A. S. H. ; SADEGH, H.; SHAHRYARI-GHOSHEKANDI R., 2015. Characteristics and electrical conductivity of graphene and graphene oxide for adsorption of cationic dyes from liquids: Kinetic and thermodynamic study *Journal of Industrial and Engineering Chemistry vol* 28 , pag 294–301,

RONG, X.; QIU, F.; QIN, J.; ZHAO, H.; YAN,J.; YANG, D. 2014. A facile hydrothermal synthesis, adsorption kinetics and isotherms to Congo Red azo-dye from aqueous solution of NiO/graphene nanosheets adsorbent, *J. Ind and Eng Chem.* V 26 p 354-363.

RAMESHA, G. K.. 2011. Graphene and graphene oxide as effective adsorbents toward anionic and cationic dyes. *J Colloid and Interface Science,* v. 361, n. 1, p. 270–277.

ROBATI, D.; RAJABI, M.; MORADI, O.; NAJADI, F.; TYAGI, I.; AGARWAL, S.; GUPTA, K.V. 2015. *Journal of Molecular Liquids*.

SRIKANTH, V.V.; ROTTE, N.K; YERRAMALA, S.; BONIFACE, J. 2014.*Chemical Engineering Journal.* v. 258, p. 412-19, 2014.

TAN, K. B. ; VAKILI , M.; HORRI, B. H.; POH, P. E.; ABDULLAH, A. Z.; 2015, Salamatinia, B. , Adsorption of dyes by nanomaterials: Recent developments and adsorption mechanisms *Separation and Purification Technology* col 150, pag 229–242.

XU, J.; LV, H.; YANG, S.T.; LUO, J. 2013 Preparation of graphene adsorbents and their application in watter purification. Rev Inorg Chem.

YAGUB, T.;SEM, T.K.; AFROZE, S.; ANG, H.M. 2014. Dye and its removal from aqueous solution by adsorption: A rewiew., *Ad Colloid and Interface Science* – p 172-184.

The effect of climate change on urban drainage systems

Bartosz Kazmierczak, Marcin Wdowikowski, Ondrej Ledvinka

Abstract

The climate warming observed in the last century affects the amount and the intensity of the rainfalls. The increase of the average annual globe temperature causes, among others, increased water circulation in the hydrological cycle. The amount of local precipitation will vary as a result of global and regional climate changes. Nowadays, in order to minimalise the negative results of such occurrences the proper remedial planning is urgently necessary. This is because the drainage systems that are built nowadays should prove correct in the perspective of the year 2100. The European standard EN 752 (2008) allows the frequency of sewerage systems overflows to the rare repeatability of one time per 10 years to one time per 50 years – depending on the land management. Taking into consideration current knowledge about the trends of future climate changes until the year 2100, the adjustment of typical design rainfall to the safe designing of areas drainage systems can be completed by correcting their intensity. Archival pluviograms from Legnica (Poland) station from the years 1961-2010 constituted the research material. In the thesis the trend of local precipitation in Legnica were analysed. An increasing trend of maximum precipitation frequency in Legnica was proved. To a safe sewerage systems designing according to current standards (EN 752 2008; DWA-A118 2006), the precipitation frequency to the simulations of excessive accumulation occurrences to the land level should be changed.

Theme 3. Climate Change and Energy

Track 3ac. Climate Change: Predicting Impacts and Adaptation Strategies

Track 3b. Mitigating Climate Change: Renewable Energy and Energy Efficiency

Track 3ac. Climate Change: Predicting Impacts and Adaptation Strategies

Session 3ac-02

Session 3ac-05

Session 3ac-08

Sustainable electricity using sustainable water – Assessing water requirements for electricity production in the Iberian Peninsula by 2050

Afonso Pinto[1], Sofia G. Simoes[2]

[1] Departamento de Ciências e Engenharia do Ambiente, Faculdade de Ciências e Tecnologia, FCT, Universidade NOVA de Lisboa, 2829-516 Caparica, Portugal, am.pinto@campus.fct.unl.pt

[2] CENSE - Departamento de Ciências e Engenharia do Ambiente, Faculdade de Ciências e Tecnologia, FCT, Universidade NOVA de Lisboa, 2829-516 Caparica, Portugal, sgcs@fct.unl.pt

Abstract

1) Background context: The competition between water and energy needs is a critical issue from a business, security, and environmental perspective. Energy production consumes significant amounts of water. In a world where water stress is an escalating challenge, meeting future energy needs depends on water availability –and meeting water needs depends on wise energy policy decisions. The Iberian Peninsula has a long history of water stress and management practices to deal with it. Nonetheless, climate change (CC) scenarios will increase the problem, particularly as the region is asked to supply energy needs with lower or no impact on greenhouse gas (GHG) emissions. The amount of cooling water that a power plant needs depends on the type of operating technology, cooling technology and its fuel corresponding to different water withdrawal and water consumption factors. A coal power plant with closed-loop cooling system withdrawals less water than one with an open cooling system, but it may consume more water than the former. **2) Justification:** Several authors have assessed the amounts of water consumed by the power sector globally and regionally. However, there are no assessments developed for future power sector scenarios or for the Iberian Peninsula. This is relevant to understand to what extent low carbon electricity is affected by water stress, which is projected to increase, under several CC scenarios for the region. **3) Aim:** This paper aims to quantify the amounts of water required to supply the power sector in Portugal and Spain from 2010 up to 2050 and to compare these with estimated water availability scenarios at watershed level. We consider different carbon targets and CC future scenarios. **4) Methods:** We apply the water consumption and withdrawal factors from the literature to the different power sector scenarios from the National Low Carbon Road Map 2050 for Portugal and from the EU Energy Trends up to 2050 for Spain, complemented with results from the COMET EU-project. We allocate the current plants to the major watersheds. We compare future water needs for the power sector with future water availability scenarios from literature, in particular from the SIAMB project and of Rasilla et al. (2013). 5) Findings: From 2010 up to 2050 the water consumption and withdrawal due to electricity generation in Iberia will decrease 11-13% in a reference scenario. In a low carbon scenario the results vary according to the carbon mitigation pathway. **6) Conclusions:** We conclude that water use for the current and future power sector in Iberia is relevant, although not as important as concurrent uses such as for agriculture and ecosystem services. The matter should however gain more attention due to the shared nature of the three main river systems. Future work should focus on studying the effects of water use for electricity generation at monthly level since water availability has a strong intra-annual variation in the two countries.

Keywords: power sector; water for energy; water scarcity; climate mitigation; climate change

References

Rasilla, D., Garmendia, C., García-Codrona, J., 2013. Climate change projections of streamflow in the Iberian Peninsula. International Journal of Water Resources Development, 29 (2), 184-200.

Irrigation Development as a Measure to Combat Climate Change Risks

Anton Strokov[1], Alisher Mirzabaev[2], Alexey Belugin[3], Sergey Kiselev[4]

[1] Eurasian Center for Food Security at Lomonosov Moscow State University, Shosseynaya street 60-11, 109383, Moscow, Russia, strokov@ecfs.msu.ru

[2] Center for Development Research at the University of Bonn, Walter-Flex-Straße 3, D-53113, Bonn, Germany, almir@uni-bonn.de

[3] Faculty of Economics at Lomonosov Moscow State University, Leninskiye gory 1 bld. 46, 119991, Moscow, Russia, belugin89@mail.ru

[4] Faculty of Economics at Lomonosov Moscow State University, Leninskiye gory 1 bld. 46, 119991, Moscow, Russia, servikis@gmail.com

Abstract

Replacing a rainfed cropping system with an irrigated one is widely assumed to be an effective measure for climate change adaptation. But some finding suggests that reassessing climate change risk in agriculture is crucial not to overestimate potential of irrigation-based adaptation. Climate change influences production of cereals in Russia but this general perception of beneficiary effect of a warmer climate is unlikely to hold, primarily due to increasing risk of droughts in the most important agricultural areas of the country. Since Russia is a major crop producer which influences world grain prices, it is important to investigate how climate change can affect the potential growth of grain production in Russia and especially in the Southern regions of Russia, of the Black sea and Volga river basins. To achieve this, the present study seeks to answer two research questions: 1) will climate change have a positive impact on grain production in Russia? If not, 2) could the negative impacts of climate change on grain production and national food security be minimized through expanding irrigation? Using IMPACT-3 model, we analyse three scenarios for agricultural development in Russia until 2030 in the context of climate variability or change. The base scenario assumes no alteration both in the currently irrigated areas and in climate. The irrigation scenario considers the expansion of irrigated areas in the Black Sea and Volga River basins by 15% till 2025 in the context of climatic changes. The dry scenario incorporates the potential risks of global warming without the expansion of irrigated areas, resulting in the reduction of wheat, rice and vegetables yields by an average of 10-15% by 2030. The irrigation scenario projections show doubling of gross agricultural output in 2030 as compared to the dry scenario. The consumer prices under the same irrigation scenario are projected to be lower only by 5%. Expanding irrigation under wheat may lead to competition with wheat production in rainfed areas. As a consequence, the rainfed areas under wheat may decrease, whereas the production of irrigated wheat may grow. However, this growth may not fully compensate the lost rainfed production and thus may lead to lower growth rates of overall wheat production in Russia, with wide-reaching implications not only for domestic consumers, but also for the international grain market. The estimation results in the welfare module indicate that the first scenario (that of irrigated areas expansion) is more profitable for agricultural producers since their profit increases by 11%, and consumer welfare due to consumer prices decrease also increases slightly by 0.4%. The agricultural producer welfare surplus doesn't influence the consumers welfare in the proportional way because, there are other factors affecting this in Russia such as long distance between the producers and consumers, which lead to high transport costs and also the oligopoly issues on the retail market. Thus, to have a full positive impact from irrigation development Russia has to improve the situation in other spheres of economy.

Keywords: IMPACT-3 model, scenario analysis, irrigation, welfare module

1. Introduction

Global warming and consequent climatic changes have been a hot topic in the scientific literature and public discourse for more than two decades. One of the key issues relates to the impacts of climatic changes on water more specifically, will we have enough water if the climate gets dryer? And what will happen to the soils – will climate change affect organic matter in the soil, will it influence the crop yields, will we have enough water to sustain increasing yields to feed the growing population. So this complicated interactions - climate change, water, soils and people's wellbeing is the crux of climate change related research.

There is increasing evidence of environmental changes in ecosystem processes and functions, yet poor understanding of the relative contributions of land use and climate change to ecosystem services variations. Evidence shows that growing temperature influences more water use in agriculture and affects land use shifts (Pan et al., 2015). Where future changes are uncertain, the sign of the yield change is uncertain as well. Growing temperatures could reduce crop yields in the nearest future (Ummenhofer et al., 2015). At the same time we have to understand that future is uncertain and that we have to apply and model different climate scenarios in order to have a broader view of a range of possible outcomes (Thompson et al., 2015).

Climate change can also affect land use change, which will have impact on soils (Schmitz et al., 2014). Some models use climate data, land use change data, soil data and show the interconnections, in fact, on Russia as an example (Smith et al., 2007). The relationship between organic matter (OM) lability and temperature sensitivity is disputed, with recent observations suggesting that responses of relatively more resistant OM to increased temperature could be greater than, equivalent to, or less than responses of relatively more labile OM (Conant et al., 2008). Recent research showed that there's still uncertainty in soil carbon–climate feedback predictions and some projections could overestimate this interaction (Tang and Riley, 2014). Nevertheless, it is shown that if the temperatures rise there is more probabilities of more frequent draughts directly affecting soils fertility and, thus, also reducing crop yields. So we need to find some ways to sustain yields and protect the soils which could be done with optimized water management.

Water resources are also scarce. Climate change will have potentially significant effects on freshwater quality due to increases in river and lake temperatures, changes in the magnitude and seasonality of river runoff, and more frequent and severe extreme events. These physical impacts will in turn have economic consequences through effects on riparian development, river and reservoir recreation, water treatment, harmful aquatic blooms, and a range of other sectors (Boehlert et al., 2015). Global warming can affect hydrology, morphological changes to river channels and water capacity in river and sea basins, which can support the development of some regions, but challenge other ones, which face often draughts (Lotsari et al., 2015). Replacing a rainfed cropping system with an irrigated one is widely assumed to be an effective measure for climate change adaptation. However, many agricultural impact studies have not necessarily accounted for the space-time variations in the water availability under changing climate and land use. Moreover, many hydrologic and agricultural assessments of climate change impacts are not fully integrated. Other finding suggests that reassessing climate change risk in agriculture is crucial not to overestimate potential of irrigation-based adaptation (Okada et al., 2015).

There are studies focusing particularly on Russia's climate change influence and mitigation (Skrylnikova et al., 2014; Kiselev et al., 2013). Russia has a lot of fertile land but due to climate variability there is high inter-seasonal variability in crop yields (Dronin and Kirilenko, 2013). Farming in higher latitudes is generally believed to benefit from a warmer climate due to extended growing seasons, reduced risk of frost, availability of more productive cultivars, and an opening potential of farming in northern locations. Climate change influences production of cereals in Russia but this general perception of beneficiary effect of a warmer climate is unlikely to hold, primarily due to increasing risk of droughts in the most important agricultural areas of the country. (Dronin and Kirilenko, 2011). Since Russia is a major crop producer which influences world grain prices, it is important to investigate how climate change can affect the potential growth of grain production in Russia and especially in the Southern regions of Russia, of the Black sea and

Volga river basins. To achieve this, the present study seeks to answer two research questions: 1) will climate change have a positive impact on grain production in Russia? If not, 2) could the negative impacts of climate change on grain production and national food security be minimized through expanding irrigation?

To answer these research questions, we evaluate the potential scenarios of expanding irrigated areas in Russia and their impacts on agricultural output in the country. We use an updated IMPACT-3 modelling suite (Rosegrant, 2012), including also the welfare module, with the help of which we are able to estimate the impacts of expanded irrigation not only on agricultural crop yields and, consequently, on agricultural incomes (i.e. producer surplus), but also to identify any changes in the consumer surplus and the total welfare of the society.

2. Research area

Russia is rich in land resources and the present national polices are focused on increasing the agricultural production, as evidenced by the National Program for Agricultural Development and Regulating the Markets of Agricultural Products, for 2013-2020, hereinafter referred to as the National Program-2020 (National Program-2020, 2012). The big extent of Russia's territory and consequent differences in agro-climatic zones will make the impacts of climate change highly differentiated, requiring more complex and nuanced approaches in climate change adaptation (Projecting Global Climate Change, 2009). Therefore, various scenarios of agricultural development and impacts of climatic changes need to be analysed for their effects on agricultural output, consumer markets and the national economy, as a whole.

The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) enables to conduct scenario projections for agricultural development at the country level in the context of climate change (Rosegrant et al., 1995). Climate change projection estimations for Russia have already been made within this model with interesting results (Kiselev et al., 2013). Most notably, it is forecasted that by 2050 some Northern territories, the Tyumen Region, for instance, may become favourable for growing potato, barley and wheat due to the agro-ecological shifts. At the same time, some Southern regions, for instance, the Krasnodar region, may face more draughts and lower grain yields by a up to - 15% (Kiselev et al., 2013).

The latter case is problematic for agricultural production in Russia, as the majority of Russia's most productive agricultural farms are presently located in these southern regions, specifically, in the Volga and Black Sea basins. Being presently mostly rainfed, one potential adaptation option in these areas against recurring droughts would be through expansion of the supplemental irrigation for growing crops. Naturally, the related economic consequences of such shifts need to be properly analysed.

In this context, the expansion of irrigated areas in Russia offers a number of opportunities and is deemed a vital part of the National Program-2020, within the scope of the Federal Target Program "Agricultural Lands Melioration Development in Russia for 2014-2020" (Resolution №922, 2013). Irrigated agriculture not only enables to improve crop yields and profitability in the short term, but when properly applied, helps to improve soil fertility and limit soil degradation (Scientific Basis for Soil, 2013; Shchedrin and Balakay, 2014). Expanding irrigated lands shall have notable impacts on the production of rice and vegetable crops (Balakay, 2011; Vaneyan and Menshikh, 2012; Shchedrin and Balakay, 2014; Shchedrin, 2012). In Russia's central and southern regions, with irrigation, grain yields could rise by up to 40-50%, as compared to the current levels (Schierhorn et al., 2014).

Irrigated agricultural lands make up only 3% of the Russian cultivated lands (Report, 2014). Irrigation areas or irrigation units are those territories (or fields), which actually have any irrigation infrastructure. Of these available irrigation areas, only about 40% are in the actual use (Table 1). This may be due to outdated equipment that many agricultural producers are unable to repair or to replace because of difficult economic conditions (Shchedrin and Balakay, 2014). As noted in the Report on the Status and Use of Agricultural Lands prepared by the Russian Ministry of Agriculture for 2013, in 2012 "more than half of irrigation units (2.4 million ha) require improving including

2,2 million ha requiring reconstruction and technical re-equipment works" (Report, 2014). More than 70% of the irrigated lands with unsatisfactory meliorative condition are located in the Southern and North-Caucasian Federal Districts.

Table 1. Irrigated areas in Russia, as of January 01, 2012

Federal Districts	Irrigated Lands, thousand ha	from which reconstruction required
Central	480.7	352.5
Southern	1076.5	559.8
North Caucasian	1049.7	629.7
Total in the Russian Federation	**4284.6**	**2373.4**

Source: (Concept, 2012). Note: The ratio in the Central, Southern, North Caucasian Federal Districts represents 61% of total irrigated areas, including 65% of those where reconstruction is required.

As it is clear from Table 1, most irrigated areas are located in the Southern Federal District, that is the region, on the one hand, having favorable conditions for agricultural production (fertile lands, available water resources, warm climate), but also suffering from frequent droughts, which is a risk for agriculture. Therefore, optimizing the condition of irrigation facilities may be a solution for boosting future agricultural output. However, there are some indications that the quality of irrigated areas is deteriorating. According to the aforementioned Report on the Status and Use of Agricultural Lands for 2013, in 2010, 47% of irrigated acreage was not used, and in 2012 – 52% of them were not used.

Irrigation units enable agricultural producers to lessen climate risks primarily in the case of droughts. According to the National Report in 2010 when our country suffered from droughts in European Russia on rainfed territories, the wheat yields decreased by 37% as compared to the previous year, and on irrigated lands only by 12% (National Report, 2013). Thus, irrigation may not fully compensate extreme natural and climatic conditions but substantially decrease the losses and provide for output increases as compared to rainfed fields. The output from an irrigated hectare may be 2 – 5 times higher than from rainfed fields, and (Concept, 2012).

Table 2. Crop yields changes with irrigation

Crop	Region	Yield growth with irrigation, as compared to rainfed yields	Source
Wheat	Rostov	By 30%	Drobilko et al., 2009
Potato	Rostov	By 20%	Kalygin, 2005
Vegetables	Saratov	By 100%	Ovchinnikov and Gavrilov, 2010
Cabbage	Moscow	By 32%	Vaneyan and Menshikh, 2012
Sunflower	Saratov	By 25%	Bessmol'naya, 2011
Soybean	Krasnodar	By 50%	Gutrits, 2005
Grain Maize	Krasnodar	By 100%	Balakay and Orel, 2005
Sugar Beet	Rostov	By 100%	Yakovenko, 2006

The yields on irrigated lands are usually higher than on rainfed areas (see Table 2). Besides, irrigation not only influences the yield growth but also helps to store humus, preserving land's long-term fertility. To achieve full effect from irrigation one also needs proper drainage facilities, otherwise the land could quickly become salinized.

Figure 1. Russia's rivers and sea basins.

Note: in the left corner VOG_RUS is the Volga river basin, BLA_RUS is the Black Sea basin.

In the Volga River and Black Sea basins (on Figure 1 they are VOG_RUS and BLA_RUS areas, respectively), being the most developed Russian agricultural regions, irrigation is extensively applied in experimental farms and slowly but steadily is coming to large and medium sized agricultural enterprises as well, particularly in those producing rice and vegetable - highly water-demanding crops (Ovchinnikov and Gavrilov, 2010; Shchedrin and Balakay, 2014). The expansion of irrigated areas is occurring slowly due to high capital costs, financed through the limited public funds. Presently, the state property share in the number of irrigation units and waterside structures is over 60%.

In the Rostov Region, irrigation is used to cultivate wheat, potato and sugar beet with high yields; in the Krasnodar Region it is used for rice, grain maize and other grain crops; in the Saratov Region, irrigation is applied in sunflower cultivation (see table 2).

A number of studies in Russia show that irrigation preserves the soil cover structure providing favorable conditions for agriculture production for years to come (Zhaparkulova, 2014; Scientific Basis, 2013; Nevenchannaya, 2011; Ovchinnikov and Gavrilov, 2010). However, irrigation only cannot save land from erosion, sealing and soil fatigue. Complex approach is required and fertilizers shall be used together with irrigation (Gaikalova, 2006; Shuravilin et al., 2007). Annual adding of 6-8 tons of manure per 1 ha of cultivated land shall stop soil degradation processes and start soil fertility recovery (Shchedrin, 2005).

However, uncontrolled and excessive irrigation has certain risks of land degradation (Nikolaeva et al., 1995; Prikhod'ko et al., 1999; Prikhod'ko, 1994), particularly of secondary salinization, which in long term shall lower the yield and make soils unfit for agricultural use (Kalinichenko et al., 2012). In this regard, one should mind the used water quantity in agricultural production and make regular monitoring of soils acidity. So, scientifically based irrigation implementation and rational systematic exploitation may favour the moisture conservation in soil and higher land productivity, leading to increase of crop yields.

3. Methods

IMPACT-3 model is a deterministic model (Figure 2), where irrigation has a positive effect on output. The irrigated lands improve soil output. However, while interpreting projection results one should not consider the effect of irrigation separately, but in interaction with other production inputs.

The major characteristics of the IMPACT-3 model are:

1) This is a dynamic model, i.e. it has a time parameter that reflects any processes occurring in the system over time.

2) This is a simulation model since it is used for identifying prospective development pathways and for analyzing the sensitivity of the outcomes by varying some or all model parameters.

3) This is a deterministic model since each input parameter set corresponds to well-defined and definitely determined output parameter set.

IMPACT-3 model is an integrated structure and consists of several sub-modules. IMPACT-3 enables to take into consideration temperature and precipitation impact, the effect of soil quality and composition plant, and consequently, on agricultural crops yield via the integrated DSSAT model (Jones et al., 2003). IMPACT-3 includes hydrological data on rivers, water reservoirs and water resources' volumes in specific territories taking into consideration hydrologic cycle at the global level with the help of methodology by Zhu et al., (2012). Model's general structure is provided in Figure 2. Its upper and side parts contain input indices: production, export, import, prices, calibrated elasticities, water volumes, water consumption by various crops and other indices characterizing various scenarios. The equations of the model can be observed in Rosegrant, 2012.

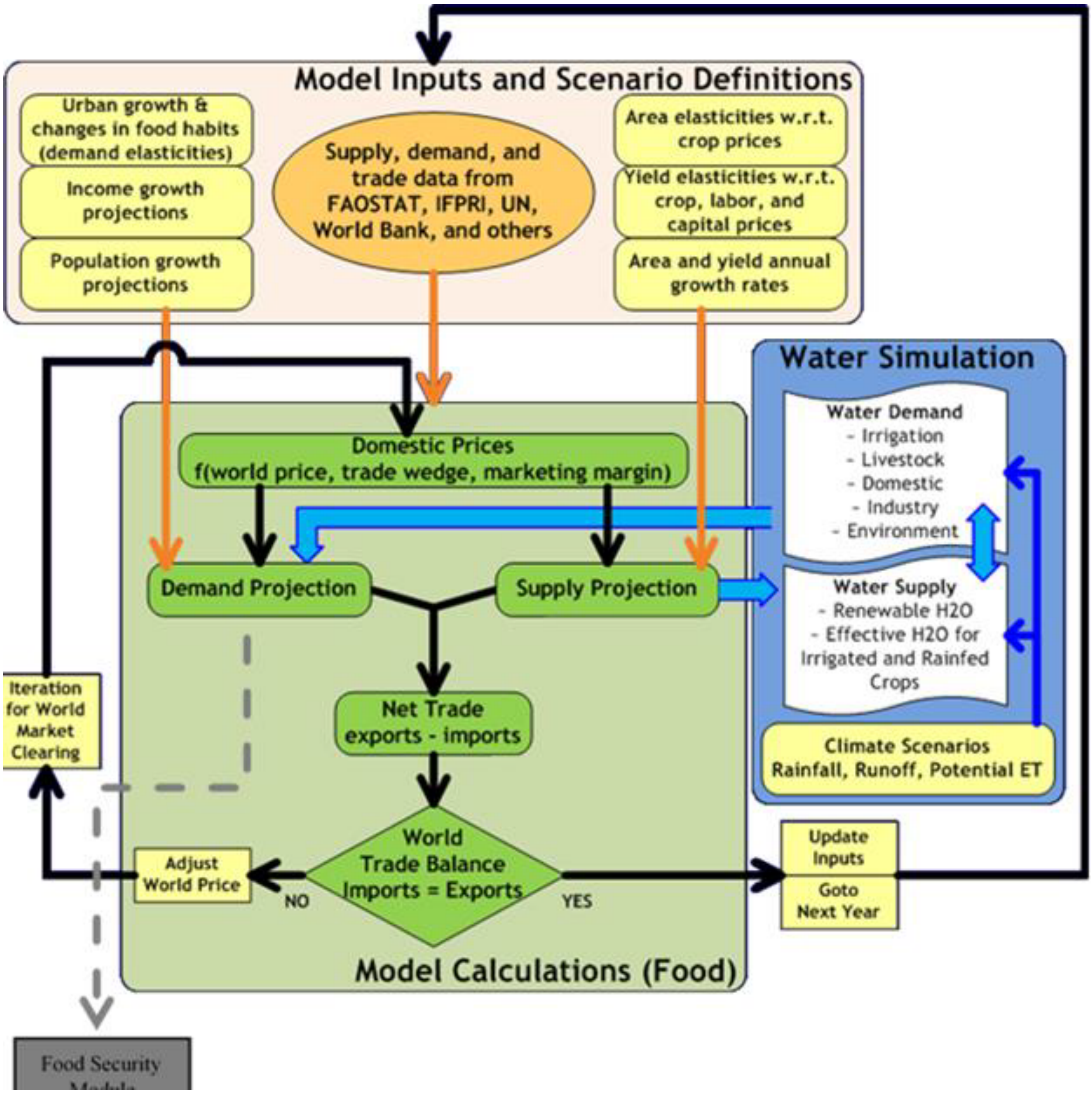


Figure 2. IMPACT-3 model structure

Coming back to Figure 2, we shall mention that to estimate the climate changing impact we use GFDL, HadGEM, IPSL, MIROC climate scenarios based on general circulation climate model (GSM). Each scenario consists of a set of parameters and determines the precipitation amount and average temperatures for specific territories in the base year and thereafter during the whole forecasting period. Table 3 sums up module characteristics giving a clear indication of modules differences: some of them show temperatures relatively high ("+" sign), in others they are relatively low ("–" sign) etc.

Table 3. Distinctive features for IMPACT-3 composite climate models

Climate model	**Precipitation**	**Temperature**
GFDL	-	-
HadGEM	-	+
IPSL	+	-
MIROC	+	+

The first two of the aforementioned climate scenarios (GFDL and HadGEM) are of the main interest for our analysis since they shall face the decline of precipitation amount and, consequently a great necessity shall arise to use irrigation in order to preserve agricultural production.

IMPACT-3 model is disaggregated taking into consideration river basins, in other words there are no common regions and federal districts. Since the majority of Russian agricultural industry is located exactly in the Volga River and Black Sea basins, we shall analyze these two regions. The Base Scenario assumes current irrigated areas preserving and rainfed areas slight decreasing, but crops yield in 2030 shall be changed depending on applying one or the other module (Tables 4 and 5).

Table 4. Agricultural crops yield in the Volga river basin in 2030 (Comparing GFDL and HadGEM climate scenarios)

Crops Name	**GFDL**	**HadGEM**	**HadGEM / GFDL Ratio**
	Tons per 1 hectare	Tons per 1 hectare	**%**
Barley	2.86	2.9	101.4
Corn	6.68	6.03	90.3
Rice	3.37	3.25	96.4
Wheat	2.95	2.85	96.6
Sugar Beet	42.13	41.17	97.7
Vegetables	30.75	29.5	95.9
Sunflower	2.1	2.11	100.5
Potato	15.7	15.26	97.2

Note: Authors' estimations made in the Base Scenario

Table 5. Agricultural crops yield in the Black sea basin in 2030 (Comparing GFDL and HadGEM climate scenarios)

Crops Name	**GFDL**	**HadGEM**	**HadGEM / GFDL**

	GFDL	HadGEM	Ratio
	Tons per 1 hectare	Tons per 1 hectare	%
Barley	4.01	4.09	102.0
Corn	6.66	6.04	90.7
Rice	4.56	4.41	96.7
Wheat	5.53	5.48	99.1
Sugar Beet	52.24	52.24	100.0
Vegetables	20.19	19.38	96.0
Sunflower	2.12	2.13	100.5
Potato	13.3	12.63	95.0

Note: Authors' estimations made in the Base Scenario

The tables show that HadGEM is a drier scenario. We shall apply irrigation expanding conditions for this scenario, and analyse the changes throughout Russia.

To make interconnections we shall use the Base Scenario and the Dry one focusing on possible drought risks. It enables to visually demonstrate any effect of expanding irrigated fields widening or the failure to expand irrigation.

4. Results and Discussion

The Base Scenario (base) assumes the preservation of the current irrigated areas and a slight decrease in rainfed areas. Scenario 1 (scen1), being the Irrigation Scenario, assumes irrigated lands expansion in the Black Sea and Volga River basins. According to our estimations, taking into consideration the implementation of Federal Target Program "Agricultural Lands Melioration Development in Russia for 2014-2020" by 2025 the irrigated areas shall be increased by 15%. Scenario 2 (scen2) being the Dry Scenario assumes the preservation of the current irrigated areas and yield declines by 15% due to climate changing. In all scenarios the rainfed arable land is declining, due to a world wide trend.

The impacts of such changes were estimated in the Model up to 2025. During 2026 – 2030 we have not entered any areas increasing parameters but analysed only the changes being the consequences of climatic factors. Table 6 specifies that after 2025 irrigated areas shall still be increasing though we do not set such increasing exogenously. This effect due to the model's responding to the production profitability on irrigated lands under drought conditions. In other words, reasonable economic behaviour in the context of climate warming involves increasing of irrigated areas.

Table 6. Projections on irrigated fields and rainfed areas in Russia (in 2 main basins), thousand ha

Indices Names	Volga River Basin	Black Sea Basin	Volga River Basin	Black Sea Basin	Volga River Basin	Black Sea Basin
	2015		2025		2030	
Rice	10	126	11	142	11.5	148
Vegetables, irrigated areas	97	124	136	172	244	304
Vegetables, rainfed areas	130	166	98	120	54	63
Wheat, irrigated areas	331	522	470	734	841	1,301

Wheat, rainfed areas	4,960	6,071	3,893	4,590	2,263	2,535
Total crops, irrigated areas	848	1,156	1,442	1,472	1,829	2,584
Total crops, rainfed areas	12,291	15,225	10,297	12,568	6,088	7,431

Note: estimation results subject to the *Irrigation Scenario* (***sc1***)

In general, vegetables and wheat cultivation would be substantially increased on irrigated fields. Wheat share grown in irrigated fields would amount to 45% of the whole planted area in 2030. In 2030, in the Volga River and Black Sea basins, there would be overall decreasing of rainfed planted areas under agricultural crops. It is due, firstly, to more frequent droughts and, secondly, to lower efficiency of rainfed farming as compared to irrigated farming under the same conditions.

In this case, the model results point at higher sensitivity of wheat responses to favourable and unfavourable conditions as compared to vegetables. The effect of irrigated acreage expansion when growing rice is less evident since rice is grown only when fields are irrigated.

The expanding of irrigated lands in main agricultural regions has its effect on whole Russia, as demonstrated below. Having high yields, irrigation increase promotes production development, and for consumers it results in much lower prices for agricultural products. When analyzing price indices we use constant prices of 2005 since that year is the base one for the model when estimating the three analysed crops.

While interpreting the results some caveats need to be taken into account. IMPACT-3 model is based on harmonization and calibration of a great number of indices. This is why the program authors (IFPRI, USA) prefer to select data for a single year and run the model based on that data. At present IMPACT-3 is operating with the database of 2005 using the data for crops production, cropped lands, producer and consumer prices, import and export volumes, etc. The data for Russia correspond to the official data by the Federal State Statistics Service and Federal Customs Service.

Owing to the fact that the base data in the model substantially differs from the official data, some of the received projection results may not always be consistent with absolute production levels over the years. In particular, forecasting production volumes for rice for 2030 in Russia have been actually achieved in 2012. We saw this when we compared the projections for different years with official statistics for the years that already passed. It must be noted that as from 2004-2005 rice cultivated areas in Russia increased for 10 years till 2014 almost by 50%, which IMPACT model couldn't predict in any scenario. However, these relative variations, in our opinion, provide a plausible view of the possible development trends for major agricultural crops and display both irrigation development in Russia and potential risks in the case of the Dry Scenario. The scenario results calculated for basins are summed up at the national level.

The expansion of irrigated lands in the Black Sea and Volga River basins positively affects the rice production throughout the country. Figure 3 displays that even upon the irrigation program ending in 2025 in Scenario 1 (*Irrigation* scenario), the rice production is still increasing. This is due to the fact that rice is a warm-weather and water-demanding crop and rational irrigation enables to keep the effect over quite a long term. Investments made to cultivated areas before 2025 shall give their results so the producers shall ramp up production on the irrigated areas even after 2025 when there are no more investments.

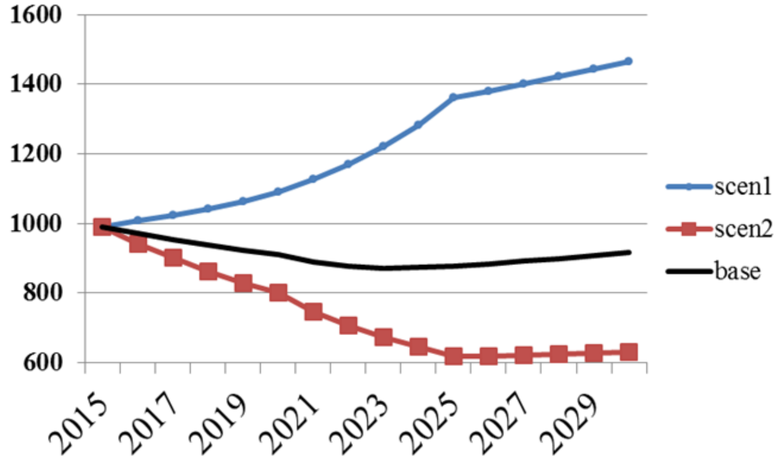


Figure 3. Rice production projections in Russia in thousand tons

Since the Dry (Shocking) Scenario (scen2) initially assumes the reduction of rainfed areas and lower yields, it shall result in production declines that are demonstrated on Figure 3: there is a wide gap between production indices in the Irrigation and Dry Scenarios. In 2030 the Dry Scenario results in rice production being 2.5 times less than in case of Irrigation Scenario.

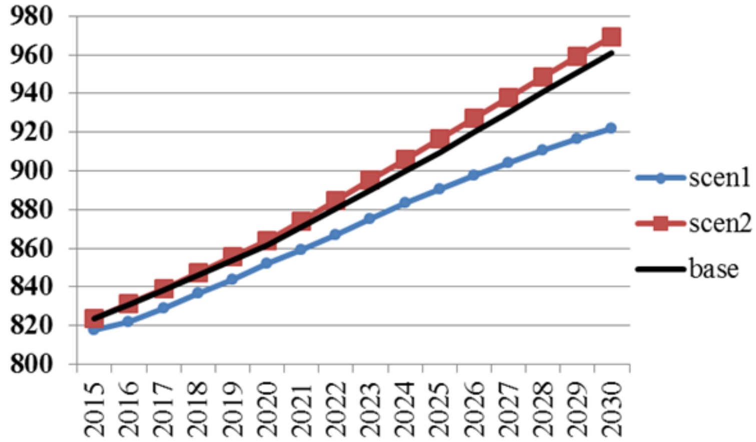


Figure 4. Rice consumer prices in Russia in USD per ton (in constant 2010 prices)

Rice consumer prices in the Dry Scenario shall be 5.4% more than in the Irrigation Scenario (Figure 4). This is due to the fact that the model has been calibrated with low price elasticity of supply, typical for rice. Thus, a sharp slump in production does not result in a proportionate growth of rice prices.

However, Figure 4 makes it clear that rice consumer prices in Irrigation Scenario assuming production growth are lower than the rice prices in the Dry Scenario. It means that the model properly reacts to the given scenarios and complies with the demand properties, whereby increase in the supply quantity of goods leads to declines in their prices.

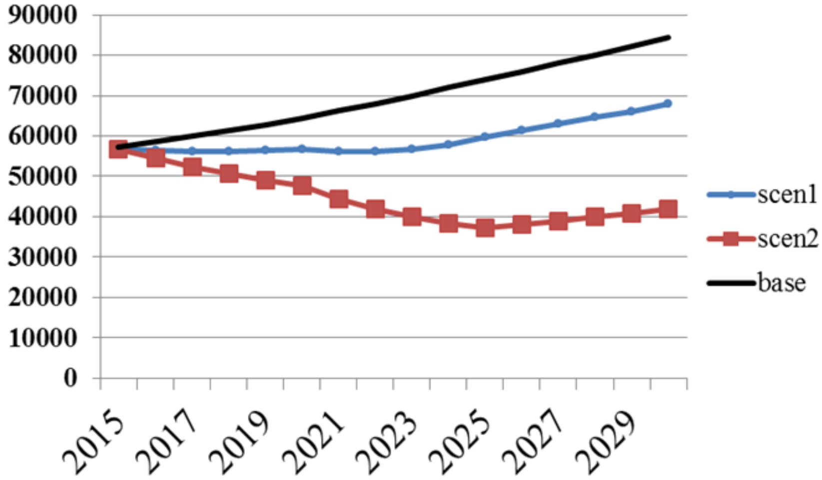


Figure 5. Wheat production projections in Russia in thousand tons

We have received rather exceptional results for wheat (Figure 5). Production dynamics in the Base Scenario are higher than production indices in the Irrigation Scenario. That means that, production volumes in the first case are higher than in case of irrigated areas increase. Somehow in the case of wheat irrigation does not have such positive effect on country's aggregate production. Experience has proven that wheat yield greatly depends on the area with winter sowing and the quality thereof that is not set in the model. This is of great practical consequence.

The expansion of irrigated areas of wheat leads to a competition with rainfed farming. The model deals with the investments made to the irrigation farming being the motivation to grow wheat on irrigated fields. This is why rainfed farming becomes less profitable for farmers relative to irrigated production of wheat (we have included the scheme thereof in Section “Welfare Module” and as Figure 10). As a consequence of such transformations, rainfed wheat production would decline, and irrigated wheat production would grow. However, that leads to lower growth rates for the overall production of wheat in Russia in the Base Scenario as compared to the Irrigation one.

As we have noticed in the situation with rice, the Dry Scenario decreases wheat production. However, after 2025 wheat production would be restored faster than rice production, and this is due to the fact that wheat better resists to draughts. But still in the Dry Scenario wheat production in twice lower than in the Irrigation scenario in 2030.

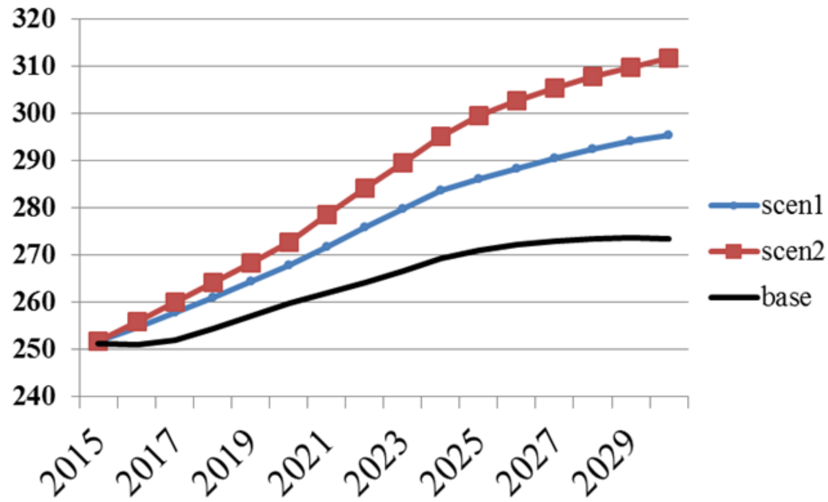


Figure 6. Wheat consumer prices in Russia in USD per ton (in constant 2010 prices)

Figure 6 reflects wheat price behaviour. Everything is consistent here: the Base Scenario offers the highest supply volume, so the prices are lower. In case of drought (scen2) the prices are growing faster and are higher than in other scenarios. Thus, it is clear that in the Dry Scenario in 2030 wheat prices are 5% higher than in the Irrigation Scenario and 12.7% higher than in the Base Scenario (Figure 6).

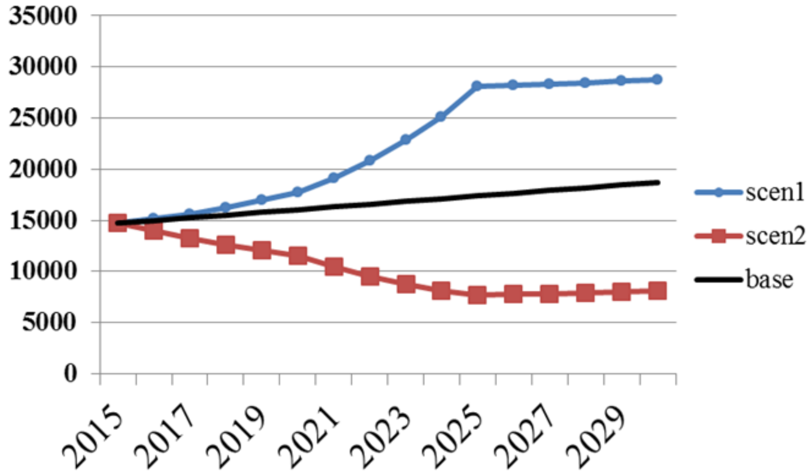


Figure 7. Vegetables production projections in Russia in thousand tons.

Figure 7 reflects the forecasts for vegetables production in Russia. High return is evident in the Irrigation Scenario resulting in production fast growing up to 2025. However, the growth is remarkably slowing down since the given programs for irrigation farming are ceasing. In other words, in case of vegetables there is no long-lasting constant effect from irrigated areas expansion.

The Dry Scenario gives a negative effect, and after 2025 vegetable production is recovering slightly since vegetables in general are very moisture-loving and non-resistant to drought. By 2030 the Dry Scenario provides 3.5 times less vegetables production than the Irrigation one.

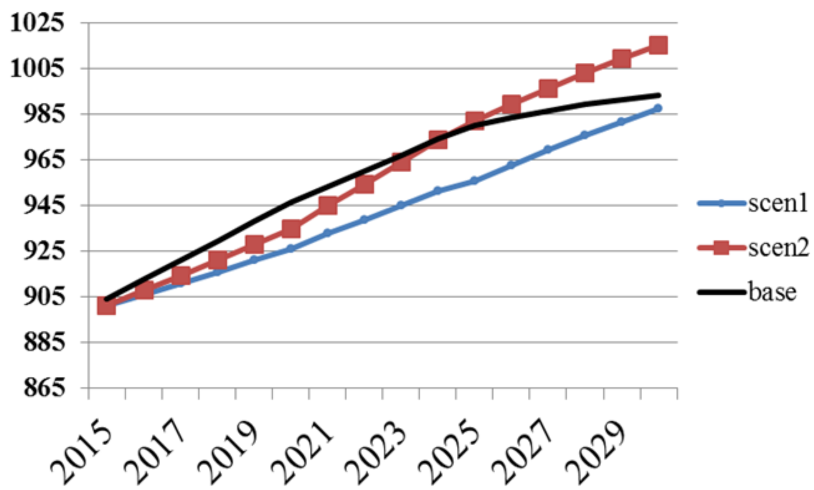


Figure 8. Vegetables consumer prices in Russia in USD per ton (in constant 2010 prices).

Vegetables price behaviour is similar to rice and wheat (Figure 8). In 2030 the prices for vegetables in the Dry Scenario are forecasted by 2.5% higher than in the Irrigation Scenario. But in the base scenario there is a bend of the curve after 2025, which reflects the priority of producers to decrease vegetable prices in order to fulfil the consumers necessity in nutrition.

Thus, it is clear that in case of the Irrigation Scenario the gross output in 2030 may increase by 2 or 3 times than under the conditions assumed by the Dry Scenario. In this case consumer sector prices shall be lower by 5% reflecting the standard situation for agricultural markets having inelastic demand. In case production starts decreasing due to drought risks the prices shall be rising that reflects economic functions.

Now we shall analyse the welfare module and draw conclusions as to how the used scenarios affected producers, consumers income and that of the whole society in Russia.

In the course of Scenarios 1 and 2 welfare module has been used to estimate how investments into agriculture may affect the agriculture producers and consumers and the whole country's welfare. Applying the welfare module, we may provide recommendations to government agencies being able to make more informed decisions considering advantages and disadvantages for various society groups.

Welfare module includes conventional economic laws enabling to estimate the benefit from some or other investment projects both for producers and for consumers. As for demand side, consumer income is estimated in order to discover the changes in consumers surplus due to changing market conditions expressed in production and price behavior for agricultural products. Figuratively speaking, consumers surplus is shown lower than the demand curve and above the market price for each agricultural product kind. Thus, consumer surplus is estimated directly through the quantity of demand and prices (Figure 9).

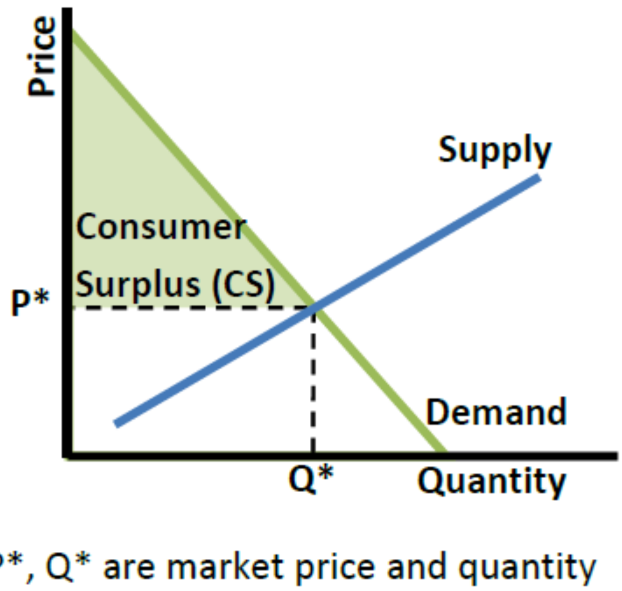


Figure 9. Consumer benefit scheme

Producer surplus is a zone above the supply curve and under the equilibrium price. However, it may not be calculated directly so it is estimated as the difference of agricultural products sales and production costs, i.e. the area below the supply curve (Figure 10).

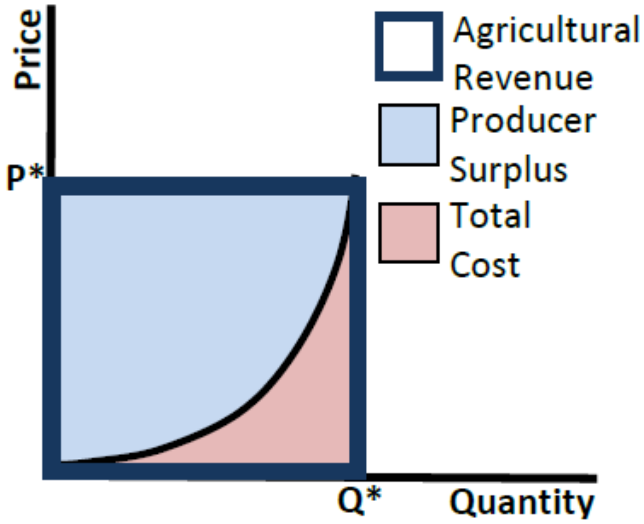


Figure 10. Producers benefit scheme

The overall welfare of society consists of combining consumer and producer surpluses in all spheres of agricultural industry. Thus, consumer and producer surpluses change from one scenario to another.

Taking into consideration the implementation parameters for Federal Target Program “Agricultural Lands Melioration Development in Russia for 2014-2020”, we assume 1 billion USD of investments into irrigation infrastructures in the studied area. The discount rate of 13% is used, corresponding to the currently prevailing rates. The estimation results indicate that the first scenario (that of irrigated areas expansion) is more profitable for agricultural producers since their profit increases by 11%, and consumer welfare due to consumer prices decrease also increases slightly by 0.4%. The agricultural producer welfare surplus doesn't influence the consumers welfare in the proportional way because, there are other factors affecting this in Russia such as long distance between the producers and consumers, which lead to high transport costs and also the oligopoly issues on the retail market. Thus, to have a full positive impact from irrigation development Russia has to improve the situation in other spheres of economy.

5. Conclusions

Expansion of irrigated agricultural lands in Russia may substantially affect the production volumes, but only slightly influence the country’s welfare. Irrigation enables not only to increase the yields and agricultural profitability, but in case applied correctly, encourages soil fertility improvements.

With the help of IMPACT-3 partial equilibrium model we have estimated and analysed the Irrigation and Dry Scenarios of agricultural development in Russia up to 2030.

The results demonstrate opportunities and challenges for the Russian agriculture. In case of the Irrigation scenario there will be shift in production from rainfed areas to irrigated areas. Under the Irrigation scenario gross output in 2030 may be higher by more than 2 times than under the Dry Scenario. In this case the consumer prices may decline by 5%. The Dry Scenario visually demonstrates global warming possible risks with wheat, rice and vegetables yields decreasing by a mean of 10% by 2030.

Rice and vegetables are deemed more sensitive to irrigation than wheat. Thus, their production in the Irrigation scenario is higher than in the Base and Dry scenarios. Wheat is more drought-resistant. Therefore, wheat production volumes in the Base Scenario exceed production volumes under the Irrigation scenario. It means that in the case of growing wheat on irrigated lands does not have an overall net positive impact on the total production volumes due to decreases in rainfed areas under wheat.

Acknowledgements. The paper was composed with financial support from the Russian Scientific Foundation, Project №14-38-00023 entitled “Land Degradation Control in the Eurasian Region”. The authors hereby express their thanks to IFPRI colleagues: Sherman Robinson, Daniel Mason-D'Croz, Shahnila Islam, who in January 2015 held an IMPACT-3 model workshop in Moscow, where the authors of the paper were trained to work with the model and evaluated the scenarios for this paper.

References

About the Course of Implementation Measures for 12 months of the 2014 provided by Federal Target Program “Agricultural Lands Melioration Development in Russia for 2014-2020”. Ministry of Agriculture of the Russian Federation. Moscow. (2015). [in Russian Language]

Balakay, G.T., 2011. Irrigation provides stable grain production. Agricultural Farming, № 5, pp. 29-31. [in Russian Language]

Balakay, G.T., Orel., VA., 2005. Watering Ways Influencing Grain Maize Growing, Development and Yield. Ways to Increase Irrigated Areas Efficiency, in Scientific Papers Collection with the Materials of the International Research and Practice Seminar “Soybean Cultivation Experience and Prospects at Russia’s Southern Irrigated Areas” December 15-16, 2005, Novocherkassk. [in Russian Language]

Bessmol'naya, E.A., 2011. Sunflower Irrigation Regime in the Povolzhye drought-ridden chernozem steppe. Synopsis of the Ph.D. Thesis. Saratov. [in Russian Language]

Boehlert, B., Strzepek, K.M., Chapra, S.C., Fant, C., Gebretsadik, Y., Lickley, M., Swanson, R., McCluskey, A., Neumann, J.E., Martinich, J., 2015. Climate Change Impacts and Greenhouse Gas Mitigation Effects on U.S. Water Quality. Journal of Advances in Modelling Earth Systems, Vol. 7, Issue 3, pp. 1326-1338.

Conant, R.T., Drijber, R.A., Haddix, M.L., Parton, W.J., Paul, E.A., Plante, A.F., Six, J., Steinweg, J.M., 2008. Sensitivity of Organic Matter Decomposition to Warming Varies With It's Quality. Global Change Biology, Volume 14, Issue 4, pp. 868–877.

Concept of Federal Target Program “Agricultural Lands Melioration Development in Russia for 2014-2020”. Ministry of Agriculture of the Russian Federation. Moscow. (2012). [in Russian Language]

Drobilko, A.D., Eletskiy, A.S., Sapronova, I.V., Drobilko, Y.A., Shevchenko, P.D., 2009. Peculiarities of Winter Wheat Cultivation after Various Preceding Crops in the course of Irrigation // Russia's Grain Farming, № 2. [in Russian Language]

Dronin, N., Kirilenko, A., 2011. Climate Change, Food Stress, and Security in Russia. Regional Environmental Change, Vol. 11, pp. 167-178.

Dronin, N., Kirilenko, A., 2013.Weathering the Soviet Countryside: the Impact of Climate and Agricultural Policies on Russian Grain Yields, 1958-2010. Soviet & Post-Soviet Review, Vol. 40, Issue 1, pp. 115-143.

Gaikalova, L.V., 2006. Land and Water Resources Rational Using in the Irrigation Farming in the Astrakhan Region. Messenger of the Astrakhan State Technical University, № 5. [in Russian Language]

Gutrits, L.S., 2005. Water and Nutrition Regime Influencing Soybean Yields. Ways to Increase the Irrigated Areas Efficiency, in Scientific Papers Collection with the Materials of the International Research and Practice Seminar “Soybean Cultivation Experience and Prospects at Russia’s Southern Irrigated Areas” December 15-16, 2005. Novocherkassk. [in Russian Language]

Jones, J., G. Hoogenboom, C. Porter, K. Boote, W. Batchelor, L. Hunt, P. Wilkens, U. Singh, A. Gijsman, and J. Ritchie, 2003. The DSSAT cropping system model. European Journal of Agronomy Volume 18, № 3-4, pp. 235-265.

Kalinichenko, V.P., Bezuglova, O.S., Solntseva, N.G., Skovpen, A.N., Chernenko V.V., Ilyina L.P., Boldyrev A.A., Shevchenko D.V., Skvortsov D.A., 2012. Negative Impact of Irrigation on Soil and Prospects and Abilities of Applying Subsurface Impulse Continual and Discreet Irrigation Paradigm. Scientific Journal of the Russian Research Institute for Melioration Problems, № 2. [in Russian Language]

Kiselev, S., Romashkin, R., Nelson, G.C., Mason-D'Croz D., Palazzo, A., 2013. Russia's Food Security and Climate Change: Looking into the Future. Economics The Open-Access, Open-Assessment E-Journal, № 39.

Kulygin, V.A., 2005. Soil Rotary Tillage at Potato Plantations during Irrigation. Ways to Increase Irrigated Areas Efficiency, in Scientific Papers Collection with the Materials of the International Research and Practice Seminar “Soybean Cultivation Experience and Prospects at Russia’s Southern Irrigated Areas” December 15-16, 2005. Novocherkassk. [in Russian Language]

Lotsari, E., Thorndycraft, V., Alho, P., 2015. Prospect and Challenges of Simulating River Channel Response to Future Climate Change. Progress in Physical Geography, Vol. 39, Issue 4, pp. 483-513.

National Program for Agricultural Development and Regulating Markets of Agricultural Products for 2013-2020., (2012). Ministry of Agriculture of the Russian Federation, Moscow. [in Russian Language]

National Report of the Implementation in 2012 of the National Program for Agricultural Development and Regulating Markets of Agricultural Products for 2008-2012., (2013). Ministry of Agriculture of the Russian Federation, Moscow. [in Russian Language]

Nevenchannaya, N.M., 2011. Irrigation Influencing the Moisture Distribution in the Profile of Meadow Chernozem Soil. Young Russia: Advanced Technologies shall be Implemented into Industry, № 5, pp. 234 – 237. [in Russian Language]

Nikolaeva S.A., Blynskaya I.V., Voznesenskaya E.A., Rozhdestvenskaya S.O., Rozov S.Y., 1995. Soils Tolerance Theory Development in the Steppe Zone in the Course of Irrigation. Scientific Report under Grant No. № 95-04-11864-a provided by the RFFI. [in Russian Language]

Okada, M., Iizumi, T., Sakurai, G., Hanasaki, N., Sakai, T., Okamoto, K., Yokozawa, M., 2015. Journal of Advances in Modeling Earth Systems, Vol. 7, Issue 3, pp. 1409-1424.

Ovchinnikov, A.S., Gavrilov A.M., 2010. Increasing Irrigation Farming Efficiency in Drought Conditions in the Russian South-East . News of the Nizhnevolzhskiy Agricultural University, No. 2. [in Russian Language]

Pan, T., Wu, S., Liu, Y., 2015. Relative Contributions of Land Use and Climate Change to Water Supply Variations over Yellow River Source Area in Tibetan Plateau during the Past Three Decades. PLoS ONE, Vol. 10, Issue 4, pp. 1-19.

Prikhod'ko, V.E., Manakhova, E.V., Manakhov, D.V., Bezuglova, O.S., Sokolova, T.A., 1999. Irrigated Areas: Functioning, Degradation, Monitoring. Scientific Report under Grant No. 97-05-65437-a provided by the RFFI. [in Russian Language]

Prikhod'ko, V.V., 1994. Irrigated Areas: Functioning, Productivity, Ecology. Scientific Report under Grant No. 94-05-17518-a provided by the RFFI. [in Russian Language]

Projecting Global Climate Changes and Risks in the Russian Agricultural Industry. Multi-authored Monograph edited by I.B. Uskov, V.P. Yakushev. RASHN, Moscow. (2009). – Page 518. [in Russian Language]

Report on the Status and Use of Agricultural Lands prepared by the Russian Ministry of Agriculture for 2013. (2014). Ministry of Agriculture of the Russian Federation, Moscow. [in Russian Language]

Resolution N 922 adopted by the Government of the Russian Federation on October 12, 2013 (amended on January 15, 2015) “About Federal Target Program “Agricultural Lands Melioration Development in Russia for 2014-2020”. – 2013. [in Russian Language]

Rosegrant, M.W., M. Agcaoili-Sombilla, and N.D. Perez., 1995. Global Food Projections to 2020: Implications for Investment. Discussion Paper, № 5. Washington, D.C.: International Food Policy Research Institute.

Rosegrant, M.W., 2012. International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) Model Description. IFPRI. Washington, DC. http://www.ifpri.org/sites/default/files/publications/impactwater2012.pdf. (accessed 11.06.2015)

Schierhorn, F., Faramarzi, M., Prishchepov, A., Koch, F., Muller, D., 2014. Quantifying yield gaps in wheat production in Russia. Environmental Research Letters, №9.

Shchedrin, V.N., 2012. Irrigation Problems and Prospects in the Rostov Region. Scientific Papers Collection/ Forest and Water Industry Melioration Role in the Agricultural Sector Development, Zernograd. pp. 567-579. [in Russian Language]

Shchedrin, V.N., 2005. Southern Federal District Irrigated Lands Effective Use Problems (by the example of the Rostov Region). Ways to Raise the Irrigated Lands Efficiency, in Scientific Papers Collection with the Materials of the International Research and Practice Seminar “Soybean Cultivation Experience and Prospects at Russia’s Southern Irrigated Areas” December 15-16, 2005, Novocherkassk. [in Russian Language]

Schmitz, C., van Meijl, H., Kyle, P., Nelson, G.C., Fujimori, S., Gurgel, A., Havlik, P., Heyhoe, E., Mason D'Croz, D., Popp, A., Sands, R., Tabeau, R., van der Mensbrugghe, D., von Lampe, M., Wise, M., Blanc, E., Hasegawa, T., Kavallari, A., Valin, H., 2014. Land-Use Change Trajectories Up to 2050: Insights from a Global Agro-economic Model Comparison. Agricultural Economics, Vol. 45, Issue 1, pp. 69-84.

Scientific Basis for Soil (Lands) Degradation Preventing in Russian Agricultural Lands and their Fertility Reproducing Systems Forming in the Adaptive and Landscape Specific Agriculture. Volume 1-3. Dokuchaev's Soil Institute. (2013) – 1465 p. [in Russian Language]

Shuravilin A.V., Starikov V.Z., Skorikov V.T., 2007. Principal Cultivation and Irrigation Methods Influencing Soils Agrophysical Properties and Winter Wheat Productivity in the Povolzhie. Messenger of the Peoples’ Friendship University of Russia, № 4, pp. 35- 39. [in Russian Language]

Shchedrin V.N., Balakay G.T., 2014. Current Situation and Prospects in Melioration Areas in the Russian South. Scientific Journal of the Russian Research Institute for Melioration Problems, № 3(15), pp. 1-15. [in Russian Language]

Skrylnikova, N., Lozhnikova, A., Muravyov, I., Kirpotin, S., Ozheredov, Y., 2014. Forecasting the Local and Global Socio-Economic Impact of Climate Change in the Boreal and Arctic Regions of Siberia. International Journal of Environmental Studies, Vol. 71, Issue 5, pp. 774-778.

Smith, P., Smith, J., Franko, U., Kuka, K., Romanenkov, V., Shvetsova, L., Wattenbach., M., Gottschalk, P., Sirotenko, O., Rukhovich, D., Koroleva, P., Romanenko, I., Lisovoi, N., 2007. Changes in mineral soil organic carbon stocks in the croplands of European Russia and the Ukraine, 1990–2070; comparison of three models and implications for climate mitigation. Regional Environmental Change, Vol. 7, Issue 2, pp. 105-119.

Tang, J., Riley, W., 2015.Weaker Soil-Carbon Feedbacks Resulting from Microbial and Abiotic Interactions. Nature Climate Change, №5, pp. 56–60.

Thompson, D., Barnes E., Deser, C., Foust, W., Phillips, A., 2015. Quantifying the Role of Internal Climate Variability in Future Climate Trends. Journal of Climate, Vol. 28, Issue 16, pp. 6443-6456.

Ummenhofer, C.C., Xu, H., Twine, T.E., Girvetz, E.H., McCarthy, H.R., Chhetri, N., Nicholas, K.A., 2015. How Climate Change Affects Extremes in Maize and Wheat Yield in Two Cropping Regions. Journal of Climate, Vol. 28, Issue 12, pp. 4653-4687.

Yakovenko E.A., 2006. Sugar Beet Irrigation Rational Regime Development. Polythematic Network Electronic Journal of the Kuban State Agricultural University, № 21. [in Russian Language]

You, L., and Wood, S., 2006. An entropy approach to spatial disaggregation of agricultural production. Agricultural Systems 90, № 1-3, pp. 329-347.

Valkov, V.F., Kolesnikov, S.I., Kazeev, K.S., 2008. Climatic and Soil Changes in the Russian South. News from Higher Education Institutions, in Natural Sciences Series, № 6, pp. 88-92. [in Russian Language]

Vaneyan, S.S., Menshikh, A.M., 2012. Irrigation Development for Vegetable and Melons in Various Russian Soil and Climate Zones. Scientific Papers Collection in Vegetables and Melons Growing for the 80th Anniversary, Russian Academy of Agricultural Science. [in Russian Language]

Zhaparkulova, E.D., 2014. Soils Fertility Increasing in Case of Irrigation. Science Way, № 10. [in Russian Language]

Zhu, T., Ringler, C. and Rosegrant, M., 2012. Development and Testing of a Global Hydrological Model for Integrated Assessment Modelling, International Food Policy Research Institute, Washington, DC.

A methodology for a preliminary risk assessment of slope instability along coastal cliffs

Paulo Sá Caetano[1], Carlos Costa[2], João Brissos[1], Marco Rocha[3], Graça Brito[1], Pedro Lamas[1], Daniel Vendas[2]

[1] GeoBioTech, Faculdade Ciências Tecnologia, Universidade Nova de Lisboa, 2829-516 Caparica, Portugal, pcsc@fct.unl.pt; jncbrissos@gmail.com; mgb@fct.unl.pt; pcl@fct.unl.pt

[2] eGiamb-Consultoria Geoambiental, Lda, 2825-159 Caparica, Portugal, carlos.costa@egiamb.pt; daniel.vendas@egiamb.pt

[3] Faculdade Ciências Tecnologia, Universidade Nova de Lisboa, 2829-516 Caparica, Portugal, marcopsrocha@gmail.com

Abstract

It is generally acknowledged that climate change will increase slope instability along coastal cliffs through sea-level rise and changes in wave conditions. However the interacting system at a local or site level may introduce considerable complexity in the response to the above mentioned constraints. A two phased methodology for a preliminary assessment of the risk associated to the occurrence of rock falls and landslides along coastal cliffs is proposed. In the first phase, work should encompass a surveying of potential risk areas resorting to desk studies as well as field campaigns directed to visual inspection of the geological, geotechnical geomorphological characteristics of the cliffs. This approach consists, therefore, of a semi-quantitative risk assessment that aims to produce a simple and rapid prioritization of the identified risks by applying a numerical categorization to the terms of the following equation allowing the determination of a preliminary “Risk Index” (RI): RI=(HPO*HM*PD)/RC; in which, HPO corresponds to the “Hazard probability of occurrence”; HM, to the “Hazard magnitude”; PD, to the “Potential damage”; and RC to the “Response capacity”. PD/RC corresponds to the vulnerability of the affected area. Each term of this equation is categorized in a 1 to 5 scale (low to high) which, according to the equation, generates the RI values corresponding to the preliminary risk index associated to the occurrence of mass movements. The matrix of the RI values for all possible outcomes varies between a minimum of 0.2 and a maximum of 125, yet these values are recalculated to a [0;1] interval in order to allow an easier understanding of their significance. The obtained matrix is then categorized in to five equal amplitude classes corresponding to non-significant, low, medium, high or very high slope instability risk. In the second phase of this methodology, resources should be centred on the most unfavourable cliffs by promoting a detailed assessment of the geomechanical behaviour of the outcropping rock masses, namely by joint properties characterization, Schmidt Hammer field trials and sampling for laboratory characterization. The collected data is used for slope stability kinematic analysis, resulting in a geomechanical zonation of the cliff faces. The “Risk Index” can then be re-evaluated and used in the implementation of an adequate monitoring and/or mitigation plan. The proposed methodology has been successfully applied to the SW coast of Portugal and is intended to help, along with other instruments for climate change impact evaluation, in shoreline management and cliff-top land use planning.

Keywords: Risk assessment, climate change, coastal erosion, slope stability, rocky cliffs, Portugal

Urban Resilience to the Impacts of Climate Change in Relation to Sustainable Development - Structuring the Problem Based on VFT Methodology

Luiz Priori Jr[1], Marcelo Hazin Alencar[2], Adiel Teixeira de Almeida[3]

[1] Universidade Federal de Pernambuco, luizpriori@gmail.com

[2,3] Universidade Federal de Pernambuco, marcelohazin@gmail.com almeidaatd@gmail.com

Abstract

This article outlines a study being carried out in the Management Engineering Department of the Federal University of Pernambuco (UFPE). It focuses on the effects of global climate change on urban sustainable development and the subsequent need to raise the level of the resilience of cities in terms of their natural and constructed environments so as to reduce the risk of urban disasters. As a consequence of their population concentrations, cities are the locations where the occurrence of disasters often causes the most damage. Moreover, losses associated with natural disasters can have impacts which go beyond the economic dimension, and when the damages affect the social and environmental dimensions it becomes more difficult to measure them solely on a monetary basis. Therefore, it is important to include climate change issues in the planning and management of sustainable urban environments, especially since the forecasts point to a growing urbanization of the undeveloped world's population. This paper presents a framework for analysing the resilience of the urban infrastructure to the potential impacts of climate change. It is based on Value-Focused Thinking (VFT) methodology, particularly with regard to five key elements that make up the urban infrastructure, namely: energy, sanitation, waste, transport and the set of buildings. By developing a framework to assist in decision-making, and basing it on seeking to ensure that the resources available are coherently implemented, this study contributes to improving sustainable urban development. To illustrate how to analyze this type of problem, the proposed framework was applied in the city of Recife, the capital of the Brazilian state of Pernambuco. The VFT methodology makes the decision-making process more consistent and effective since it generates alternatives which decrease vulnerability and augment urban resilience to the risks from disasters, thereby contributing to urban planning policy. A baseline study helped to deepen understanding of urban vulnerability in relation to resilience to the impacts of climate change. This was achieved by exploratory research through direct observation, which aimed to identify (in situ) and document aspects that corroborate any increase in vulnerabilities in the infrastructure of the city's neighborhoods. The data collected in the exploratory research were analyzed by experts in urban systems, amongst whom were members of UFPE research staff and highly experienced public and/or private sector professionals. These consultants also responded to a semi-structured questionnaire formulated to stimulate and create ideas, and thereby to generate alternatives. The relevance of this study lies in the possibility of applying it to any urban agglomeration which experiences problems related to extreme hydrological events. Although urban resilience is specific to the environments of each individual city, cities have enough characteristics in common to permit this methodology to be applied to any city.

Keywords: climate change; sustainability; urban resilience; VFT methodology

1. Introduction

Climate change is a risk to people in all countries, though it is a particularly serious risk to the poorest countries because of the high-speed growth of their populations (UNEP, 2012). Therefore, several authors (Beatley, 2009; Cramer and Karabell, 2010; Friedman, 2008; Sachs, 2008) discuss the growth of the world's population and its associated impacts, such as increased urbanization. They forecast that by the year 2050, 70% of the world's population will live in urban environments.

Moreover, this increase will occur mainly in less-developed regions of the planet.

According to the Brazilian Panel on Climate Change – PBMC – Brazil is likely to be at least 3°C warmer by the end of the 21st century and, furthermore, the precipitation index may increase by 30% in some regions of Brazil and diminish by 40% in others (PBMC, 2013). The northeast region of Brazil, Pernambuco in particular, due to the irregularity in the distribution and the high interannual variability of rainfall, is notably vulnerable to the occurrence of extreme hydrological events, like drought and storms. Northeastern Brazil has an average cumulative rainfall which can vary from less than 500 mm/year to more than 2,000 mm/year, which makes the region vulnerable to floods in the rainiest years as was highlighted in 1964, 1967, 1974, 1985, 1986, 1988, 1989, 1994, 2004, 2009 and 2010. (Lacerda et al., 2010, Nobre et al., 2013).

The City of Recife (Figure 1) has an area of 210 km², which corresponds to only 0.2% of the territory of the State of Pernambuco. However, according to the latest population census, the city had 1,537.704 inhabitants (IBGE, 2015) spread over 94 districts and around four million people in its metropolitan area, the latter amounting to 45% of the population of the State of Pernambuco. As a result of the large volumes of surface water from heavy and/or prolonged rains, together with the erosion of hill-sides and embankments, the city is very often at risk of flooding. These risk factors are likely to increase with climate change (Priori Jr., 2013).

Figure 1. View of the sea-front in Boa Viagem, Recife

Source: Authors' files

It is important to stress that Recife's infrastructure systems are highly vulnerable to disasters. However, these systems are of vital significance for emergency response and for the quick recovery of activity in the community and its economy (Procyk, 2010a; Procyk, 2010b; Yu, 2010). Therefore, the planning of sanitation, energy and transportation systems must be able to forecast potential failures. These can then be reduced by conducting redundancy planning and having back-up measures in place, thus diminishing the vulnerability of built structures in a way that is least harmful to society (World Bank, 2013).

Moreover, major urban infrastructure systems, such as electric power, transportation, in addition to being vulnerable, are also interdependent. Hence, city planners need to consider possible sources of multiple disasters, methods for detecting and correcting system failures, and the cascading interdependencies among these systems, as well as the many potential alternative procedures that could diminish failure risk within and across all systems (Chang et al., 2014).

2. Impacts of Climate Change and Sustainable Development

Sustainability cannot be seen only as a condition or state of the socio-ecological system on the planet Earth that ensures the continued existence of Homo sapiens on Earth. It must also be understood as Sustainable Development: the attempt of humans to continue to improve the welfare and quality of life for most people on the planet, thereby preventing the extinction of the human species - a result of humans' inability to live within the limits of the planetary ecosystem or to adapt to its changing conditions (Du Plessis, 2009).

Moreover, hundreds of millions of urban dwellers in middle-income countries are at risk of suffering direct and/or indirect impacts from climate change. As the number of people living in cities and towns has grown - more than half the world's population now lives in urban areas - the number of urban residents vulnerable to climate change has also increased (Bartlett et al., 2012), not just by the fact of urban areas containing more people but especially because the infrastructure needed to cope with large additional numbers of people has not kept pace with this growth and/or has been inappropriately sited and thus increased probability of the additional infrastructure being a further source of climate change or located in areas more likely to suffer severely from natural disasters.

Urban areas have unique characteristics that make their residents active and particularly vulnerable to climate change. A large number of major urban centers are located along the coast or in low-lying areas around the estuaries of major rivers, thus putting economic capital and the population at greater risk to climate-related changes, including from rising sea levels and flooding resulting from severe rainfall. Furthermore, the construction of urban spaces on floodplains reduces the flow of waterways by reducing the river channels and accentuates the problem of how and where excess water can accumulate on floodplains. When not solved, this causes even worse damage (Gasper et al., 2011; Tingsanchali, 2012).

Recent literature illustrates the socioeconomic challenges faced by cities around the world as a result of climate change (Beatley, 2009; Gasper et al., 2011). These include there being more power shortages, more damage to infrastructure, industries suffering greater losses because of excess heat, mortality rates increasing as is the spread of diseases, and there being a greater lack of food and water. These challenges are interrelated. Economic losses make it difficult for residents to maintain their livelihoods and may therefore exacerbate social problems such as abject poverty and hunger. At the same time, some demographic and socioeconomic characteristics of cities may make them more vulnerable to the impacts of climate change.

Numerous weather events may be potentially related to global climate change (Baetley, 2009; Baker, 2012; Gasper, 2011; IPCC, 2012; Molion, 2012; Pilkey and Young, 2009; Ribeiro, 2008; Satterthwaite, 2007), but in this study, the authors only considered those that may occur in the coastal cities of the northeast of Brazil. These include the rise in temperature and in outbreaks of heavy rainfall, and the effects of these on the urban environment.

The increase in the intensity and frequency of extreme hydrological events will more frequently expose urban areas to the risk of flooding caused by heavy and prolonged rains. Buildings, roads, infrastructure, and other impervious surfaces prevent rainwater from seeping into the soil, thus reducing natural drainage and increasing the flow of water, and overwhelming urban drainage systems (Satterthwaite, 2007). In addition to flooding, as the rain becomes more concentrated, the volume of water will gather more speed and thus more power to create channels and transport sediment, which will accelerate the erosion of hill-slides and slopes (Priori Jr., 2013).

Hundreds of millions of urban dwellers in middle-income countries are at risk of suffering direct and/or indirect impacts from climate change. At the same time, several geographic and socioeconomic characteristics of cities may make them more vulnerable to the impacts of climate change. (ARUP, 2011; Bartlett et al., 2012; Barbieri, 2011; Beatley, 2009; Gasper et al., 2011; Lomborg, 2007; Molion, 2012; Wilde and Coley, 2012). For example, the location of low-lying coastal cities, such as Recife, makes drainage difficult without pumping. Moreover, high tides and/or storms can hinder water draining into the sea and cause prolonged flooding, with floodwater sometimes being polluted. This can aggravate urban public health problems. The effects of climate change may well increase the occurrence and frequency of heavier rains, which can make when, where and how to cope with floods less predictable (Tingsanchali, 2012).

Another consequence of climate change will be the increasing frequency of high intensity rainfall. The explanation for this is the high surface temperature of a metropolis, which increases global warming, due to large numbers of vehicles radiating the heat produced by their engines and also due to the cooling systems of buildings emitting warm air which exits from their interiors into the environment. As a result, masses of cold air rush are expulsed with more intensity at certain points, which results in intense local disturbances such: flooding of roads, severe traffic congestion, loss of housing for low-income people, damage to property and, in the severest of cases, deaths, especially but by no means limited to the very old and very young. Residents in areas that come to be seen as at risk usually have no alternative but to occupy the banks of rivers or steep hill-sides which end up slipping due to the soil becoming saturated with intense rainwater and/or run-off.

Besides the flooding problem, another risk factor which is likely to become more severe as a result of climate change is the erosion of slopes and hill-sides. As the rains become more intense in some regions, the run-off will gain in velocity and power and thus gouge out both deeper and new channels. These will carry the resulting sediment downstream, which will cause and/or accelerate erosion. Erosion can endanger homes, or worse, amid a heavy downpour, wash away what is on the surface, including people and their homes. In addition, more intense erosion adds to the siltation of bodies of water, which increases the possibility of valley bottoms becoming flooded.

3. The Resilience of Urban Infrastructure

Resilience is “the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a potentially hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions” (IPCC, 2012:34).

Resilience is inversely related to vulnerability; that is, more resilience equals less vulnerability in communities which potentially are at risk from a disaster. Vulnerability is “the propensity or predisposition to be adversely affected”. This encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt”. Resilience is the capacity of systems to cope with a hazardous event or disturbance, and being able to reorganize them in ways that maintain their essential function and structure, while maintaining their capacity for adaptation and transformation (IPCC, 2014:5).

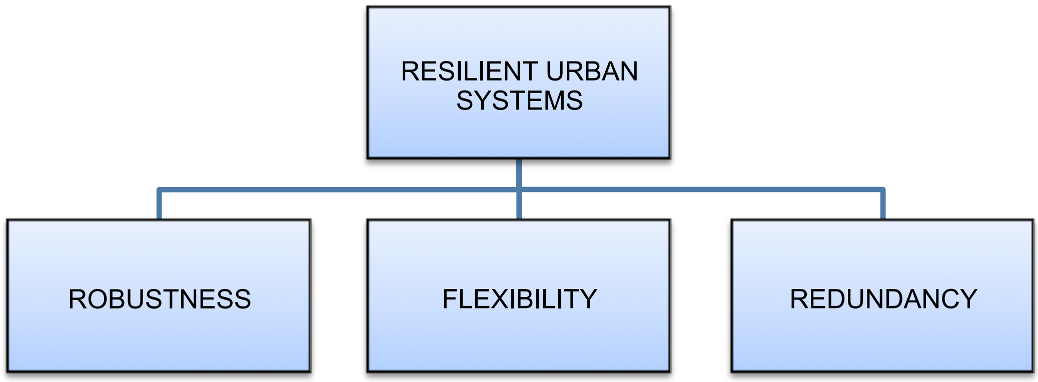
So, resilience is shaped by vulnerability, which in turn incorporates the capacity to adapt (Adger and Vincent, 2005; Adger et al., 2005a; Adger et al., 2005b; Birkmann, 2006; Brooksa, 2005; Confort et al., 2012; Gallopín, 2006; Pelling, 2011; Smit and Wandel, 2006; Walker and Salt, 2006). The term "resilience" can be applied to cities, as they must respond to crises and adapt to hazards. Cities require strong physical structures and a sturdy built environment (Newman et al., 2009).

Resilient cities are built to be strong and flexible rather than brittle and fragile (Godschalk, 2003). Infrastructural resilience sets up an inverse relationship. It reduces the vulnerability of a constructed environment, namely one composed of buildings and physical systems; for example, a city (which must provide mobility, energy, sanitation, etc.). This also relates to a city´s capacity to furnish shelter, to make roads available for evacuation, and for transporting supplies post-disaster (UNISDR, 2012; World Bank, 2012).

An important characteristic of resilient systems is that they can be flexible and adaptable in the event of disturbances, whether or not these are familiar (Figure 2) (Walker and Salt, 2006). Uncertainty requires preparation and additional redundancy in disaster planning. A resilient effort requires appropriate redundancy and flexibility so as to be able to continue to provide basic needs for outstanding risks and future uncertainties (Vale and Campanella, 2005). Thus, in the event of a disaster, it can respond appropriately to cascading failures and/or punctual failures.

The complexity of urban infrastructure increases exponentially as the area expands in population and density. Moreover, the need for redundancy and flexibility increases with the size and complexity of an urban area. For example, when it increases in size, the available transportation system quickly reaches its saturation limit and is no longer able to meet the basic needs of the community.

Figure 2. Characteristics of resilient urban systems



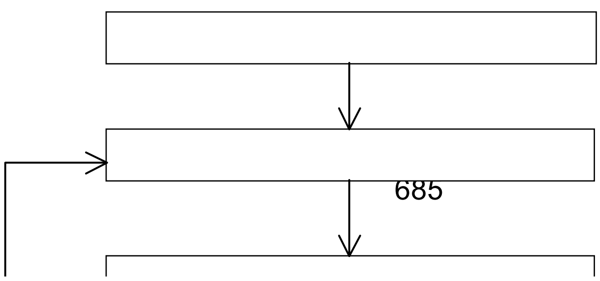
Source: The authors

The central problem of resiliency is that buildings and infrastructure cannot be adapted to being able to mitigate the impacts of disasters arising from reasonably predictable risks if the infrastructural systems are not there. Moreover, the risks to the inhabitants of poorer areas are very often aggravated by limited access to basic infrastructure and public services in the areas in which they live. Therefore, adapting the existing infrastructure and its systems to the probable risks of climate change is more likely to be successful only in prosperous and well-governed cities (Baker, 2012; PROVIA, 2013; Satterhwaite et al., 2007).

4. The VFT Methodology

This research study aims to identify and document aspects that correspond to increased urban vulnerability and compare them with the effects of climate change (Figure 3), particularly with regard to five of the key elements that make up urban infrastructure, namely: energy, sanitation, waste, transport and the set of buildings (Priori Jr., 2014). The data were analysed and discussed with experts in urban infrastructure systems. The results were structured according to Value-Focused Thinking (VFT) methodology (Keeney, 1992), with the goal of generating alternatives for improving urban city systems and contribute to making the decision-making process more consistent.

Figure 3. How the Research Study was developed



VFT

Source: The authors

Through the VFT methodology, the information gleaned from experts in urban systems – university research staff and highly experienced public and private sector professionals – during interviews, were re-arranged so as to simplify, aggregate and quantify the alternatives in order to highlight their significance. The methodological objective was to seek solutions in a creative way and not be limited to alternatives that were already known, as the first alternative that comes to mind is often similar to those already used (Alencar et al., 2011).

VFT has been applied in a wide range of contexts in order to identify decision-makers' objectives, including in areas such as the military sector, mobile technology, tourist management, terrorists' objectives, environmental aspects, and telecommunications management (Alencar et al., 2011; Hassan, 2004; Kajanus et al., 2004; Keeney, 2001; Keeney and McDaniels, 2001; Keeney and Winterfeldt, 2010; León, 1999; Merrick and Garcia, 2004; Merrick and Grabowski, 2014; Morais et al., 2013; Sheng et al., 2005; Yooa, 2001).

The VFT method is based on values, which must be the driving force for this process because they are fundamental to everyday decisions (Keeney, 1996). Furthermore, the adoption of values improves the decision-making process. Three aspects characterize the objectives: 1) the decision context, 2) an object, and 3) a preference direction (de Almeida et al., 2015).

To begin applying VFT methodology, it is important to provide a decision-making structure, which consists of the subject's context and fundamental objectives. The context of the problem defines the set of alternatives suitable for consideration in a specific situation, and the alternatives are the means by which the fundamental value is found. It is important to remember that the core of any decision is the desire to avoid adverse effects and bring about desirable ones (Keeney, 1992).

Within the context of the issue under study, strategic decisions must be identified from the set of all possible alternatives. Thus, the fundamental objectives are explicitly values, and they define the class of consequences. Therefore, it is important to identify the structures, to analyse them, and to deeply understand them. Using this approach, experts in urban systems were interviewed on the subject under study. First, they answered a semi-structured questionnaire formulated to stimulate the creation of ideas. Next, they analysed each of the urban infrastructure systems in order to generate alternatives.

5. Results and Discussion

The VFT methodology begins by defining the strategic objective, then it identifies the fundamental and means objectives, and constructs a hierarchy of fundamental objectives and a network of means-ends objectives. This is intended to elucidate the relationships among all of the objectives (Morais et al., 2013). The main difference between a strategic objective and a fundamental objective is that a strategic objective can be influenced by factors outside this decision frame and a fundamental objective cannot (Merrick and Grabowski, 2014).

A fundamental objective is not a means to an end, but it is the end objective for a specific decision frame. Therefore, the terms means 'finality' while a 'strategy' relates to an objective within a decision frame. However, a means objective for one scenario may be a fundamental one for another decision frame. Equally, an objective may be fundamental to one decision frame and strategic to another one.

The first step was to define the strategic objective: "Alternatives for improving the urban infrastructure resilience to possible impacts from hydrological extreme events in the city of Recife". After defining the strategic objective, the second step was to identify the fundamental objectives of the research. For this purpose, the urban infrastructure was broken down into five key urban systems: energy, sanitation, waste, transport and the set of buildings. These were analysed by evaluating their level of robustness, flexibility and redundancy, in the event of their suffering an extreme hydrological event. Thus, the fundamental objectives, which are designed to meet the strategic research problem, were defined to evaluate the elements of urban infrastructure by assessing the resilience capacity of their components (Table 1).

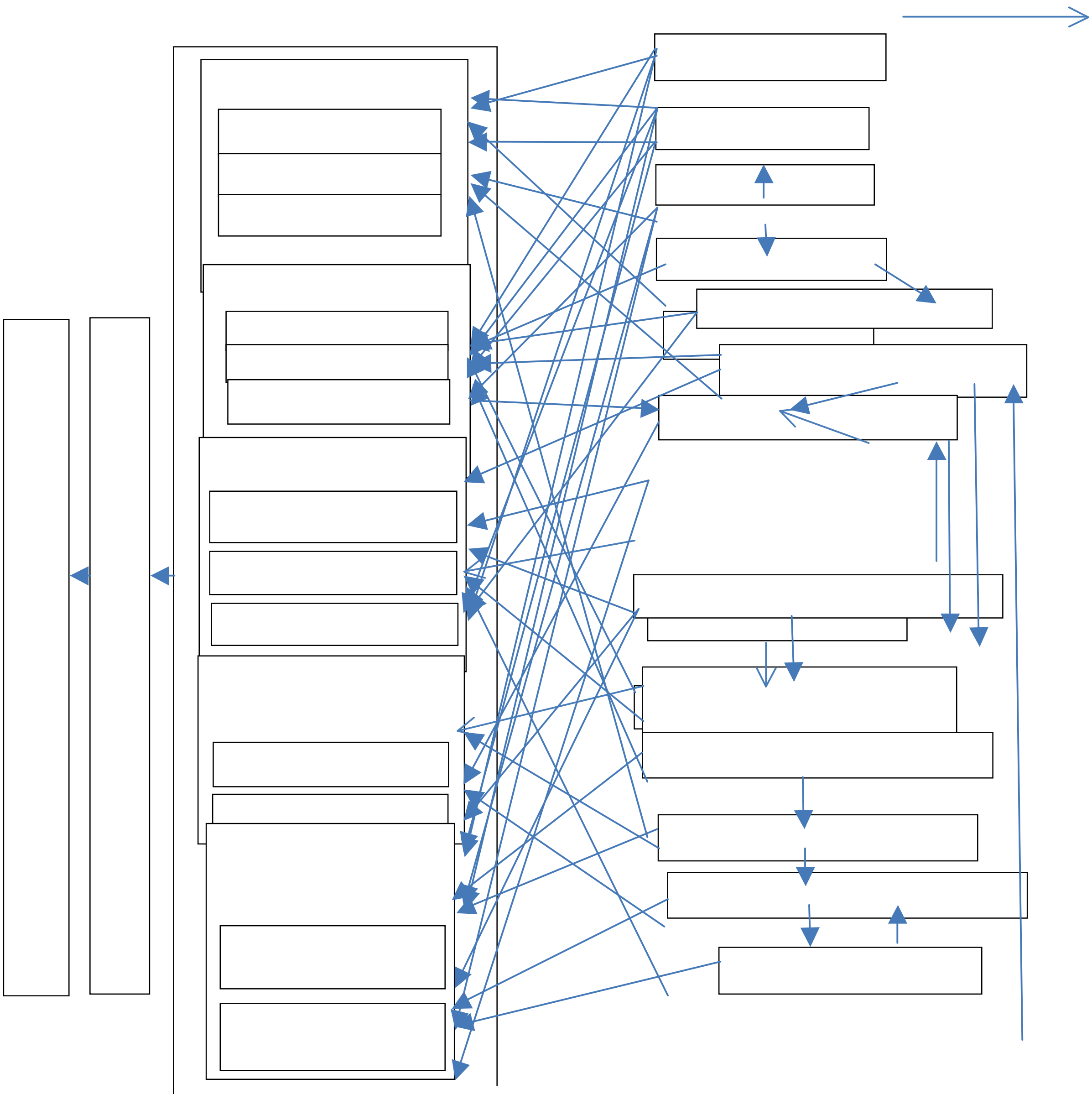
Table 1. Hierarchy of fundamental objectives

Alternatives for improving urban infrastructure resilience to possible impacts from extreme hydrological events in the city of Recife (strategic objective).
1. Analyse the robustness, flexibility and redundancy of the physical structure for power transmission and generation in the city of Recife in relation to:
1.1 The transmission capacity of electrical power systems 1.2 The gas-powered thermal power generation systems 1.3 The photovoltaic power generation systems
2. Analyse the robustness, flexibility and redundancy of the structure of the sanitation systems in the city of Recife in relation to:
2.1 The distribution and treatment of potable water systems 2.2 The distribution and treatment of domestic sewage systems 2.3 The macro drainage systems 3.4 The micro drainage systems
3. Analyse the robustness, flexibility and redundancy of the municipal waste management structure in the city of Recife in relation to:
3.1 The management of organic waste 3.2 The management of recyclable waste 3.3 The management of construction and demolition waste
4. Analyse the robustness, flexibility and redundancy of the structure and capacity of the transport network in the city of Recife in relation to:
4.1 The transportation systems 4.2 The means of transport
5. Analyse the robustness of the structure of the set of buildings and shelters available to house people in case of disaster in the city of Recife in relation to:
5.1 The physical structure of the buildings 5.2 The level of accommodation available

Source: The authors

It is important to distinguish between "fundamental objectives" and "means objectives". Fundamental objectives concern the ends that decision-makers value in a specific decision context, while means objectives are the methods to achieve these ends. It is important to bear in mind that ends and means are context dependent. Means objectives can suggest alternatives that will achieve fundamental objectives. As a third step, the network of means-ends objectives was set, experts were interviewed, and methods through which the attributes should be achieved were determined (Figure 4).

Figure 4. Network of means-end objectives



5.1 Attribute

The achieve ective is measured in terms of an attribute. Therefore, the structure co attributes that provided the decision-maker with a general idea of the p permitted him/her to emphasize higher value alternatives (Keeney, 20

Based on di e network of means-ends objectives was determined, and the attributes ves were generated, as described in Table 2.

Table 2. Attributes of the fundamental objectives

Number	Description
1	**ROBUSTNESS, FLEXIBILITY AND REDUNDANCY OF THE POWER GENERATION AND TRANSMISSION SYSTEM**
1.1	**The electrical power systems**
1.1.1	Percentage of the properties legally connected to power network

1.1.2	Percentage of households with electricity in subnormal agglomerates
1.1.3	Percentage of the area of the city supplied by street lighting
1.1.4	Percentage of the network that is underground
1.1.5	Percentage of isolated electrical conductors
1.1.6	Percentage of defaulted consumers
1.2	**The thermal power generation system that uses gas as fuel**
1.2.1	Percentage of households served by gas network
1.2.2	Percentage of the network that is underground
1.3	**The photovoltaic power generation systems**
1.3.1	Percentage of properties generating electricity by photovoltaic panels
1.3.2	Percentage of public lighting generated by photovoltaics
2	**ROBUSTNESS, FLEXIBILITY AND REDUNDANCY OF THE SANITATION SYSTEM STRUCTURE**
2.1	**Distribution and treatment of potable water**
2.1.1	Percentage of population served by potable water
2.1.3	Percentage of transmission losses in the pipelines
2.2	**Distribution and treatment of domestic sewage**
2.2.1	Percentage of households served by the sewage network
2.2.2	Percentage of households that throw sewage directly into waterways
2.2.3	Percentage of sewage treated
2.2.4	Percentage of households with septic tanks
2.2.5	Percentage of households with rudimentary drains and ditches
2.3	**Macro drainage system**
2.3.1	Percentage of the city area served by the macro drainage network
2.3.2	Percentage of population living in areas subject to flooding
2.3.3	Percentage of channels that are potentially navigable
2.4	**Micro drainage system**
2.4.1	Percentage of the city area covered by the micro drainage network
2.4.2	Percentage of the city area suffering flooding
3	**ROBUSTNESS, FLEXIBILITY AND REDUNDANCY OF THE MUNICIPAL WASTE MANAGEMENT STRUCTURE**
3.1	**The management of organic waste**
3.1.1	Percentage of households with regular garbage collection services
3.1.2	Percentage of households with no accumulated garbage in nearby parks
3.1.3	Percentage of households' regular garbage that is sent to landfills
3.2	**The management of recyclable waste**
3.2.1	Percentage of the solid waste that is recycled
3.3	**The management of construction and demolition (C&D) waste**
3.3.1	Percentage of C&D waste that is recycled

3.3.2	Percentage of C&D waste that is deposited at appropriate locations
4	**ROBUSTNESS, FLEXIBILITY AND REDUNDANCY OF THE SYSTEMS AND MEANS OF TRANSPORT**
4.1	**The transportation systems**
4.1.1	Percentage of households located in paved streets
4.1.2	Percentage of roads with exclusive lanes for buses
4.1.3	Percentage of properties with sidewalks considered legally adequate
4.1.4	Percentage of roads with bike lanes
4.1.5	Percentage of waterways that are navigable
4.1.6	Growth of the death rate from traffic accidents in the last decade
4.2	**The transportation means**
4.2.1	Percentage of the population that owns a car
4.2.2	Percentage of population transport serviced by bus
4.2.3	Percentage of bus fleet with accessibility for the disabled
4.2.4	Percentage of bus fleet that can be electronically monitored by firefighters
4.2.5	Percentage of buses in urban fleet
4.2.6	Percentage of population that is served by the subway
4.2.7	Percentage of the population that is served by Light Rail Transport (LRT)
4.2.8	Percentage of Bus Rapid Transport (BRT) lanes in the urban network
4.2.9	Percentage of population that has a motorcycle
5	**ROBUSTNESS OF THE BUILDINGS STRUCTURE AND REDUNDANCY OF THE SHELTERS AVAILABILITY TO HOUSE PEOPLE IN CASE OF DISASTER**
5.1	**The physical structure of the buildings**
5.1.1	Percentage of buildings with resistant masonry on 3-4 floors and at potential high risk from collapse
5.1.2	Percentage of buildings with masonry walls
5.1.3	Percentage of inhabitants in subnormal agglomerates
5.1.4	Percentage of buildings located in barrier fall risk sectors
5.1.5	Percentage of risk sectors classified as being at a high and/or very high risk of collapse
5.1.6	Percentage of risk sectors classified as being at a high and/or very high risk of flooding
5.2	**The level of accommodation available**
5.2.1	Percentage of residents in risk areas that can be housed in the case of extreme weather
5.2.2	Percentage of residents in risk areas that can be sheltered in the case of extreme weather

Source: The authors

5.2 Creating Alternatives

The VFT methodology was used to understand the problem and to induce creative thinking by stimulating the creation of alternatives as a starting point for understanding decision opportunities.

Therefore, the following alternatives – to improve the infrastructure systems and the city's resilience to possible impacts from extreme hydrological events – were developed by exploring the objectives identified after applying VFT methodology (Table 3).

Table 3. Alternatives to improve the infrastructure systems and the city's resilience

•	ENERGY
o	Improve the physical structure of the street light poles.
o	Improve the security conditions of the power grid by isolating overhead cables and conductors, as well as underground pipe lines.
o	Create an incentive program for families in substandard clusters to standardize their connections to the power grid.
o	Improve monitoring with the objective of reducing the number of households connected irregularly to the network, which overloads the system.
o	Invest more in alternative energy sources that can be generated within the city, such as photovoltaic and thermal gas.
•	SANITATION
o	Promote the expansion of the water and sewer network to adapt it to the needs of the city's growing population.
o	Implement a regular maintenance program for the water networks, thus reducing water waste.
o	Investigate and repair the numerous points of leakage in sewer lines which pollute the streets.
o	Implement a maintenance plan for the regular cleaning of the urban drainage and street galleries.
o	Adapt the city's canals so that they are navigable by public transportation and for evacuation purposes.
•	WASTE
o	Supervise and prohibit the disposal of industrial waste and domestic sewage in the rivers that run through the city.
o	Implement a plan for urban cleansing to deal with the amount of trash on public roads and sidewalks.
o	Prohibit the use of plastic bags for disposal of household waste on the sidewalks.
o	Implement a program to encourage the recycling of solid waste.
o	Encourage the reuse of demolition and construction waste.
•	TRANSPORT
o	Expand and diversify the transport systems to attend to the needs of the growing population.
o	Encourage the population to walk by implementing an urgent plan for the maintenance and restoration of the sidewalks.
o	Supervise and organize parking lots, not permitting vehicles to park everywhere, which will encourage the population to use public transportation.
o	Invest in partnerships with the private sector to expand the metro and to implement other mobility models such as BRT and LRT.
o	Apply charges for private cars that circulate in certain areas of the city, thereby encouraging the use of public transport.
•	BUILDINGS
o	Encourage, through the exemption of municipal taxes, the restoration and maintenance of buildings at risk of collapse.
o	Create a plan for restoring historic buildings, in partnership with the private sector.
o	Supervise the demolition of irregular buildings, which makes it difficult for civil defence forces to respond in emergency situations.
o	Update the municipal plan for land use and occupation.
o	Investigate and adjust to meet real needs the number and distribution of dwellings and shelters to accommodate at-risk populations.

Source: The authors

6. Conclusions

Sustainable development can be influenced by the impacts of climate change, which can increase the vulnerability of urban populations to disasters. Extreme hydrological phenomena, such as increases in heavy rain, and can expose Brazilian cities to situations of serious risk such as floods and landslides, which impacts urban infrastructure systems. This can leave their inhabitants vulnerable to disasters, which converge over three main areas: damage to urban settlements, failures in sanitation systems and electricity supply, and urban mobility.

It was observed throughout the exploratory survey conducted in Recife that urban vulnerabilities include electrical poles and wires, urban drainage problems, losses from the water distribution network, lack of maintenance of the sewage collection network, and the irregular collection of municipal waste.

The inadequate mobility of vehicles and pedestrians and the lack of maintenance of sidewalks are also important urban weaknesses. Irregular buildings occupying the roads were also found in all districts. Thus, it is possible to generalize the vulnerability of urban infrastructure systems for the entire city of Recife and say that the city is not prepared to face the impacts of potential climate change.

When the experts' ideas, opinions, and proposals were being analysed, the VFT methodology was fundamental in structuring the problem and enabled the decision-making context to be better evaluated. Moreover, the VFT method enables concepts to be clarified and hidden objectives to be identified, thereby creating new problem-solving alternatives. As a result, attributes have been defined to measure the fundamental objectives. The decision opportunities and the aspects that served as input for the development of alternatives were also identified.

Even though it was specifically applied to the infrastructure of the city of Recife, and the results are limited to the situation investigated, the methodology used here can be used to structure analogous problems in other cities. To analyse and structure other problems, the point of view already known should be set aside and all stakeholders must be involved in finding a solution for the problem being considered.

Future studies should consider the application of MCDM (Multi-Criteria Decision Making) approaches as a way of selecting and prioritizing the relevant alternatives with regard to improving the resilience of the urban infrastructure to extreme hydrological events. The probabilistic context can be considered by applying MAUT (Multi-Attribute Utility Theory), taking into account the decision-maker's preferences and considering different losses resulting from the consequences of each dimension under study.

Acknowledgements

This study was partially sponsored by the Brazilian Research Council (CNPq) and the Brazilian Coordination Unit for Higher Education Personnel (CAPES) for which the authors are most grateful. The authors also gratefully acknowledge the valuable suggestions made by the experts who collaborated with this research study.

References

Adger, W. N., Vincent, K., 2005. Uncertainty in adaptive capacity. C. R. Geosci. 337, 399-410.

Adger, W. N., Arnell, N. W., Tompkins, E. L., 2005a. Adapting to climate change: perspectives across scales. Global Environ. Chang. 15, 75-76.

Adger, W. N., Arnella, N. W., Tompkinsa, E. L., 2005b. Successful adaptation to climate change across scales. *Global Environ. Chang.* 15, 77-86.

Alencar, L. H., Mota, C. M. M., Alencar, M. H., 2011. The problem of disposing of plaster waste from building sites: Problem structuring based on value focus thinking methodology. Waste Manage. 31, 2512-2521.

ARUP C40 Baseline Report, 2011. Climate Action in Megacities: 40 cities Baseline and Opportunities. Version 1.0.

http://www.arup.com/Homepage_Cities_Climate_Change.aspx

Baker, J. L. (ed), 2012. Climate change, disaster risk, and the urban poor – cities building resilience for a changing world. The International Bank for Reconstruction and Development / The World Bank. Washington DC.

Barbieri, A. F., 2011. Mudanças climáticas, mobilidade populacional e cenários de vulnerabilidade para o Brasil. *Rev. Inter. Mob. Hum.*, Brasília, XIX, 36, 95-112.

Bartlett, S., Dodman, D., Hardoy, J., Satterthwaite, D., Tacoli, C., 2012. Social aspects of climate change in urban areas in low and middle income nations. International Institute for Environment and Development (IIED). *The World Bank*, Washington DC.

Beatley, T., 2009. Planning for coastal resilience: Best practices for calamitous times. Washington, DC: Island Press.

Birkmann, J. (ed), 2006. Measuring vulnerability to natural hazards – towards disaster resilient societies. Tokyo: United Nations University Press.

Brooksa, N., Adgera, W. N., Kellyc, P. M., 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environ. Chang.* 15, 151-163.

Chang, S., McDaniels, T., Fox, J., Dhariwal, R., Longstaff, H., 2014. Toward disaster-resilient cities: Characterizing resilience of infrastructure systems with expert judgments. *Risk Anal.* Vol 34, # 3.

Confort, L. K., Boin, A., Demchak, C. C. (Eds), 2012. Designing resilience preparing for extreme events. Pittisburg: University of Pittisburg Press.

Cramer, A., Karabell, Z., 2010. Sustainable excellence: the future of business in a fast-changing world. New York: Rodale.

de Almeida, A. T., Cavalcante, C. A. V., Alencar, M. H., Ferreira, R. J. P., Almeida-Filho, A. T., Garcez T. V., 2015. Multicriteria and multiobjective models for risk, reliability and maintenance decision analysis. Int. Ser. Oper. Res. Man. Vol 231. New York: Springer.

Du Plessis, C., 2009. An approach to studying urban sustainability from within an ecological worldview. PhD Thesis. University of Salford, UK.

Friedman, T. L., 2008. Hot, flat and Crowded: why we need a green revolution and how it can renew America. New York: Farrar, Straus and Giroux.

Gallopín, G. C., 2006. Linkages between vulnerability, resilience, and adaptive capacity. Global Environ. Chang. 16, 293-303.

Gasper, R., Blohm, A., Ruth, M., 2011. Social and economic impacts of climate change on the urban environment. Curr. Opin. Environ. Sustainability 3, 150-157.

Godschalk, D. R., 2003. Urban Hazard mitigation: creating resilient cities. Nat. Harzard. Rev., August, 136-143.

Hassan, O., 2004. Application of value-focused thinking on the environmental selection of wall structures. J. Environ. Manage. 70, 181-187.

IBGE – Brazilian Institute of Geography and Statistics. (2015) Censo 2010. http://cidades.ibge.gov.br/xtras/perfil.php?lang=&codmun=261160&search=pernambuco|recife,

IPCC – INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE. 2012. Managing the risks of extreme events and disasters to advance climate change adaptation. http://www.ipcc.ch/pdf/special-reports/srex/SREX_Full_Report.pdf

IPCC – INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE. 2014. Managing the risks of extreme events and disasters to advance climate change adaptation. http://www.ipcc.ch/pdf/special-reports/srex/SREX_Full_Report.pdf

Kajanus, M., Kangasb, J., Kurttilac, M. 2004. The use of value focused thinking and the A'WOT hybrid method in tourism management. Tourism Management 25, 499-506.

Keeney, G. L., Winterfeldt, D. V., 2010. Identifying and structuring the objectives of terrorists. *Risk Anal.* 30(12), 1803-1816.

Keeney, R. L., 2007. Developing objectives and attributes, in advances in decision analysis. Edwards, W, Miles, R F, and von Winterfeldt, D (eds). Cambridge University Press, 104-128.

Keeney, R. L., McDaniels, T. L., 2001. A framework to guide thinking and analysis regarding climate change policies. Risk Anal. 21(6), 989-1000.

Keeney, R. L., 2001. Modeling Values for Telecommunications Management. IEEE T. Eng. Manage. 48(3), 370-379.

Keeney, R. L., 1996. Value-focused thinking: identifying decision opportunities and creating alternatives. Eur. J. Oper. *Res.* 92, 537-549.

Keeny, R. L., 1992. Value-focused thinking: a path to creative decision making. Cambridge, Massachusetts: Harvard University Press.

Lacerda, F. F., Silva Júnior, H. D. da, Assad, E. D., Assis, J. M. O., Moura, M. S. B., 2010. Extremos e variabilidade climática no Nordeste brasileiro e em Pernambuco. In Galvíncio, J. D. Mudanças climáticas e impactos ambientais. Ed. Universitária da UFPE, pp. 1–23. Recife.

León, O. G., 1999. Value-focused thinking versus alternative-focused thinking: Effects on generation of objectives. Organ. Behav. Hum. Dec. Vol 80, # 3, 213–227.

Lomborg, B., 2007. Perspectives on climate change. Copenhagen: Consensos Center.

Merrick, J. R. W., Grabowski, M., 2014. Decision Performance and safety performance: A value-focused thinking study in the oil industry. Decision Analysis. Published online in Articles in Advance, March, 1-1219. http://dx.doi.org/10.1287/deca.2014.0291

Merrick, J. R. W., Garcia, M. W., 2004. Using value-focused thinking to improve watersheds. J. Am. Plann. Assoc. 70(3), 313-327.

Molion, L. C. B., 2012. Considerações sobre o aquecimento global antropogênico. Instituto de Ciências Atmosféricas, Universidade Federal de Alagoas. October 2. http://www.luisbuarque.com.br/wp-content/files_mf/1340202776SiteArtigoLuizCarlosMolion2.pdf

Morais, D. C., Alencar, L. H., Costa, A. P. C. S., Keeney, R. L., 2013. Using value-focused thinking in Brazil. Pesquisa Operacional 33(1), 73-88.

Newman, P., Beatley, T., Boyer, H., 2009. Resilient cities – responding to peak oil and climate change. Washington: Island Press.

Nobre, P., Siqueira, L. S. P., Almeida, R. A. F. de, Malagutti, M., Giarolla, E., Castelão, G. P., Bottino, M. J., Kubota, P., Figueroa, S. N., Costa,M. C., Baptista JR., M., Irber JR., L., Marcondes, G. G., 2013. Climate simulation and change in the Brazilian Climate Model. J. Climate, n. 26, pp. 6716-6732. DOI: 10.1175/JCLI-D-12-00580.1.

Pilkey, O. H., Young, R., 2009. The rising sea. Washington, DC: Island Press.

Pelling, M., 2011. Adaptation to climate change. London: Routledge.

PBMC – The Brazilian Panel on Climate Change, 2013. Contribuição do Grupo de Trabalho 1 ao Primeiro Relatório de Avaliação Nacional do Painel Brasileiro de Mudanças Climáticas. Sumário Executivo GT1. Rio de Janeiro.

Priori Jr., L., 2013. The possible impacts of climate change in the city of Recife, Brazil. IAPS -

International Association People – Environment Studies Symposium 2013. In Mira, R G and Dumitru, A (Eds), Book of Proceedings. La Coruña.

Priori Jr., L. 2014. Resiliência urbana de cidades costeiras: um recurso para enfrentar as mudanças climáticas. Research Report. Recife: CAPES/PNPD/UFPE.

Procyk, A., 2010a. Creating Alternatives for Improving Infrastructure

Interdependency Resilience. Analyzing Infrastructures for Disaster-Resilient Communities. Practioner report #3. The University of British Columbia. http://www.chs.ubc.ca/dprc_koa/pdf_files/PR_No3_Creating%20Alternatives.pdf

Procyk, A., 2010b. Setting Priorities for Improving Infrastructure Interdependency

Resilience. Analyzing Infrastructures for Disaster-Resilient Communities, Practioner report #4. The University of British Columbia. http://www.chs.ubc.ca/dprc_koa/pdf_files/PR_No4_Setting%20Priorities.pdf

PROVIA – The Global Programme of Research on Climate Change Vulnerability, Impacts and Adaptation (2013) PROVIA Guidance on Assessing Vulnerability, Impacts and Adaptation to Climate Change. Consultation document, United Nations Environment Programme, Nairobi, Kenya, 198pp.

Ribeiro, W. C., 2008. Impactos das mudanças climáticas em cidades no Brasil. Parcerias Estratégicas, # 27, 297-321. Brasília.

Sachs, J., 2008. Common wealth – economics for a crowded planet. London: Penguin books.

Satterhwaite, D., Huq, S., Reid, H., Pelling, M., Lnkao, P. R., 2007. Adapting to Climate Change in Urban Areas – The possibilities and constraints in low and middle income nations. International Institute for Environment and Development. www.iied.org/pubs/display.php?o=10549IIED

Satterthwaite, D., 2007. Climate change and urbanization: effects and implications for urban governance. United Nations Expert Group Meeting on Population Distribution, Urbanization, Internal Migration and Development. New York.

Sheng, H., Nah, F. F., Siau, K., 2005. Strategic implications of mobile technology – A case study using Value-Focused Thinking. J. Strategic. Inf. Syst. 14, 269-290.

Smit, B., Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. Global Environ. Chang. 16, 282-292.

Tingsanchali, T., 2012. Urban flood disaster management. Procedia Engineering 32, 25-37.

UNEP – United Nations Secretary-General's High-level Panel on Global Sustainability, 2012. Resilient People, Resilient Planet: A future worth choosing. United Nations. New York.

UNISRD – United Nations International Strategy for Disaster Reduction, 2012. How to make cities more resilient. A contribution to the global campaign 2010 – 2015.

Vale, L. J., Campanella, T. J., 2005. The resilient city – how modern cities recover from disaster. Oxford: Oxford University Press.

Yooa, S. H., Kimb, J. S., Kimc, T. Y., 2001. Value-focused thinking about strategic management of radio spectrum for mobile communications in Korea. Telecommun. Policy 25, 703-718.

Yu, A., 2010. Infrastructure disruptions and interdependencies during floods events. Infrastructures for Disaster-Resilient Communities. Practioner report #5. The University of British Columbia. http://www.chs.ubc.ca/dprc_koa/pdf_files/PR_No5_Flood%20Events.pdf

Walker, B., Salt, D., 2006. Resilience thinking – Sustaining ecosystems and people in a changing world. Washington: Island Press.

Wilde, P., Coley, D., 2012. The implications of a changing climate for buildings. *Build. Environ.* 55, 1-7.

World Bank, 2012. Building Urban Resilience: Principles, Tools and Practice. International Bank for Reconstruction and Development / The World Bank, Washington DC.

_______. 2013. Turn down the heat: Climate extremes, regional impacts, and the case for resilience. International Bank for Reconstruction and Development / The World Bank, Washington DC.

Assessing High School Student Perceptions and Comprehension of Climate Change

Ulisses Azeiteiro 1,2, Paula Bacelar-Nicolau 1,2, Paulo Santos 3, Leonor Bacelar-Nicolau 4, Fernando Morgado5

1 Departamento de Ciências e Tecnologia, Universidade Aberta, Portugal

2 Centre for Functional Ecology, Universidade de Coimbra, Portugal

3 Faculdade de Ciências, Universidade do Porto, Portugal

4 Institute of Preventive Medicine and Public Health & ISAMB, Faculdade de Medicina, Universidade de Lisboa, Portugal

5 Departamento de Biologia, Universidade de Aveiro, Portugal

Abstract

The purpose of this study was to investigate High Scholl (HS) students' perceptions of Climate Change (CC) and Global warming (GW). This work was conducted within Portuguese High Scholl students and the results in this context should have meaningful implications for national CC policies in the future as well as HS curricula adaptation to the students' perceptions. Research was conducted at a high school in Central Portugal. The survey was applied to all the high school students from the 10th to the 12th grade, enrolled in the areas of Sciences and Technology, Languages and Humanities, Socio-economical Sciences and Professionalization. The data were collected through a self-completion questionnaire consisting of 29 closed-ended questions and two open questions aiming at characterizing students from the socio-demographic, and from their perceptions, beliefs, motivations, attitudes, knowledge relating to the topic of CC. Google Drive was used to host the questionnaire and allow for the online survey. Statistical exploratory univariate and bivariate analyses were performed on the data collected (frequencies, total and column percentages, adjusted residuals). All statistical tests were two-tailed, with significance levels of 5%. Only statistically significant results were commented on the results section. Majority of students believed that CC was happening and also perceived that human activities were an important cause of CC. Still, the surveyed students hold some misconceptions about basic causes and consequences of climate change. Students' gender influenced their perceptions of time scale of CC impact on both human and biotic communities. Most students state that their training had focused enough on the topic of CC and felt they had a moderate technical knowledge about the topic of CC (students' knowledge of how their behaviour influenced CC followed a similar pattern). There was a large conviction that the main actions in mitigating CC effects should be taken by governments and regarding the perception of the importance of CC for their future professional carrier, 48 % considered that this topic was "moderately important" and 29 % considered it as "very important". However as individuals, and globally, 74 % had not taken actions to mitigate CC (only 26% of the respondents had taken some actions to mitigate the causes of CC). Further research is necessary so that curricula programs can be adequate to promote better knowledge and attitudes about climate change and an active engagement of future participative citizens, as part of the solution for climate change problems.

Keywords: Climate change, High School students, Curriculum, Knowledge, Attitudes and behaviours

GestAqua.AdaPT – Climate change adaptation in the management strategy of reservoirs in Alentejo

Paulo A. Diogo (1), Pedro F. Beça(2), António C. Rodrigues (3), Rafael Lino (4), João P. Nunes(5), João Rocha (6), Cláudia C. Santos (7), Carlo Aal (8) Deborah Davies(9)

1 - MARE & DCEA-FCT-UNL, Faculdade de Ciências e Tecnologia, 2829-516 Caparica, pad@fct.unl.pt
2 - CENSE & DCEA-FCT-UNL, Faculdade de Ciências e Tecnologia, 2829-516 Caparica, pmfb@fct.unl.pt
3 - MARE & DCEA-FCT-UNL, Faculdade de Ciências e Tecnologia, 2829-516 Caparica, acr@fct.unl.pt
4- MARE, Faculdade de Ciências e Tecnologia, 2829-516 Caparica, rafaelcasanovalino@gmail.com
5 - CESAM & Dept. Environment and Planning, University of Aveiro, Portugal; jpcn@ua.pt
6 - CESAM & Departamento. de Ambiente e Planeamento, Universidade de Aveiro, Portugal; joaocrocha@ua.pt
7 - CESAM & Departamento. de Ambiente e Planeamento, Universidade de Aveiro, Portugal; c.carvalho.santos@ua.pt
8 - Vestlandforsking, Norway; caa@vestforsk.no
9 - Vestlandforsking, Norway; ded@vestforsk.no

Abstract

According to the Climate Change (CC) scenarios currently defined by the IPCC, the Mediterranean region is one of the potentially most affected by the increase in average annual temperature as well as changes in precipitation regimes. These changes are likely to lead to an increase in the frequency and intensity of extreme hydrological events, which may result in reduced water runoff and increased soil erosion. These factors are real risks to the availability and quality of water resources, evidencing the importance of implementing adaptation strategies to ensure the sustainability of the resource. The GestAqua.AdaPT project aims to develop and implement adaptation strategies to CC in the water sector, particularly for the management of multipurpose reservoir systems. The case study comprises two reservoirs - Monte Novo and Vigia - both used as urban supply and irrigation water sources in the central Alentejo region. The choice for these two systems is justified by its multipurpose feature, regional relevance (urban supply for the city of Évora) and current sustainability status already facing water scarcity issues. The methodology used in the project is based on the sequential application of a hydrological model and a hydrodynamic and water quality model, based on results from climate models. This modeling approach is used for the quantification of water availability and quality in the reservoirs for the period up to the year 2100. The project is still ongoing; thus far preliminary results from climate and hydrological modeling, evidence that there is an annual trend of increase on average temperature, a decrease in annual precipitation, as well as a decrease in water runoff to the basin. Implementing the described methodology will allow a detailed characterization of water hydrodynamics, availability and quality in face of CC scenarios, hence the definition of adaptation strategies for both reservoir watersheds, including procedures for reservoir operation and agricultural management. These comprise the definition and implementation of reservoir operation curve rules, assessment of structural solutions for the water transfer from other reservoirs and alternative agricultural practices focused on water resources sustainability. GestAqua.AdaPT is intended to provide a significant contribution to improve knowledge and water management routines, through a better understanding of the impacts of climate change on the quality and availability of water resources, with emphasis on the effects of extreme phenomena such as droughts and floods. The study area is also representative of multi-purpose water supply systems, thus the methods and obtained results may be transferred to similar systems, improving the development of adaptation strategies in the water sector in general. These factors establish valid contributions to a more sustainable use of water, through better planning and management of water resources in situations of scarcity, as well as the development of emergency response plans.

Keywords: Climate change, adaptation, modelling, water management

1. Introduction

According to the climate change scenarios predicted for the Mediterranean region, it is expected along the XXI century for temperatures to rise and precipitation to decrease (Giorgi, 2006). Even with the variability and uncertainty among the possible scenarios, this combination of impacts might increase climate aridity and water resources may decrease in availability (Nunes et al., 2008), expanding the pressure over the existing resources, degrading water quality and possibly creating conflicts regarding its use (Alcamo, et al., 2003). These facts constitute effective risks to the availability, accessibility and quality of water resources, thus the importance of implementing adaptation measures for its management.

Evaluating the impacts of climate change in available water resources is a complex task that requires an approach that foresees multiple aspects of the problem: climate change, socioeconomic aspects, hydrology, water balances and water uses. Water quality is an equally important matter since the increasing temporal variability of precipitation may lead to more erosion, solid material transport and a higher nutrient affluence to the waterbodies, potentiating its degradation. Temperature may as well have an important role regarding water quality, conditioning stratification periods in water bodies and determining the most favorable conditions for primary production, hence potentiate eutrophication in waterbodies.

In this context, Xu and Singh (2004) propose the sequential use of climate and eco-hydrological models, resorting to climate downscaling techniques to adjust the scales between both modelling approaches. Nunes *et al.* (2013) and Grosso *et al.* (2014) integrate a water balance in these methods, adding a hydrodynamic and water quality model applied to reservoirs in order to estimate water availability for its multiple uses and evaluate its potential impacts in water quality.

The impacts of climate change in availability and water resources management represent one of the most relevant challenges of present times, particularly in the south of Portugal, under Mediterranean climate and where water quality and quantity problems are already a reality. In this context, the ongoing project GestAqua.AdaPT is aimed at developing and implementing climate change adaptation strategies in the water resources sector, namely in the management of multi-purpose reservoir systems. The study case, the reservoirs of Monte Novo and Vigia, in Alentejo, are both urban supply water sources for supply withdrawal the central Alentejo region, as well as water source for irrigation of agricultural areas with considerable regional importance.

GestAqua.AdaPT is financed by the EEA Grants and the Portuguese Carbon Fund, and is build upon a partnership between Portuguese and Norwegian research institutions, as well as Águas de Portugal (AdP), one of the main water stakeholders in Portugal, thus including multiple aspects associated with water use and management in both reservoirs. The ongoing study also foresees an evaluation of the water transfers to the Monte Novo and Vigia system from the Alqueva reservoir, considering the quantitative and qualitative aspects of the transfer, as well as energy related issues. The adaptation strategies that are under development will include operation rule curves for each reservoir, adjusted according to estimated climate risks of the region, as well as to the total water needs and having in perspective sustainability of the available resource and optimization of the operation for the whole system. In the present paper, along with the methodologies adopted, partial project results obtained so far are also presented, namely in the evaluation of climate models and calibration of hydrological and water quality models for both reservoirs.

2. Study Area

The case study of GestAqua.AdaPT comprises the reservoirs of Monte Novo and Vigia, and its respective watersheds (Figure 1). These reservoirs are water sources for the municipalities of Évora, Reguengos de Monsaraz, Redondo and Mourão. Besides the water supply for human consumption, both reservoirs are also a source of water for irrigation in areas located both inside and outside of the drainage basins of both reservoirs.

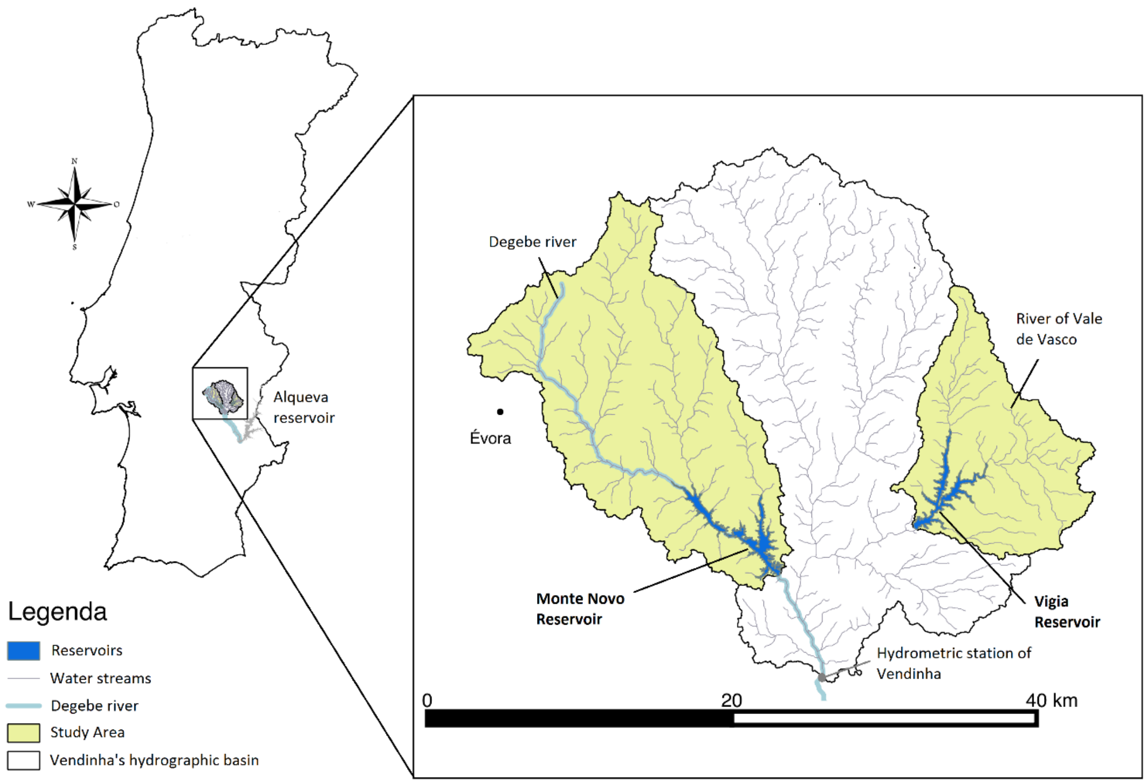


Figure 1 – Study area: hydrographic basins of Monte Novo and Vigia.

The Monte Novo reservoir was built in 1982 with the main goal to provide water to the city of Évora. The amount of collected water has been growing according to the increase of supplied number of households. Vigia's reservoir dates from 1986, providing mostly water for irrigation but also for human consumption, although the latter in fewer amounts compared to Monte Novo.

Both the reservoirs have significant water quality problems associated with advanced eutrophication processes (Ferreira *et al.*, 2009; Diogo, 2012), which at times have been limiting the water uses, especially concerning human consumption. Nevertheless, the water treatment plants for both Vigia and Monte Novo have managed to respond adequately in most of the times, due to a careful operation and adequate control of the most problematic pollutants in waterbodies, like solids, phosphorous and nitrogen.

In the more recent years the availability of water in the Monte Novo reservoir has been a concern, mostly with the increase of total water withdrawal. As a solution for the risk of water scarcity, a water transfer system was built to supply water from the Alqueva reservoir that proved to be essential to overcome the periods of extreme droughts that have taken place during the year 2012 and in the final months of 2015. The Vigia reservoir also has a more recent transfer system from the Alqueva reservoir, in operation since 2015.

The soil in both hydrographic basins is essentially occupied by agriculture, being reduced the number of point sources of pollution. Hence diffuse pollution is of great importance in the inflows to the two reservoirs, being the essential cause of most of the observed water quality problems in both waterbodies (Diogo, 2012).

3. Methods

3.1. General description

The methods implemented in GestAqua.AdaPT have been defined with the objective of addressing the specific problems of the two waterbodies, but also considering its suitability and reproducibility to other water systems. The main goal is to identify and determine adaptation measures for the management of the two reservoirs through a description of the risks associated with water uses and the definition of operation curve rules, in a way that ensures the sustainability of water resources. During the development of the project the water quality of both reservoirs will be monitored and, in a future phase, strategies for reduced irrigation needs will be evaluated facing climate change scenarios.

The GestAqua.AdaPT methods are based in the sequential implementation of simulation models, having a starting point in a climate simulation obtained by the combination between global and regional climate models (GCM and RCM). After an analysis of the obtained climate simulation results for the period between 1971 and 2005 resorting to 10 conjugations of different climate models, the identified sets of simulations until 2100 to be considered in the project were chosen to implement the hydrological and water quality models. The results obtained from the hydrological model SWAT – Soil and Water Assessment Tool (Neitsch *et al*., 2005) were used to define the water balances in both reservoirs, which are afterwards used in the hydrodynamic and water quality modeling using the CE-Qual-W2 (Cole e Wells, 2015).

3.2. Climate scenarios definition

Defining climate scenarios involved a cooperative analysis for simulation results obtained through the program EURO-CORDEX (Jacob *et al.* 2014), which coordinates a large set of climate modelling groups to create a consistent simulation in European territory with a horizontal resolution up to 12 km. Climate simulations from the combination of global models (GCM) used to force different regional models (RCM) in the same horizontal grid. In this context, two IPCC global warming scenarios were considered: RCP 4.5 and RCP 8.5, integrated from a control simulation correspondent to the climate between 1971-2000. Climate simulation results consist of daily values for 9 points of a grid defined so that it is possible to categorize the whole study area.

The obtained results were subjected to evaluation for the selection of the most adequate models, based on the analysis of rainfall and temperature for the entire control period, with daily description, comparing them to observed data in each basin. Considering that all results from climate simulation are asynchronous, this evaluation was made with aggregated values (30 years, decades or monthly mean values).

3.3. Hydrological modelling

The hydrological modelling component was defined to characterize future affluences do the reservoirs, not only quantitatively but also qualitatively. For that effect was implemented the model SWAT (Neitsch *et al*., 2005), an eco-hydrological model for river basins capable of simulating vegetable growth, water balances, soil loss and nutrient cycle responses to climate change, atmospheric CO_2 concentration, farming practices and residual water discharges. SWAT is one of the most utilized models in the world and has been used to simulate the impacts on climate change in Portugal (Nunes *et al*., 2008, 2011; Nunes e Seixas, 2011, Nunes *et al*., 2012, Grosso *et al*., 2014). In this project it will be used to simulate surface runoff, nutrient affluences from diffuse sources, solids transport thus characterizing the affluences to both reservoirs.

SWAT was implemented for both drainage basins according to reservoir branches configuration, allowing the discriminated calculations according to relevant sub-basins. This spatial conjugation is determinant for the integration of both models, granting the quantification of affluences to the waterbodies and respecting the correct hydrodynamics of the system. Results from simulations were obtained in a daily scale but analysis was performed on a monthly scale, being the latter more adequate for the study of long periods of time like the ones considered in the present study.

Model calibration was made by comparing the obtained results from SWAT with reservoir inflows estimated from a reservoir water balance model as no gauging stations upstream of the waterbodies are available. The same goes for water quality data, and SWAT calibration was based on monthly nutrient loads estimates from water quality models and observed concentrations in the waterbodies. SWAT results for nitrogen could not be effectively calibrated due to its complex cycle and potential atmospheric contribution, making reverse modeling ineffective.

3.4. Hydrodynamic and water quality modelling

For hydrodynamic and water quality simulation for Monte Novo and Vigia the model CE-Qual-W2 (Cole & Wells, 2015) was used. It's a bi-dimensional, laterally averaged model that is adequate to narrow and deep waterbodies where lateral variations aren't so important. Its implementation is based on a conceptual representation of the system that works like a grid divided in longitudinal segments and vertical layers of variable size that can be managed to adapt to the necessary resolution. It is a very flexible model allowing the simulation of multiple types of hydraulic structures, withdrawals, outlets, inflows and outflows with different depths, locations and geometric characteristics.

CE-Qual-W2 has the capability to determine water levels, vertical and horizontal velocities and temperature in the calculations of the system's hydrodynamics due to its effect on water density (Cole e Wells, 2015). For each one of the reservoirs the conceptual representation was made to secure a correct hydrodynamic representation of reality, considering two branches in Monte Novo (rivers Degebe and Bencafete) and three branches in Vigia (Rivers Vale do Vasco, Casa Branca and Vale Figueira (Figure 2).

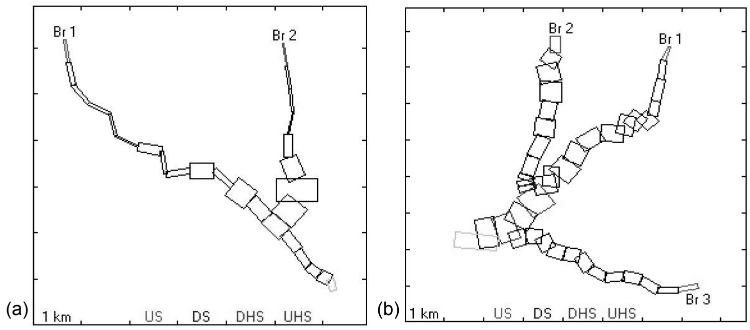


Figure 2 – Longitudinal segments for the bathymetric representation of Monte Novo (a) and Vigia (b) reservoirs.

Model calibration for each reservoir was done for the period between 1994 and 2005, taking into account that for past years there wasn't any data available regarding water quality. The entire data was gathered from SNIRH, from hydrometric and water quality stations for both reservoirs. Calibration was based on a monthly water balance, mostly because there isn't data with better temporal resolution. The obtained water balance was used for calibration of monthly surface runoffs calculated by the model SWAT for the same period (1995-2005).

4. Results and Discussion

4.1. Climate scenarios

The analysis of climate scenarios was based in the comparison between climate simulation results for 10 combinations of GCM and RCM models (Table 1). Results were gathered for the control scenarios of 1971-2000 and up until 2100, with daily data for the following variables: rainfall, mean temperature, maximum temperature, relative mean humidity and wind direction and speed.

Facing the great variability of results for the considered climate variables and between the many considered series, it was decided to choose two sets of results that showed the best rainfall representation for the control period. This option must be kept in mind during the analysis of hydrological simulation results since temperature has influence in a vast array of variables like evapotranspiration.

Table 1 – Considered climate models from EUROI-CORDEX.

Institution	Model	Forcing Model
Climate Limited-area Modelling Community	CCLM4-8-17	ERAINT
		MPI-M-MPI-ESM-LR
		ICHEC-EC-EARTH
		CNRM-CERFACS-CNRM-CM5
Danish Meteorological Institute	HIRHAM5	ERAINT
		ICHEC-EC-EARTH
Hungarian Meteorological Service	ALADIN52	ERAINT
		CNRM-CERFACS-CNRM-CM5
Instituto Dom Luiz	WRFV350D	ERAINT
		IDL-EC-Earth
Institut Pierre Simon Laplace and Institut National de l Environnement industriel et des RISques	WRF331F	ERAINT
		IPSL-IPSL-CM5A-MR
Koninklijk Nederlands Meteorologisch Instituut	RACMO22E	ERAINT
		ICHEC-EC-EARTH
Swedish Meteorological and Hydrological Institute	RCA4	ERAINT
		CNRM-CERFACS-CNRM-CM5
		ICHEC-EC-EARTH
		IPSL-IPSL-CM5A-MR
		MOHC-HadGEM2-ES
		MPI-M-MPI-ESM-LR
		CCCma-CanESM2
		CSIRO-QCCCE-CSIRO-Mk3-6-0
		MIROC-MIROC5
		NCC-NorESM1-M
		NOAA-GFDL-GFDL-ESM2M

It was considered that rainfall would be the main parameter to consider taking into account the objective of quantifying future water resources, having been chosen the models RCA4 - Swedish Meteorological and Hydrological Institute and RACMO22E - Koninklijk Nederlands Meteorologisch Instituut, both forced by GCM EC-Earth.

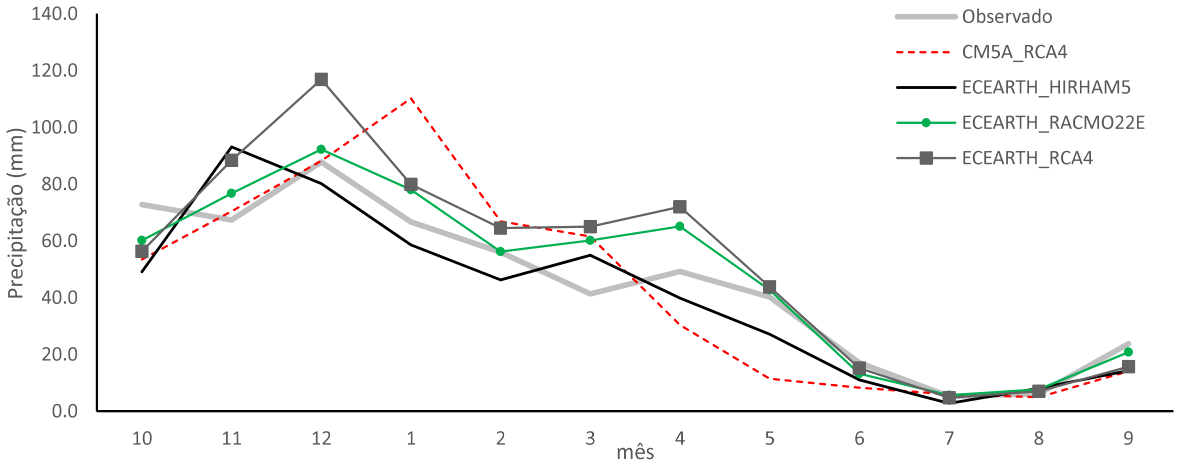


Figure 3 – Mean monthly rainfall observed and simulated in the period of 1971-2000.

For both chosen models there was an analysis to the climate anomalies of rainfall and temperature, comparing the control period of 1971 to 2000 with the scenarios RCP 4.5 and 8.5 during the periods of 2011-2040, 2041-2070 and 2071-2100. Following the results, it's possible to admit that there's an increase in average temperatures, more intense in RCP 8.5, especially in the end of the century (Annual average temperature: +2.27ºC 2041-2070; +3.95ºC 2071-2100). Seasonally, in RCP 8.5, the increased temperature will be felt specially during the century's final summers (Figure 4) and the model RACMO22E predicts a gradual temperature increase during summer and autumn while RCA4 is more abrupt with bigger oscillations.

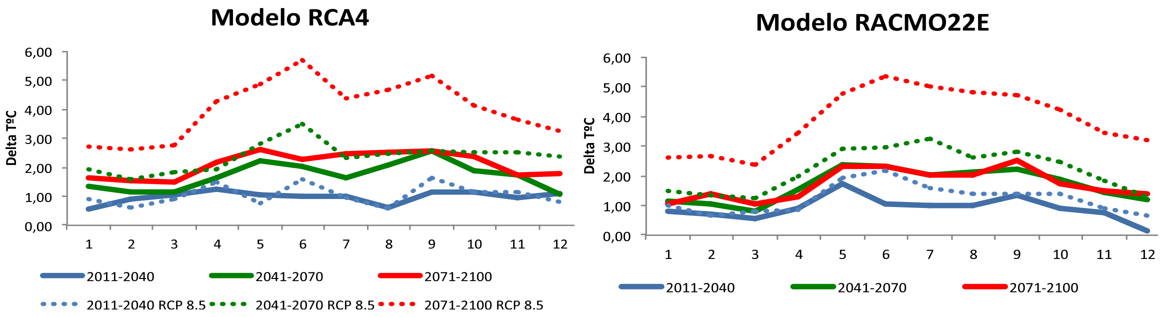


Figure 4 – Temperature's anomaly (ºC) for the periods of 2011-2040; 2041-2070; 2071-2100.

The annual rainfall's decrease will be more noticeable in the end of the century, mostly in the scenario RCP 8.5 (-15.2% 2071-2100). Seasonally, there's a tendency for a decrease in rainfall during spring months (April and May) and more severe precipitation during autumn (October, November and December) in the scenario RCP 8.5 (Figure 5). Summer period isn't defined equally for both climate models and scenarios, verifying that rainfall registers ups and downs, respectively in RACMO22E and RCA4. There's an increase in precipitation during summer in RCP 4.5 while in RCP 8.5 there's a downfall during the final periods of 2041-2070 and 2071-2100. The climate scenarios will be the foundation for the hydrological simulation to develop in the project GestAqua.AdaPT.

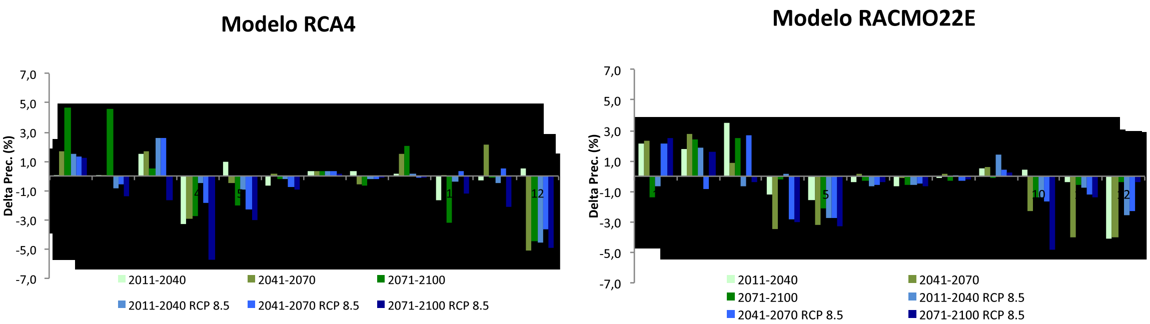


Figure 5 – Temperature's anomaly (ºC) for the periods of 2011-2040; 2041-2070; 2071-2100.

4.2. Hydrological modelling

The implementation of the hydrological model SWAT is done with the objective of simulating the surface runoff affluent to the reservoirs and the quality of the solids transportation in the studied basins. The model was implemented for the comprehended period between 1973 and 2012 with 4 years of pre-stabilization, using precipitation data from Azaruja and Santa Susana's weather stations, and climate data from Mitra-Évora's station.

Parameterization strengthened the model and made the simulation more reliable, as it reduced the uncertainties induced by the used data and model. Was based in previous studies for the experimental Guadalupe's drainage basin, mounted and studied by a partnership between Universidade de Aveiro and Universidade de Évora. As for the parameterization itself was given particular emphasis to farming practices and water consumption and availability.

For the analyzed drainage basins there is neither flow nor nutrient monitoring. This way, SWAT's performance evaluation along the calibration process was determined by a comparison between the simulated flows in the model and the monthly water and nutrient balances done in Diogo (2012) for both reservoirs based on volume balances and water quality models. To determine SWAT's performance, were used four different statistical indicators that permitted a qualitative and quantitative evaluation on the model's performance (Table 2).

Table 2 – Statistic performance indicators, adapted from Moriasi *et al.* (2007).

Performance level	*R²*	*NSE*	*PBIAS* % stream	*PBIAS* % Nutrients
Very good	0.75< R² ≤ 1.00	0.75 < NSE ≤ 1.00	PBIAS < ±10	PBIAS < ±25
Good	0.65< R² ≤ 0.75	0.65 < NSE ≤ 0.75	±10 ≤ PBIAS < ±15	±25 ≤ PBIAS < ±40
Satisfactory	0.65< R² ≤ 0.75	0.65 < NSE ≤ 0.75	±15 ≤ PBIAS < ±25	±40 ≤ PBIAS < ±70
Insatisfactory	R² ≤ 50	NSE ≤ 50	PBIAS ≥ ±25	PBIAS ≥ ±70

Notes: NSE: Nash e Sutcliffe efficiency index; PBIAS: mean error (%); R²: determination coefficients.

With this, in what refers to monthly average affluent flows, are present in Figure 6 the results obtained in Monte Novo and in Figure 7 the results in Vigia, both for the period of 1994 to 2005.

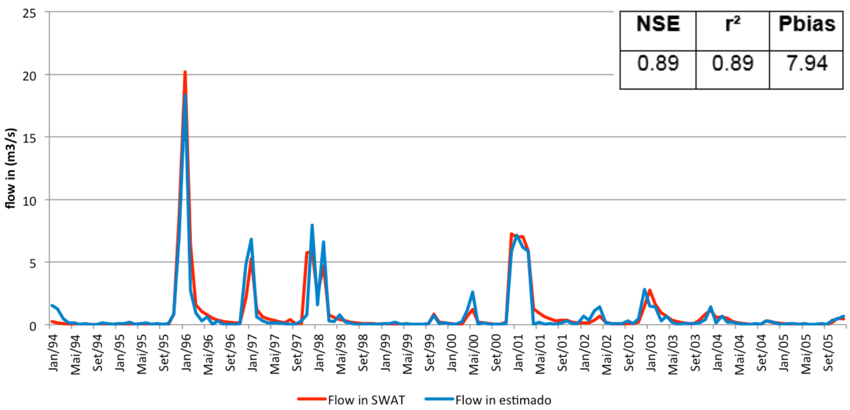


Figure 6 – Monte Novo Inflows, simulated (Flow in SWAT) and from Diogo (2012) (Flow in estimado).

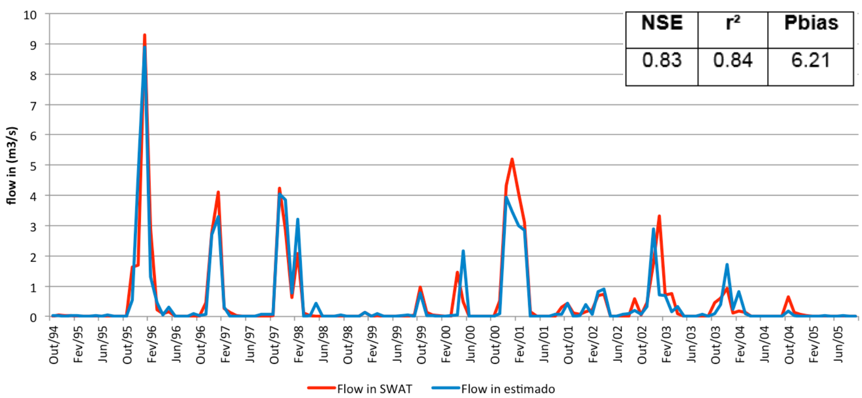


Figure 7 – Inflows to Vigia, simulated (Flow in SWAT) and from Diogo (2012) (Flow in estimado).

SWAT also allows the simulation of nutrient transportation. Considering the water problems in both reservoirs, it is important to study the nutrients in the system, giving phosphorus a particular attention (Figure 8).

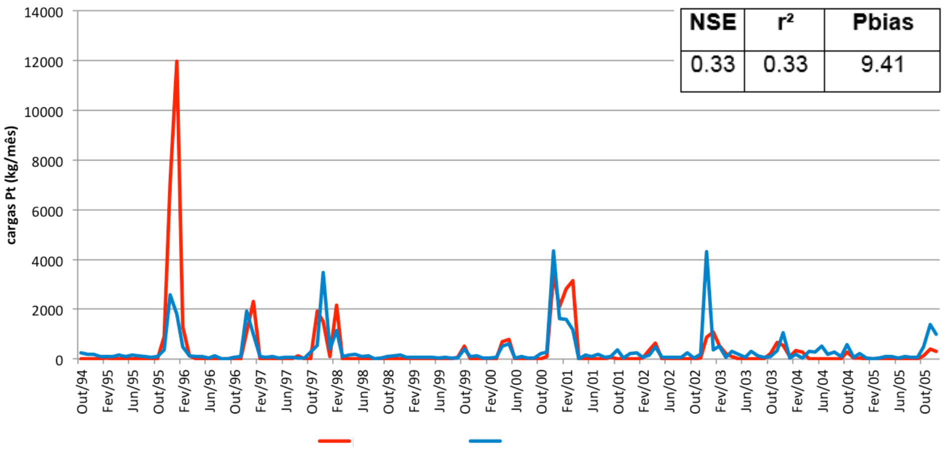


Figure 8 – Total phosphorus inflow loads to Monte Novo, simulated (SWAT) and obtained from Diogo (2012) (estimated).

4.3. Water quality modelling

Water quality simulation is based in the obtained results of the hydrologic models. Until now in GestAqua.AdaPT, it was only proceeded to calibrate the hydrodynamic and water quality of CE-Qual-W2 to Monte Novo, with Vigia still being under calibration. Hydrodynamic calibration was based on a water balance, based on stored volumes registered on SNIRH (Figure 9 and Figure 10) and in the water balances presented in Diogo (2012).

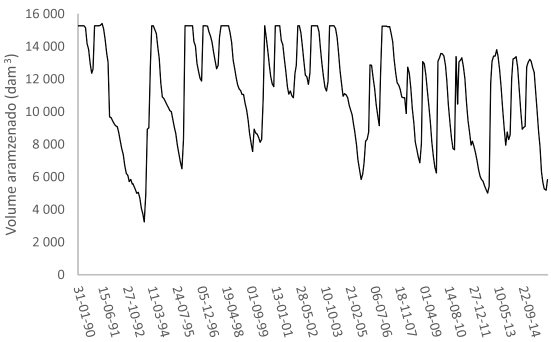


Figure 9 – Stored volumes – Monte Novo

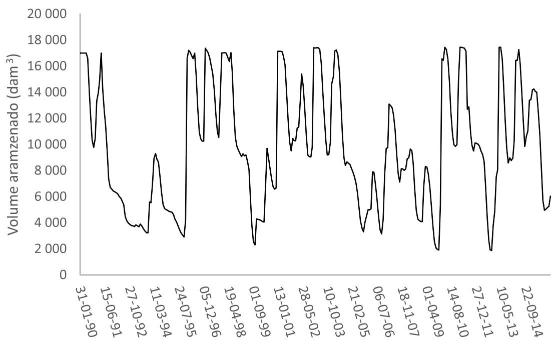


Figure 10 – Stored volumes – Vigia

As it can be seen in Figures 11 a 15, CE-Qual-W2 reproduces satisfactorily the vertical and temporal variations in water quality in Monte Novo.

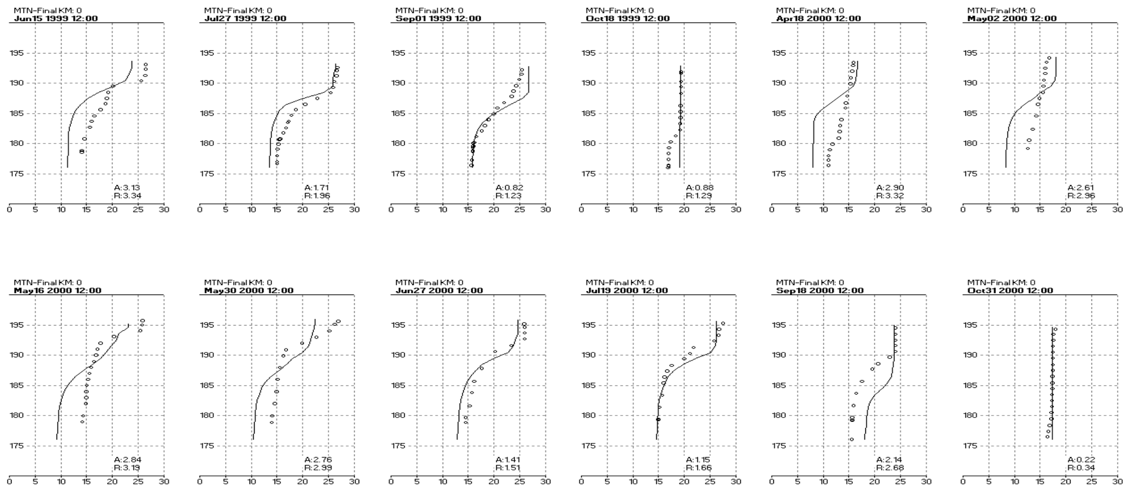


Figure 11 – Vertical profiles of temperature, observed and simulated in Monte Novo

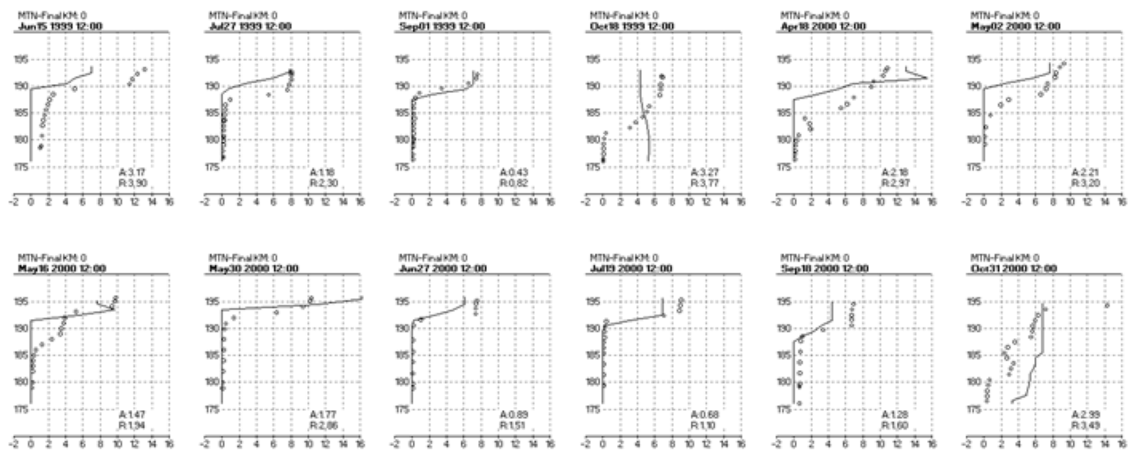


Figure 12 – Vertical profiles of dissolved oxygen, observed and simulated in Monte Novo

4.3. Reservoir water balance

Based on the flow results obtained from the SWAT model for the period from 2010 to 2100, reservoir monthly water balances may be developed in order to obtain estimates for the performance of the water supply infrastructure. In order to do so some assumptions must be considered: constant withdrawal for irrigation and urban supply – according to present water needs, constant, urban supply is limited bellow water level 188 m (according to the characteristics of the withdrawal infrastructure), no water transfer from the Alqueva reservoir and no storage volume management is considered (withdrawal according only to water needs and infrastructure limitations). Results are presented in Figure 13 and Figure 14.

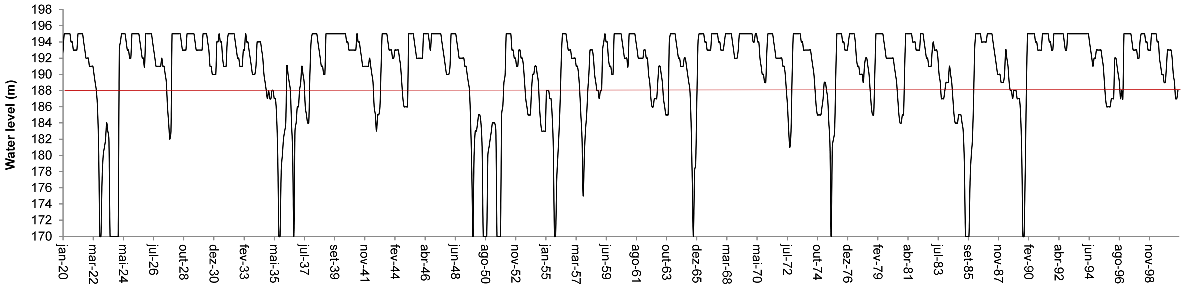


Figure 13 – Simulated water levels at Monte Novo (2010-2100) - RACMO RCP 4.5

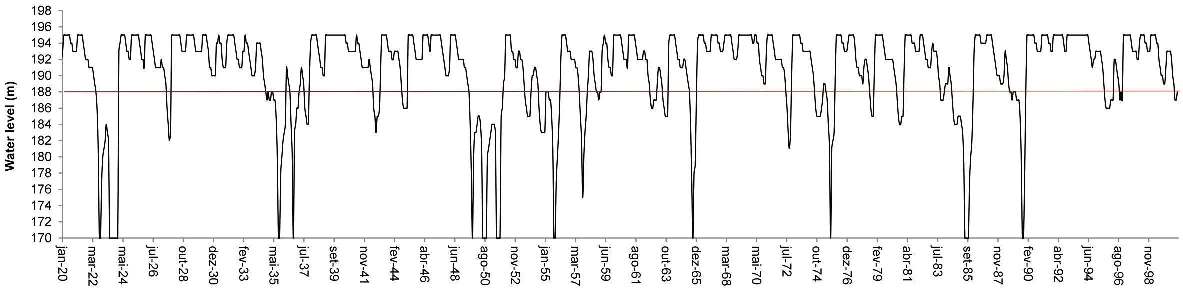


Figure 14 – Simulated water levels at Monte Novo (2010-2100) - RACMO RCP 8.5

Presented results are in accordance with the expected quantity water related problems and RCP 8.5 tends to lead to more severe water scarcity until the decade 2040-2050. From this period on the two scenarios tend to have the same impacts on water availability (Figure 15).

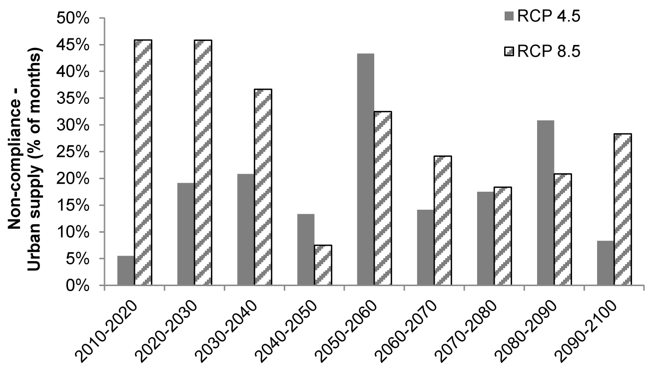


Figure 15 – Periods (% of total months) when water level at Monte Novo is insufficient for urban water supply – RACMO, with RCP 4.5 and 8.5.

5. Conclusions

The project GestAqua.AdaPT was outlined with the perspective of studying water use sustainability in a Mediterranean region for which significant impacts from climate change are likely to occur. In fact, taking aside the great variability of the results obtained from different climate models combination, obtained results denote a tendency in temperature increase and a reduction in precipitation with amplitudes that depend on the considered models.

The ongoing project considers the sequential use of mathematical simulation models that are able to provide information for the definition of adaptation strategies in the operation of multiple use reservoirs. The two case studies - the reservoirs of Monte Novo and Vigia – are examples of water use for human consumption and irrigation for agriculture, located in the hydrographic basin of the river Degebe, the largest affluent in Portugal to the Alqueva reservoir. Nowadays there are significant water quality issues in this region, resulting largely from the accumulation of phosphor in the waterbodies through diffuse origin affluences, from agricultural activities in the drainage basin. Furthermore in the Monte Novo reservoir the risk of resource insufficiency is recurrent and more recently mainly originated from the high water demand for agriculture.

According to the climate scenarios that have been analyzed, the risk of sustainability of water resources tends to increase due to the expected climate change in the region. This makes the adaptation measures to be defined in the project effectively relevant in the management of both reservoirs, either through a reduction in water needs or through a reduction in nutrient inflow to the waterbodies. The results that will be obtained in the project shall include the definition of operation rule curves for both reservoirs, taking into account the quantitative and qualitative aspects of both waterbodies and include the operation of transfers from the Alqueva reservoir.

According to the analysis of the results obtained for climate simulation there is a tendency for the temperature to increase, as well as decreased precipitation and changes in the precipitation intra-annual distribution patterns. The suitability of SWAT to quantify surface runoff was confirmed, taking in account the results of the model calibration in both reservoirs. In the case hydrodynamic and water quality modeling using CE-Qual-W2, it's equally established its suitability to the Monte Novo reservoir, being possible to replicate the water quality patterns observed in this waterbody. In the case of Vigia, the model is still being calibrated.

Among the innovative aspects of the project it's important to mention the sequential use of mathematical simulation models for an integrated analysis of the hydrologic cycle, namely the models SWAT and CE-Qual-W2. In fact, the complementarity between both models allows the appropriate simulation of the entire basin, allowing a quantification of surface runoff, solids transportation, as well as the assessment of impacts in land use with a conceptual description and spatial resolution suited to the study of effective operation and management measures for the resources. Benefiting from this potential and associating the application of these models to climate change scenarios, the evaluation of the impacts to land use or the adoption of more sustainable farming practices is a determinant result to define management strategies, minimize risks and adaption strategies to the potential climate change.

The results obtained in this project have the potential to be replicated to other hydric systems with clear benefits to multiple purpose waterbodies, which can also include energy production and water transfer issues. This reproducibility of methodologies and results, along with the definition and implementation of climate adaptation measures, support one of the central objectives of the ADAPT program, financed by EEA Grants and Fundo de Carbono, in which GestAqua.AdaPT is inserted. The project shall be concluded in October 2016.

References

ALCAMO, J.; DOLL, P.; HENRICHS, T.; KASPAR, F.; LEHNER, B.; ROSCH, T.; SIEBERT, S. – "Global estimates of water withdrawals and availability under current and future "business-as-usual" conditions". *Hydrological Sciences Journal – Journal Des Sciences Hydrologiques*, 48, 3, 2003, pp. 339 - 348.

Cole, T.M., and Wells, S. A. (2015) "CE-QUAL-W2: A two-dimensional, laterally averaged, hydrodynamic and water quality model, version 4.0". Department of Civil and Environmental Engineering, Portland State University, Portland, OR.

Diogo. P.A. (2012). Quantificação de poluição difusa de origem agrícola na bacia hidrográfica do rio Degebe. Dissertação de Doutoramento em Ambiente, Faculdade Ciências e Tecnologia, Universidade Nova de Lisboa, Lisboa, Portugal.

Giorgi, F., 2006. Climate change hot-spots. Geophys. Res. Lett., 33, L08707.

Grosso, N., Nunes, J.P., Diogo, P., Nascimento, J., Rodrigues, A.C., Cruz, M.J. (2014). 3. Avaliação das Vulnerabilidades. In Contribuição para o estudo das Alterações Climáticas e Adaptação do Ciclo Urbano da Água, EPAL Tecnhical Editions, 2, September, Lisboa. ISBN 978-989-8620-05-7.

Ferreira M.T., Morais M., Cortes R.V. Sampaio E.C. Varandas de Oliveira S., Pinheiro P.J., Hughes S.J., Segurado P., Albuquerque A.C., Pedro A., Nunes S. Novais M.H., Lopes L.T., Rivaes R.S, Abreu C., Verdaguer R. (2009). Qualidade ecológica e gestão integrada de albufeiras. UTAD/Fundação Molina/ADISA, Contrato nº2003/067/INAG, Lisboa, Portugal.

Jacob D, Petersen J, Eggert B, Alias A, Christensen OB, Bouwer LM, Braun A, Colette A, Déqué M, Georgievski G, Georgopoulou E, Gobiet A, Nikulin G, Haensler A, Hempelmann N, Jones C, Keuler K, Kovats S, Kröner N, Kotlarski S, Kriegsmann A, Martin E, van Meijgaard E, Moseley C, Pfeifer S, Preuschmann S, Radtke K, Rechid D, Rounsevell M, Samuelsson P, Somot S, Soussana J-F, Teichmann C, Valentini R, Vautard R, Weber B (2014) EURO-CORDEX: New high-resolution climate change projections for European impact research. Regional Environmental Change, 14, 563-578.

Moriasi D.N., Arnold J.G., Van Liew M.W., Bingner R.L., Harmel R.D., Veith T.L. (2007). Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. American Society of Agricultural and Biological Engineers, 50 (3), pp. 885-900.

Nunes, J.P., Diogo, P.A., Ribeiro, L., Grosso, N., Cruz, M.J. (2013). A multi-compartment modeling framework to study the impacts of climate change on the Lisbon water supplies. TWAM 2013 - Transboundary water management across borders and interfaces: present and future challenges. Aveiro, Portugal, 16 a 20 de Março.

Nunes, J. P., Seixas, J., & Pacheco, N., 2008. Vulnerability of water resources, vegetation productivity and soil erosion to climate change in Mediterranean watersheds. Hydrol. Process. 22(16), 3115 - 3134.

Nunes, J.P.; Seixas, J. – "*Modelling the impacts of climate change on water balance and agricultural and forestry productivity in southern Portugal using SWAT*", in *Soil Hydrology, Land-Use and Agriculture. Measurement and Modelling*, editado por M.K. Shukla, Wallingford (GB), CABI, 2011, pp. 366 - 383.

Nunes, J.P.; Seixas, J.; Keizer, J.J. – "Modeling the response of within-storm runoff and erosion dynamics to climate change in two Mediterranean watersheds: a multi-model, multi-scale approach to scenario design and analysis". *Catena*, 2011. DOI: 10.1016/j.catena.2011.04.001.

Nunes, J.P. Diogo, P.A., Colaço, P.D., Rodrigues, A.C., Rodríguez, J.A., Tao, J., Cruz, M.J (2012). Implementação sequencial de modelos matemáticos para o estudo de impactes de alterações climáticas em bacias hidrográficas. 11º Congresso da Água, Porto, Portugal.

Xu, C. -Y., & Singh, V. P., 2004. Review on Regional Water Resources Assessment Models under Stationary and Changing Climate. Water Resources Management, 18, 591-612.

How does adaptation project work in practice? Lessons learnt from flood risk reduction pilot projects in the Lower Mekong region

Linh Nguyen

GIZ, dieu.nguyen@giz.de

Abstract

The Lower Mekong Basin has been identified as one of the most severely affected region by global climate change. Within the framework of the German Federal Ministry of Environment's "Adaptation to Climate Change through Climate Sensitive Flood Management in the Lower Mekong Basin", GIZ supported the Flood Management and Mitigation Programme of the Mekong River Commission Secretariat to tackle two major challenges of climate change and flooding. A core component of this support is the development and implementation of four climate sensitive flood risk reduction pilot projects. The overall goal was to increase community resilience through the implementation of climate sensitive flood risk reduction measures in particularly vulnerable areas. The four commune-level adaptation pilots selected are the flood prone areas of (i) Khammouane province in Laos, (ii) Takeo province in Cambodia, (iii) Dong Thap Province in the Mekong delta of Vietnam and (iv) Chiang Rai Province in Mae Kok River Basin of Thailand. The pilot projects were completed in 2016 and required conducting vulnerability assessments (both social and physical/economic) and implementation of selected measures. An innovative methodology was adopted for the vulnerability assessment in that it integrated social and economic vulnerabilities to formulate, prioritize and cost justify the selected adaptation measures. The social vulnerability adopted GIZ's Vulnerability Sourcebook and a risk matrix methodology to analyze the results of community consultations and household surveys. The presentation contributes a number of important results and lessons learnt from the implementation of these pilots: (i) the need to better integrate social and economic vulnerability assessments (ii) the need to tailor internationally acknowledged tools and guidelines in their application at the local/commune level (iii) the need to understand the complexities of addressing governance mechanisms that involve multi stakeholders across the different sectors and administrative structures of the four countries (iv) the need to develop appropriate mechanisms through which these pilots can inform strategic planning at higher levels and (v) how to assess and maintain the effectiveness of the implemented adaptation strategies and initiatives on community's resilience, life and wellbeing.

Keywords: flood risk reduction, pilot project, vulnerability assessment

Community-Based Adaptation to Climate Variability and Change: Mapping and Assessment of Water Resource Management Challenges in the North Pare Highlands, Tanzania

Thomas A. Smucker (1), Kgosietsile Velempini (2), Kyle Clem (3)

(1) 122 Clippinger, Department of Geography, Ohio University, Athens, OH 45701, USA. Email: smucker@ohio.edu

(2) International Development Studies, Center for International Studies, Ohio University, 56 E. Union St., Athens, OH 45701, USA. Email: kv374509@ohio.edu

(3) School of Geography, Environment and Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington, New Zealand. Email: kyle.clem@vuw.ac.nz

Abstract

Many researchers have identified potential synergies between sustainable development (SD), disaster risk reduction (DRR), and community-based adaptation (CBA). Indeed, progress toward the post-2015 Sustainable Development Goals will require comprehensive integration of climate change adaptation and disaster risk reduction into policies and programs that seek to encourage sustainable development. However, where adaptation efforts ignore the historical institutional and cultural dimensions of resource access and management, adaptation could be fundamentally at odds with core notions of sustainable development and even threaten progress toward poverty alleviation. Recent experiences with community-based adaptation (CBA) to climate change have emphasized the importance of integrating local and external specialist knowledge in the identification of priorities for adaptation. Furthermore, such research has highlighted the importance of the historical institutional contexts in which local knowledge systems have evolved. This research examines linkages between the evolution of local institutional frameworks and water resource management through a case study based in the North Pare Mountains, Tanzania. Field research was undertaken to bring together external and local climate knowledge as a means of exploring prospects for future adaptation, in this case related specifically to the management of small-scale “traditional” water resources. The paper begins by highlighting questions about community-based adaptation as they relate to the role of local knowledge and local institutions in water resources management in Tanzania. We situate these questions within the North Pare Mountains, an intensively cultivated landscape where communities perceive declining availability of water from local springs and reservoirs due to changing climate variability and local land use practices. Our case study draws on community mapping and assessment of small-scale water resources to examine the potential contribution of CBA in light of institutional challenges at the local level. We argue that the institutional dimensions of adaptation are multifaceted and attention to their historical evolution is important to assessing their role in future community-level initiatives. We conclude that this and other place-based assessments have the potential to be “scaled up” by informing regional climate change adaptation programs and locally-generated initiatives in similar communities across the Kilimanjaro region.

Flood adaptation measures applicable in the design of public spaces: identification and characterization

Maria Matos Silva[1], João Pedro Costa[2]

[1] Cr. Polis – Grc arte, ciudad, Universidad de Barcelona, Pau Gargallo, 08028 Barcelona Spain, m.matosilva@fa.ulisboa.pt

[2] Research Centre for Architecture, Urbanism and Design (CIAUD), Faculty of Architecture, University of Lisbon, Rua Sá Nogueira - Pólo Universitário da Ajuda, 1349-063, Lisboa Portugal, jpc@fa.ulisboa.pt

Abstract

Urban flooding is an old and recurrent phenomenon that every year disturbs our cities, in some cases severely. On the other hand, climate change research, while evidencing that floods may become more frequent and intense, alerts for the fact that urban territories cannot continue the path of "business as usual". These two subject-matters, widely present within scientific discourse, prompt the emerging need for governing agencies to actively discuss and employ adaptation strategies and measures. This paper presents as its primer premise that the design of future public spaces will be determinant for the adaptation of urban territories in face of unprecedented flooding events. At the same time that public spaces are particularly exposed to climatic hazards, their design may significantly contribute to the reduction of society's vulnerabilities. In light of this argument, this paper identifies and characterizes wide range of flood adaptation measures applicable in the design of urban public spaces. The presented research is primarily based on the literature review of previously conducted studies. As a result of the state of the art analysis it was possible to initiate the process of identification, classification and characterization of the adaptation measures specifically targeted to the scope of this research. Since every situation is dependent on context specificities, the exposed typification is not intended to offer ultimate design resolutions. Instead, it strives to assist anyone involved in the initial brainstorming phases of a public space project concerned with flood adaptation. Ultimately, it intends to be a practice-oriented contribution to the local scale adaptation agenda.

Keywords: Adaptation, Flood Risk Management, Public Space

1. Introduction

Surpassing the question that cities are particularly vulnerable to climate change when compared to other territories (Ruddell et al. 2012); within the city, its public spaces and public life deserve a particular emphasis, notably for two reasons: firstly, it's exposure to climatic hazards, and secondly, its essence of common space of social exchange. Unlike interior spaces, outdoor spaces directly suffer from the impacts caused by extreme meteorology such as wind currents, sun exposure or flood waters. Considering exterior public spaces as a "collective good of the community" (Brandão 2011, p.34), social activities and serene responses to climatic stimuli are particularly threatened. On the other hand, public spaces, or 'the life between buildings' as Jan Gehl eloquently states (Gehl 1987), are considered by many as "the space that is the founder of the urban form" (Brandão 2011, p.34). At the same time, urban studies specialists inarguably indicate that the quality of urban life is strongly dependent on the quality of urban design (Among others: Jacobs 1992[1961], Carmona et al. 2010, Whyte 1980).

When considering the opportunities that loom within its particular characteristics, public space finds a niche of potentiality for climate change tackling. Adjacently, and although it is within public spaces that vulnerability can have significant connotations upon its enclosed functions, safety, and activity; these features are those that also present prospects to diminish impending future risks. Findings from Ruddell et al. indicate that "It is critical to ground support for climate adaptation and mitigation initiatives within local contexts of shared experiences" (2012). The authors furthermore draw to the attention that local action has the advantage of relying less on "justifications from atmospheric science" (Ruddell et al. 2012, p.601) and its associated greater uncertainties. Although scientific knowledge will always be fundamental, in public spaces, where hazards are tangible to a community, bottom-up approaches find its vocation through adaptation and awareness actions.

2. Methods

With different purposes and different priorities, several research undertakings have enumerated and organized different types of flood adaptation measures. Acknowledging 'learning' as a major component of adaptation processes, a state of state of the art overview on previously developed research was developed. More specifically, nineteen (19) references were analysed with the goal to highlight flood adaptation measures specifically applicable in the design of urban public spaces, namely four from research centres, ten R&D projects, and five books/reports.

For each analysed reference a particular synthetization and systematization process was developed. This process followed a specific criteria that included: 1) the highlighting of flood adaptation measures that 2) can be applicable in the design of public spaces and 3) are relevant in urban contexts. Of these measures, 4) only operational measures were selected, that is, measures that include technical design. This last criteria specifically aims to distinguish approaches that use design as a tool to face potential vulnerabilities, namely the ones associated to the projected increase of flood hazards, from those that are more strategic, institutional, regulatory or political, such as forecasting, warning, information, evacuation, aid services, building codes or shared risk and compensations.

The selection criteria was further bounded by the need to have information available in English, Spanish, or Portuguese. As the particular area of climate change adaptation is very vast and contains continuing developments and findings, adaptation to urban flooding will continue to be included in the development of new relevant studies. Nonetheless, within the scope of this research, the corresponding findings started to provide redundant results.

Although not evidenced in this paper, in parallel with the classification process based on external research findings, a portfolio screening was developed. This database of real-case examples was specifically targeted at confronting the initial conceptual classification in order to assess and validate the identified types of measures. It further served to deduce and propose additional types of measures that were not considered in the primary.

3. Results

3.1 Research programmes

Among the analysed research programmes are: 1) 'Adaptation Planning, Research and Practice' (WeAdapt) from the Stockholm Environment Institute (SEI), 2) 'United Kingdom's Climate Impacts Programme' (UKCIP) from the Environmental Change Institute (ECI) at the University of Oxford, 3) 'Climate Adaptation Knowledge Exchange' (CAKE) created by the American NGO EcoAdapt and Island Press, and 4) the 'European Climate Adaptation Platform' (Climate-ADAPT) from the European Commission and European Environmental Agency (EEA).

All these mentioned investigation programmes have in common a 'general' adaptation scope, that is, they cover a variety of topics pertaining to climate adaptation and not solely flood adaptation, namely health, finance or biodiversity. As such, only some deliverables from each identified research study were analysed. They further entail the constituent goal to provide and share information through online databases of case studies, reports or articles. Another common characteristic is their aim to promote the exchange of experiences between practitioners, researchers and decision makers from all evolved disciplines, through online sharing platforms.

WeADAPT is an online webpage dedicated to facilitate “learning, exchange, collaboration and knowledge integration” (weADAPT 2011) or a professional community of practice on adaptation issues. It's a collaborative and distributed network of many contributing organisations and individuals but its technological development is led by the Oxford Office of the Stockholm Environment Institute with input on strategic direction provided by all partners. WeADAPT began originally as wikiADAPT in 2005. Their outputs, which can be specifically related to the identification of adaptation measures to urban flooding, include articles, case studies and the Google Earth ‘Adaptation Layer’ interface.

UKCIP research essentially provides tools and information to help organisations to consider climate risks and to plan to adapt. In their own words, the programme “coordinates and influences research into adapting to climate change, and shares the outputs in ways that are useful to stakeholders” (UKCIP 2012). In the scope of this research, the most relevant deliverables from this programme include the ‘adaptation case studies database’ and the AdOpt report (Identifying adaptation options).

CAKE is an online sharing platform and database focused on the management of natural and built systems in the face of climate change. It further aims to build a community of innovative practice (CAKE 2010). Among others, it provides a series of case studies and a virtual library.

Climate-ADAPT is a European Commission initiative that helps decision makers to access and share information on: expected climate change in Europe, current and future vulnerability of regions and sectors, national and transnational adaptation strategies, adaptation case studies and potential adaptation options, and tools that support adaptation planning (Climate-ADAPT 2012). The unlimited information provided in the online sharing platform is expected to be periodically updated through the years. Among the knowledge generated, compiled and shared through this programme, the most significant to the conducted research are the ‘Adaptation options database’ and the ‘Case study search tool’.

3.2 R&D projects

The studied R&D projects can be divided in those which approached adaptation measures generally, i.e. covering more than just flood adaptation, from those that are specifically focused on water management and those specifically focused on flood management.

The analysed R&D projects which encompassed a general scope are: 5) the Dutch national project ‘Climate 'changes' Spatial Planning programme’ / ‘Klimaat voor Ruimte’ (CcSP/KvR); 6) the European project ‘Adaptation and Mitigation - an Integrated Climate Policy Approach’ (AMICA); 7) the European programme ‘ADaptation And Mitigation Strategies: supporting European climate policy’ (ADAM); 8) the European project ‘Green and Blue Space Adaptation for Urban Areas and Eco Towns’ (GRaBS); 9) and the German national project ‘The Climate Impacts: Global and Regional Adaptation Support Platform’ (ci:grasp).

The studied R&D projects which specifically covered water management adaptation measures are: 10) the European project ‘European Spatial Planning: Adapting to Climate Events’ (ESPACE); 11) the Belgian project ‘Towards an integrated decision tool for adaptation measures. Case study: floods’ (ADAPT); 12) the European programme ‘Managing Water for the City of the Future’ (SWITCH); and 13) the European project ‘Climate Adaptation – modelling water scenarios and sectoral impacts’ (ClimWatAdapt). Finally, the scrutinized R&D project that is particularly focused on flood adaptation is the 14) ‘Foresight project on Flood and Coastal Defence’ (Foresight projects), managed by the United Kingdom.

The Dutch national project ‘Climate 'changes' Spatial Planning programme’ had as its primer goal the introduction of climate change and climate variability as one of the guiding principles for spatial planning in the Netherlands. Moreover it envisioned the generation of international alliances that would provide a competitive knowledge base that would support practice in the face of climate change (CcSP 2004). Their agenda was specifically centred in five main themes (climate scenarios, mitigation, adaptation, integration and communication) and in a wide range of sectorial areas, namely coastal areas and water. Among the used deliverables from this project are: Final report COM11: "Deltas on the move" and Report A11 – "Routeplanner 2010 – 2050".

The AMICA project is a European project that aims to help local and regional entities to adopt a comprehensive approach to climate change. It is their objective to motivate local governments to include climate protection and adaptation in their planning practices. In order to fulfil their objectives, AMICA developed three central online tools: the adaptation tool, the mitigation tool and the integration tool. In the scope of this research, the adaptation tool is the most relevant. Its main components correspond to a matrix of adaptation measures and a list of evaluated practice examples. The matrix of adaptation measures explores various possibilities of adapting to climate variability and climate change on the local and provincial scales. The matrix has more than 40 adaptation measures, organized in four impact types and nine categories of measure (AMICA 2006). A detailed description of the measure is also available in this online tool.

ADAM programme essentially aims at a better understanding of the synergies, trade-offs and conflicts that exist between adaptation and mitigation policies at multiple scales. Amongst the project's objectives is the goal to create a "Digital Compendium" that can contribute to the emerging knowledge on adaptation. This virtual manual organizes results from four types of analysis: Workshops and interviews; meta-analysis of climate change impact, vulnerability and adaptation case studies, adaptation catalogue and risk analysis (ADAM 2009). Focusing on the "adaptation catalogue" output, an examination of adaptation measures across the EU was undertook, paying particular attention to pioneering measures and institutions that either manage, reduce, or transfer the risks associated with extreme events. In summary, the catalogue acts as an inventory of options, differentiating between alternatives according to the form of adaptation (institutional structures and processes, planning and management practice, financial / legal, or technological), hazard, landscape type (urban, rural, coastal), economic sector, geographical region, responsible actor (highlighting whether public or private), and the scale of implementation (e.g. adapting to heat waves can involve action at the city, neighbourhood or individual building level; flood risk management can operate from the level of the catchment down to individual responses). A brief characterization is further provided for each measure, namely by comprising the answers to the questions of "what", "why", "how and who", "implications" and "resources".

GRaBS project encompasses a consortium of 14 project partners, drawn from 8 EU Member States and is specifically targeted to the adaptation to climate change through the use of green and blue infrastructure. Among others, results are presented in the form of an online database and in the form of an adaptation action planning toolkit (GRaBS 2008).

Ci:grasp project consists on a climate information service that aims to provide state of the art knowledge on projected climate stimuli, climate impacts and adaptation options. Research is targeted at national, sub-national and regional scales. The particular goal to supply information on adaptation options is based on the analysis of adaptation projects, targeted at specific impacts (ci:grasp 2008).

The main goal of the ESPACE project consisted on influencing the "philosophy and practice of spatial planning by recommending how adaptation to climate change can be incorporated into spatial planning policies, processes and practices" (ESPACE 2007). Among their research findings, the most relevant in the scope of this research, i.e. the most relevant for the identification of different types of flood adaptation measures, is the "SERRA toolkit". One of its purposes is to serve as a guidance document on delivering climate change adapted development through planning at the local level. It was designed for planning professionals and developers, assisting them in the integration of water management and climate change adaptation issues into all stages of the planning and development processes. It further adds information on ten "Good Practice Case Studies" on water management adaptation options.

The ADAPT project is composed of two parts. The first part consists on a general introductory research on available knowledge about climate change while in the second part the determining and assessment of possible adaptation measures (ADAPT 2005). Among used deliverables from this research project is its final report from phase 1 (Hecq(coord.) et al. 2008).

SWITCH research project essentially aims to change the paradigm of urban water management "from existing ad hoc solutions to a more coherent and integrated approach" (SWITCH 2006). Two particularly interesting deliverables of SWITCH are: 1) the manual "Water Sensitive Urban Design. Principles and Inspiration for Sustainable Stormwater Management in the City of the Future" (Jacqueline Hoyer et al. 2011) and the "Handbook Adapting urban water systems to climate change" (Loftus 2011). Both research outputs explore possible innovations on sustainable stormwater management, elucidating how they can be applied in cities while at the same time taking advantage of the opportunities to use it for the improvement of the cities' urban experience. Examples of specific measures are further contrasted with the analysis of corresponding case studies.

Outputs from the ClimWatAdapt research project include tools which can help improve the knowledge base on adaptation measures, facilitating the exchange of adaptation best practice between countries and regions (ClimWatAdapt 2010), namely the "inventory of measures" database that is particularly relevant in this conducted analysis. In this database, measures are inventoried through four groups of attributes: 1) 'Basic attributes' that includes name and description, 2) 'Descriptive attributes' that comprise: the "category of measure" (Technical measures, Measures related to "green" infrastructure, Measures changing management or practices, Risk prevention measures, among others), the "character of measures" (Preventive, Preparatory, Reactive, Recovery), the "objective of measures" (reduce exposure and sensitivity, increase adaptive capacity, to exploit benefits), "climate events" (not enough water, too much water, impaired water quality, snow related events), and "sector affected" (Water management, Agriculture, Energy, Industry, among others); 3) 'Assessment attributes' that include effectiveness, economic effects (cost), side effects, flexibility, and acceptance (implementation and time to implement); and (4) 'Additional information' that includes references and comments.

UK's Government Office for Science has been developing "foresight projects", which consist on in-depth studies that look at major issues for 20-80 years in the future. They are based on the latest scientific evidence and futures analysis in order to tackle complex issues and to provide strategic options for policy (Neue Ufer 2013). The particular foresight project on Flood and Coastal Defence produced two reports: "Future Flooding volume 1" and "Future Flooding volume 2". While the first was focused on the elaboration of scenarios regarding the risk and extent of fluvial and coastal flooding over the next 30-100 years, the second report assessed the techniques or responses that are available to meet the flooding risk, and the key issues associated with their use. In this latter report, researchers developed literature reviews, interviews and workshops in order to gather information on scientific developments and international best practice in flood and coastal defence. They started by looking at the measures which are currently in use, considering the extent to which they are adaptable to future flood risk. Afterwards new tools and techniques were evaluated in order to identify which should be further included and analysed in the concerning study.

3.3 Books and reports

Among the analysed books and reports within this state of the art research, which also included further analysis on the identification and categorization of different types of flood adaptation measures, are 15) three Technical reports from the European Environmental Agency (EEA). More specifically,, report No 2/2012 – 'Urban adaptation to climate change in Europe' (EEA 2012) and report No 18/2011 – 'Green infrastructure and territorial cohesion' (EEA 2011) of general nature; and report No EEA/ADS/06/001 – 'Report on good practice measures for climate change adaptation in river basin management plans'(EEA 2009) that specifically focused on water management. Other analysed reports for the encompassing classification process of flood adaptation measures include the 16) 'Climate Change adaptation by design' guide (TCPA 2001), provided by UK's Town and Country Planning Association and with a general scale extent; and the 17) 'Adaptation Inspiration Book' (CIRCLE-2 2013), compiling a series of case studies and corresponding brief analysis.

Further information from the 18) 'Toolbox Adaptive Measures', developed by Dutch Doepel Strijkers Architects, was added to the literature review process. In this unpublished work adaptation measures, which are specifically related to flooding, are organized in eight strategies (embanking, elevating, wet-proofing, temporary adaptation, floating, evacuation, regulation and communication) and subsequent types of measures (such as 'Constructing and furnishing of watersides', 'Temporary adaptations on a building', 'Floating or amphibious platforms', 'escape ways', among others).

Lastly, the book 19) 'River.Space.Design' Planning Strategies, Methods and Projects for Urban Rivers was also considered in the conducted state of the art analysis. Although this book is particularly focused on urban river landscapes, and thus has no direct relation to climate change related adaptation measures, it provides assessments on additional case studies and includes catalogued and categorised information that further helps the conceptual organization of potential adaptation measures.

4. Discussion

Seventeen measures from ESPACE research project were highlighted together with fifty seven measures from the Foresight project, twenty measures from the AMICA project, nineteen measures from ADAM project, thirty eight measures from ClimWatAdapt project, and so on. Measures that did not fit the abovementioned criteria were excluded such as "Information folder" (AMICA), "Flood-risk mapping" (Foresight project), "Flood insurance" (ADAM), "Buffer strips between water bodies and agricultural fields and within fields" (ClimWatAdapt) or the often repeated measure of "off-shore barrier".

The resulting highlighted measures were subsequently systematized and compared with the help of multiple worksheets. In this process, common perspectives and redundancies were identified, namely in the given nomenclature. Mentioning just a few, River.Space.Design book mentioned "Floating jetties" and "Floating islands" while the Toolbox work mentioned "Floating platform or building block"; the Foresight project included the measure of "Permeable land cover" and the ESPACE project the measure of "permeable and porous paving surfaces"; while ADAM project included the measure of "Enhancing storage for water", AMICA project included the measure of "Water Storage"; "Dams" were suggested by the Foresight project, ADAM and the Toolbox work; "Reservoirs" were mentioned in the research projects ClimWatAdapt and ADAM; "Floodwalls" were included in the research projects ESPACE, AMICA, ADAM and in the book River.space.design and Toolbox work; although latter substituted by their synonym "Levee", "Dikes"were mentioned in ADAM research project, Foresight project and Toolbox work.

In order to choose the most appropriate vocabulary for the scope of this research, a semantics analysis was also conducted. This analysis permitted further conceptual clarifications. More specifically, it was not only important to choose between nomenclatures, namely between "Floating jetties", "Floating platform" or a new terminology, but also to clarify conceptual divergences, such as between "underground storage" and "reservoirs". Other relevant semantic resolutions helped, for instance, elucidate the difference between 'retention' and 'detention'. Other potential ambiguities, namely in the identified measures "Detention ponds" (Future flooding), "Catchment basins" (AMICA), "Retention basins" (River space design) and "Detention basins" (ESPACE) which seemed to be referencing similar concepts, where also clarified.

Overall, as illustrated in table 1, the combination of the classification process based on external research findings together with the portfolio screening and the associated empirical observations enabled the identification of thirty nine (39) types of measures arranged in sixteen (16) categories. It is however important to highlight that this process is open ended and built on the premise to be continuously revisited in light of new findings.

Table 1 - Identified categories and types of flood adaptation measures applicable in the design of urban public spaces

	Category		Type
1	Urban greenery	1	Green walls

2	Urban furniture	2	Inverted umbrellas
		3	Art installations
3	Rooftop detention	4	Green roofs
		5	Blue roofs
4	Reservoirs	6	Artificial detention basins
		7	Water plazas
		8	Underground reservoirs
		9	Cisterns
5	Bioretention	10	Wet bioretention basins
		11	Dry bioretention basins
		12	Bioswales
		13	Bioretention planters
		14	Rain gardens
6	Permeable paving	15	Open cell pavers
		16	Interlocking pavers
		17	Porous paving
7	Infiltration techniques	18	Infiltration trenches
8	Stream recovery	19	Stream rehabilitation
		20	Stream restoration
		21	Daylighting streams
9	Open drainage systems	22	Street channels
		23	Extended channels
		24	Enlarged canals
		25	Check dams
10	Floating structures	26	Floating pathways
		27	Floating platforms
		28	Floating islands
11	Wet-proof	29	Submergible parks
		30	Submergible pathways
12	Raised structures	31	Cantilevered pathways
		32	Elevated promenades
13	Coastal defences	33	Multifunctional defences
		34	Breakwaters
		35	Embankments
14	Floodwalls	36	Sculptured walls
		37	Glass walls
15	Barriers	38	Demountable barriers
16	Levees	39	Gentle slope levees

4.1 Overall characterization of the identified types and categories of measures

There are several descriptions of the previously identified flood adaptation measures presented by literature. Most of which entail specific purposes such as the execution technics, materials, costs or the assessment of infrastructural efficiency. As emphasized in table 2, the presented analysis specifically assess and characterizes the identified measures in regards to their applicability in the design of public spaces.

The coming descriptions are mostly supported by the literature from the aforementioned state of the art overview. Among the main consulted references are Philip (2011), Prominski et al. (2012), Novotny et al. (2010) and LNEC (1983). In this characterization process, all measures are equally considered in accordance to their specific features. There are no value judgements as each measure is diverse and highly dependable upon different contexts.

4.1.1 Urban greenery

Every living plant can be considered as part of the urban greenery of a city. From the smallest *Bryophyta* (Moss) to the biggest tree, all living vegetation contributes to the “harvest” and “detention” of rainwater, thus contributing to the adaptation of floods specifically associated with rainstorms (pluvial floods). Measures within this category further include adjacent benefits such as carbon capture, microclimatic balance or biodiversity enrichment both flora and fauna wise. Although tree alignments or vegetated balconies form part of the category of ‘urban greenery’, ‘green walls’ is the only highlighted measure essentially because of its novel and increasing use as an adaptation measure with significant aesthetical and infrastructural contributions. Today there are many iconic examples of green walls in most major world-wide capitals.

4.1.2 Urban furniture

Urban furniture as a contributing element to flood adaptation entails innovative ideas prompt by the increasing contemporary concerns presented by climate change. Among the materialized ideas are the ‘inverted umbrellas’ and ‘art installations’ of specific purposes. As the name indicates, inverted umbrellas resemble upside-down traditional umbrellas and may have various shapes and sizes. With inverted umbrellas, incoming water flows inwards into the central column which may then lead it to a storage tank or into the drainage system for reuse or distribution. Besides taking advantage of rainwater as a precious resource through harvest and storing functions, this measure may also serve as a shadowing structure, thus further contributing to microclimatic melioration through albedo reduction.

Regarding art installations, namely the ones associated to flood adaptation purposes, most have as its primary motive the communication of information, of a problem or concern and thus can more likely be related to strategic measures. However, they may also entail operational measures. That is the case, for instance, of the existing art installation that looks like a water harvesting “mupi”. In this situation, a large-sized funnel is placed above a rectangular shaped and transparent water collecting tank onto which rainwater is drained. Other benefits provided by this measure, adjacent to its operational function to collect and retain rainwater, include informational and educative purposes related to awareness raising.

4.1.3 Rooftop detention

Roofs are a privileged area among urban territories as they comprise an elevated impermeable area from which the supply of good quality water can be easily collected for later use. Rooftop detention systems mostly comprise a multi-layers structure that is designed in accordance to the function and size of the roof system. This measure can be applied in small or large scale areas, from singular buildings to housing developments, from elevated obsolete train-lines to industrial estates. Public spaces may exist among any of these areas. Besides the fact that capturing and reusing rainfall from roof surfaces can significantly attenuate overall urban runoff, rooftop detention further contributes as a reliable source of water for irrigation and other non-potable uses on-site such as toilet flushing, heating systems, direct groundwater recharge, among others. The identified measures encompassed within the category of rooftop detention are ‘green roofs’ and ‘blue roofs’. Both of which are particular adequate for the adaptation to pluvial floods.

4.1.4 Reservoirs

In the scope of this research, the category ‘reservoirs’ groups measures that store water either from traditional “grey” sewage drainage systems or from other measures such as bioswales, blue roofs, green walls, among others. Their main common purpose is not to lessen the volume of urban stormwater through natural infiltration or evapotranspiration but to provide temporary storage during heavy rainfall and thus attenuate intensity peak flows through the posterior gradual release of runoff. Accordingly, they are rarely stand-alone solutions, requiring supporting infrastructure both up and downstream its implementation site. Among the measures related to this category are ‘artificial detention basins’, ‘water plazas’, ‘underground reservoirs’ and ‘cisterns’.

4.1.5 Bioretention

Bioretention measures can be generally characterized by their capacity to simultaneously include the processes of detention, infiltration and evapotranspiration. They consist on excavated landscaped areas in which runoff is collected and infiltrated through the soil below and, if necessary, into an underdrain to the drainage system. Measures included in this category generally entail a broken stone bottom layer and engineered soil in order to offer high infiltration rates and efficient pollutant removal, as well as fertile growing conditions for vegetation. Planted vegetation may vary from herbaceous species to woody bushes and even trees. Through the implementation of these measures it is possible not to increase flood risk in new housing developments and its associated roads, pavements and parking lots. When encompassing vegetation, these measures additionally provide amenity value for urban environments. The visual impact of spaces comprising these measures is improved together with biodiversity and the quality of water and air. Among the measures included in this category are ‘wet bioretention basins’, ‘dry bioretention basins’, ‘bioswales’, ‘bioretention planters’ and ‘rain gardens’. It is further important to bear in mind some important implementation and maintenance specificities that are common to all the aforementioned measures, namely the need to conduct short-term maintenance in the first and second year’s common to any landscape design, the ongoing need to remove trash and debris as well as the requirements to check for clogging and the removal or trimming of undesired plants.

4.1.6 Permeable paving

Permeable paving or pavement is a pervious surface that allows rainwater to infiltrate through its surface and into an underlying storage layer. From this storage layer, water can be infiltrated into the ground, can be reused or can be conveyed into other measure such as a raingarden for instance. Permeable pavements can therefore attenuate runoff and, when provided with a filtration medium, can remove common street pollutants such as hydrocarbons and metals through absorption and filtration processes occurring in their pervious surface as well as their hidden sublayers. Measures associated to this category are generally able to cope with severe storms and are beneficial for the adaptation to pluvial, fluvial and coastal floods. Among the highlighted measures within this category are: open cell pavers, interlocking pavers and porous paving. While open cell pavers allow water to enter through the spacing’s between the pavers, porous paving is made of aggregate materials with some porosity that allow water to pass through their surface. All of which can be designed for car or pedestrian traffic and can be implemented in almost any urban area. Presently, there is a wide variety of pavement designs and materials, which can further add to the aesthetic quality of a space.

4.1.7 Infiltration techniques

In the scope of this analysis, the measures associated to this category are primarily targeted at fulfilling the purpose of infiltration or, in other words, the rapid infiltration of surface stormwater. This approach does not neglect the fact that other measures, integrated within other categories, might also encompass the same infrastructural function as a secondary purpose. Among the measures specifically targeted to infiltrate stormwater, one may consider: infiltration trenches, leaky wells, geocellular systems and green gutters. Regardless, only infiltration trenches were substantiated with implemented examples. This specific measure features underground layers that may be composed by gravel, sand, and other minerals or broken stones. The design criteria, such as the materials to use or the dimensions of each underground layer is highly dependable on rainwater intensities and the conditions of local soil and available space. They can be implemented in various urban settings from public gardens to roadside alignments, from parking lots to roundabouts. Measures within this category are not adequate for areas with high water levels as well as for areas that receive runoff with high pollution levels. They are also particularly inappropriate when subsurface soil is not sufficiently permeable.

4.1.8 Stream recovery

Stream recovery, here only focused upon urban territories, essentially entails the processes of improving or recuperating, totally or partially, the natural ecosystem of a watercourse. This process may be accomplished in a small section of the stream or in its total length. It is however important to note that stream recovery is only possible when major pollution sources have been eliminated. Public spaces generated out of stream recovery projects are common nowadays. Considering the extended literature on the subject of urban rivers and its recovery, a significant number of examples can be considered as exemplary in the improvement of a communities' quality of life. Most examples are also exemplary as flood adaptation undertakings applied to most types of floods. Measures within this category also contribute to the increase of flow capacity of the river system during flood events and can reduce the velocity of water flows. By improving the riparian habitat of streams, these measures also 'harvest' stormwater and promote groundwater recharge. Among the highlighted processes of stream recovery are: stream rehabilitation, stream restoration, and the process of daylighting streams that were formerly concealed.

4.1.9 Open drainage systems

Open drainage systems are uncovered water channels that are complementary or alternative to underground drainage systems. These open channels should only receive water that has been previously treated or is already free from pollutants. While some measures within this category include the improvements made in pre-existing watercourses, other measures serve to convey cleaned stormwater arising from other types of measures, such as rooftops or bioswales, leading it into the underground sewage system, or to a receiving water body or to other types of adaptation measures such as rain gardens or bioretention basins. Among the measures presented within this category are: street channels, extended channels, enlarged canals and check dams. All of which can be designed in various dimensions and forms and all of which can be particularly effective when tackling pluvial and fluvial floods. In similarity to other measures that instigate the communities' approximation to the processes of natural water systems, the aforementioned measures can also greatly change the perception of an urban space and its social appropriation. By exposing a fragment of the water cycle and by inviting users to part of it, education and awareness is promoted

4.1.10 Floating structures

Floating structures are an old concept and practice that has been revisited in recent years, likely as a result of climate change threats. New designs and experimental approaches have been recently exploring the potential of floating structures as the ultimate flood resilient measure, one that tolerates and adapts to any type of flood, being it pluvial, fluvial, groundwater, artificial drainage or coastal flood. Floating structures can range from floating mega structures such as sea oil platforms, to floating urban developments and floating buildings. Likewise, floating structures can also be built to support public spaces. Designs can have as many dimensions and forms as the advances in technology permit. Among the types of floating structures that can be specifically associate to public space design, the following were highlighted: floating pathway, floating platform and floating islands.

4.1.11 Wet-proof

Adaptation measures within the identified wet-proof category include different types of public spaces that are resistant to the periodic and temporary submersion by floods. Among the alternatives, submergible parks and submergible pathways were singled out. In most situations these measures are applied in flood prone areas, which can exist in interior lowlands or in areas adjacent to natural water streams. They are particularly adequate to the adaptation to pluvial, fluvial and coastal floods. Urban elements used in the design of these measures, such as pavement or urban furniture, must be particularly resistant in order to assumedly sustain the impacts of recurrent flood events. More specifically they must be made out of robust materials and a particular attention must be given to their constituent foundations. In the same line of reasoning, the used vegetation must also be suitable. Species originating from the habitat of riparian woodlands can tolerate the oscillations between flood and drought. Once the risk of flooding is high in these areas, their design must also encompass clear and visible information signage and escape routes.

4.1.12 Raised structures

Raised structures as an adaptation category in the scope of this research is interpreted as the public space structures that are elevated or suspended over the maximum levels of a watercourse in order to be unaffected by flood events. The concept to elevate a structure in order to protect against flooding is long-established. Expectedly, this concept is also often applied in the design of public spaces, namely in promenades, passageways, stages, esplanades, plazas, gardens, among others. This approach is generally used in waterfront margins albeit being also possible to implement in interior flood prone areas. In waterfronts, measures within this category are commonly used in densely urbanized areas where free available space is limited. Through overhanging balconies or elevated platforms, space is extended over the water as part of the waterfront structure. Construction techniques used in the implementation of these measures include the use of stilts (pillars, pilotis) or cantilevered structures. Among the different possible types of 'raised structures' adaptation measures, the following were identified in the scope of this research: cantilevered pathways and elevated promenades.

4.1.13 Coastal defences

In the scope of this research, the category of coastal defences specifically includes the coastal management measures that aim to adapt urban territories to the impacts of storm events that lead to flood occurrences, namely the impacts from fluvial floods as well as storm surges and sea level rise. Various examples have proven to be possible to maintain the high standards of hard engineering flood defence while also benefiting from the opportunities provided by interdisciplinary and multifunctional spaces of public utility. Along these opportunities is the potential available space for public encounter. Through public spaces the engagement in climate adaptation action can be enhanced, namely when the impacts of extreme weathers can be made tangible. In carefully designed coastal defences that also encompass public spaces, the power of water dynamics becomes meaningful for citizens and their livelihoods. Measures highlighted in this category of coastal defence are: multifunctional defences, breakwaters and embankments.

4.1.14 Floodwalls

Floodwalls can be characterized by being artificial flood barriers of relatively small scale, generally consisting on extensive reinforced concrete vertical platforms perpendicular to the ground an alongside a watercourse. Their size and shape varies considerably deepening on the projected flood characteristics. They are mostly used in dense urban settings where available space is very limited. In similarity to other measures that must comprise applied engineering techniques, floodwalls are not required to have its infrastructural flood defence purpose as a sole objective. Although in most situations they are implemented without aesthetic considerations, they have the potential to be integrated as part of a public space design. Today's knowhow allows for floodwalls to be artistic sculptural elements or didactic structures while maintaining their robustness and efficiency as a flood barrier. That is the case of the adaptation measures here highlighted, namely sculptured walls and glass walls.

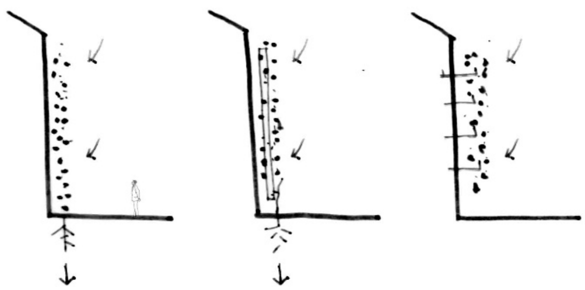
4.1.15 Barriers

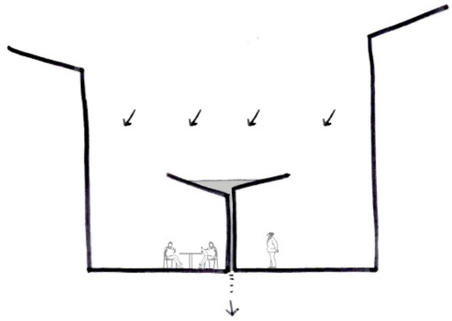
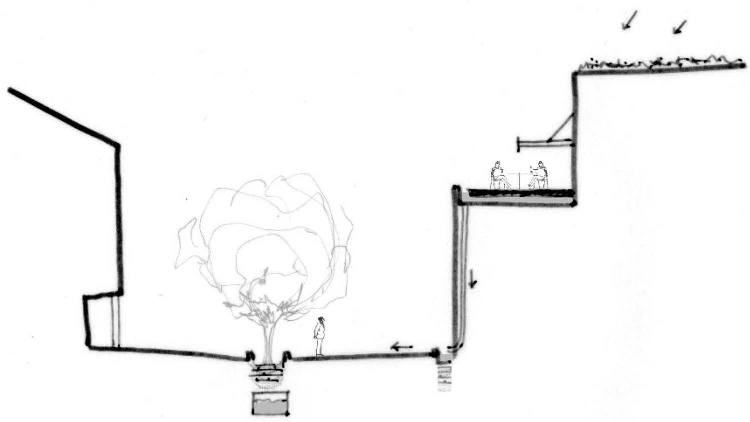
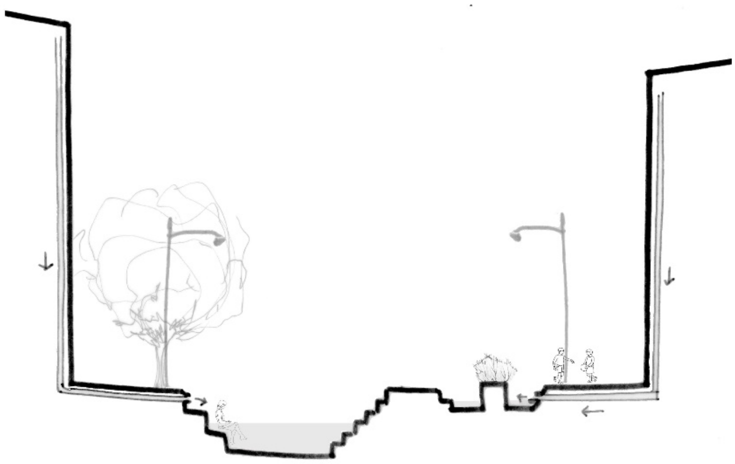
This category of adaptation measure refers to the group of flood defences that are locally implemented either through temporary or permanent demountable mechanisms. They are mostly applied when facing fluvial and coastal floods. Temporary barriers can be generally described as a provisional flood protection mechanism that is composed of detachable flood protection products that are exclusively installed during a flood event and are totally removed once flood levels are no longer a nuisance (EA 2011). Demountable barrier is here understood as a permanent flood protection, albeit movable, that has been pre-installed and requires operation during a flood event (EA 2011). Demountable barriers can include various types of mechanisms, from sectional barriers to flood gates.

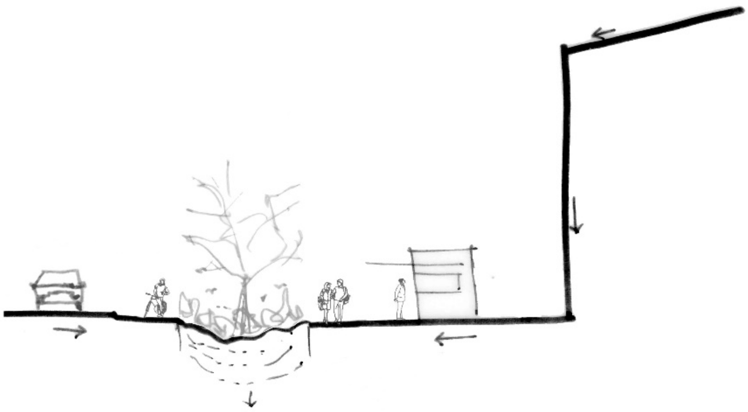
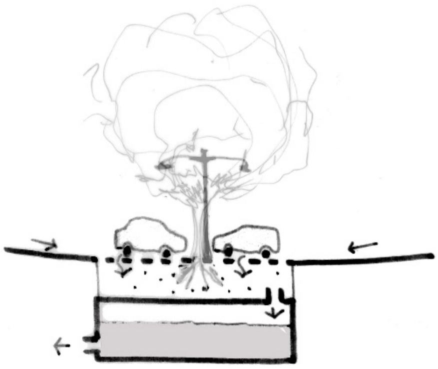
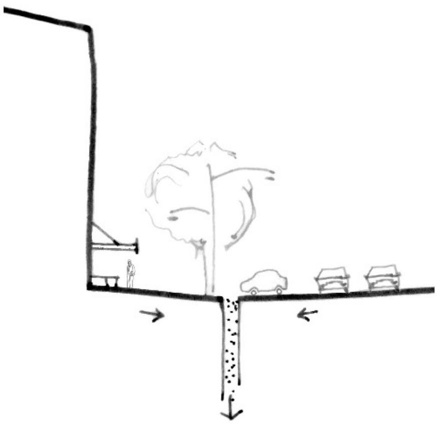
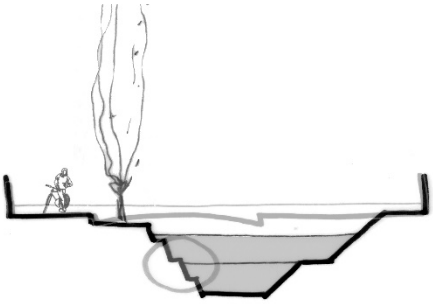
4.1.16 Levees

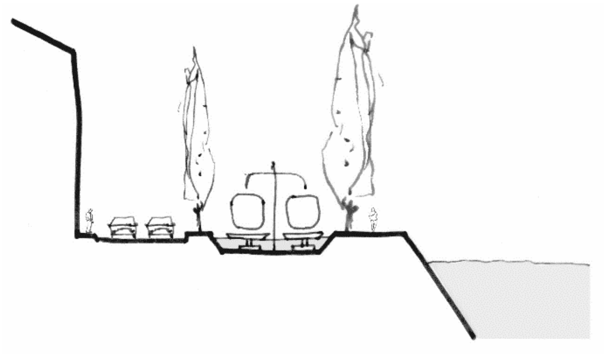
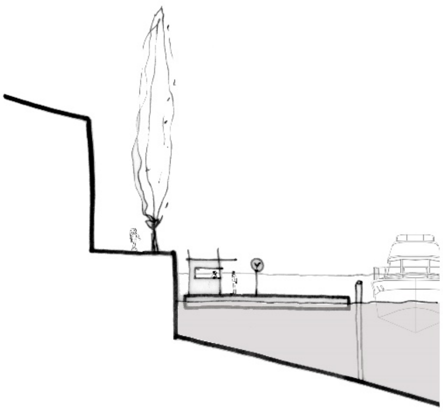
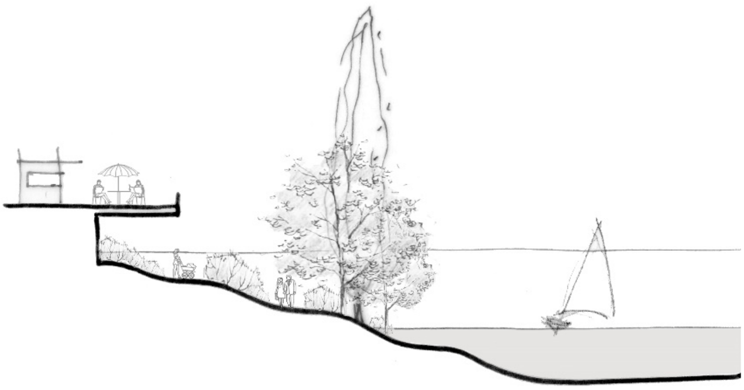
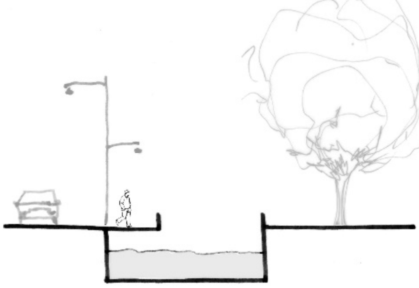
Levees are an old category of flood defence infrastructure. They can also be dikes, embankments, floodbanks or stopbanks. They are generally characterized as natural or artificial slopes that regulate water levels. They are usually made out of earth, although they can be reinforced by strengthening their inner core, with other types of materials such as steel, or by improving the characteristics of the levee's surface in order to contribute to the overall stability of the levee. Levees can also be re-enforced by heightening or broadening their scale. They are often implemented parallel to the path of a watercourse either in urban or agricultural lands. In other situations, levees are unrecognized by being designed together with the design of parks or other types of public space. In these cases, the adaptation measure of gentle slope levees is identified.

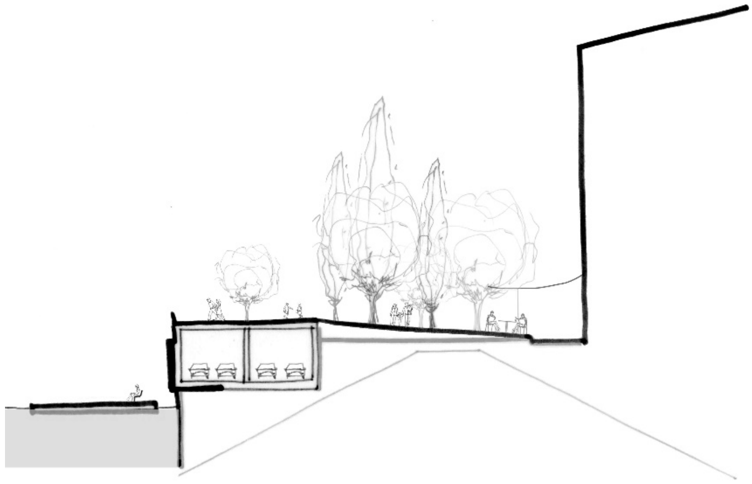
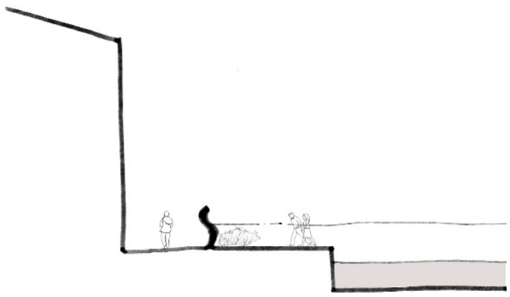
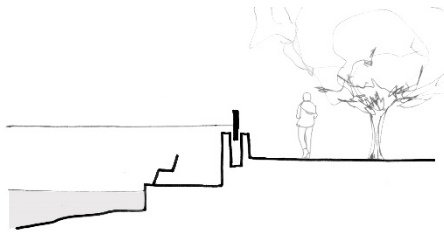
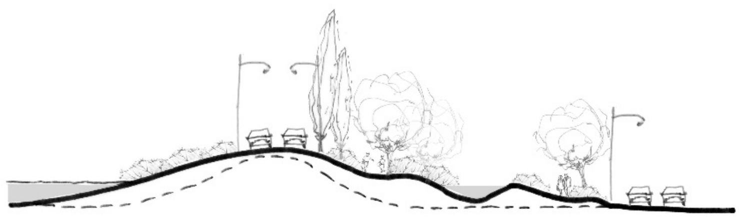
Table 2 - Illustrative and schematic drawing of one type of measure for each identified flood adaptation category.

	Category	
1	Urban greenery	 Green walls (#1)

2	Urban furniture	 Inverted umbrellas (#2)
3	Rooftop detention	 Blue roof and other measures (#5 and #s 3, 4 and 9)
4	Reservoirs	 Water plazas (#7)

5	Bioretention	 Rain gardens (#19)
6	Permeable paving	 Permeable paving (with cistern) (#s 15, 16 or 17 and 9)
7	Infiltration techniques	 Infiltration trenches (#18)
8	Stream recovery	 Daylighthing streams (#21)

9	Open drainage systems	 Street channels (in train or tram tracks) (#22)
10	Floating structures	 Floating platforms (#27)
11	Wet-proof	 Submergible parks (#29)
12	Raised structures	 Cantilevered pathways (#31)

13	Coastal defences	 Multifunctional defences (#33)
14	Floodwalls	 Flood walls (#36)
15	Barriers	 Demountable sectional barriers (#38)
16	Levees	 Gentle slope levees (#39)

5. Conclusions

Flood management has been mostly controlled by specific technical and specialized disciplines that have authoritatively decided on the actions to take. Yet nowadays, and as suggested by other authors such as White and Howe (2004), Lennon et al. (2014) among others, this matter requires a greater knowledge. One that embraces and integrates a broader range of stakeholders and disciplines, from the local community to evolved public companies, from landscape architects to climate change researchers, from urban planners to microclimatic experts, and so on.

In light of the presented premise that quality of our future cities will be dependable on local adaptation measures applied in public spaces, this manuscript specifically addresses the identification and characterization of flood adaptation measures applied in public space design. Through an exhaustive literature review, the assessment of examples (portfolio screening) together with empirical observations, it was possible to identify thirty nine (39) types of measures grouped within sixteen (16) categories. A range of presented options, which can be combined and used in very different contexts, envisioned to assist anyone involved in the design of a public space with flood adaptation purposes.

Prompt by the urging need to adapt our urban territories for the upcoming unprecedented climatic changes, this paper contributes for a different approach to flood management. Through the design of public spaces with flood adaptation purposes, not only is the anticipated target of interdisciplinary practice consummated but also additional and alternative measures may serve to challenge traditional practices.

Lastly, it is important to note that the presented results must be revisited through time as new information or knowledge becomes available. It is a research that must be acknowledged as an "Open Work" (Eco 1989), prepared to evolve and be restructured as new learnings, concepts or approaches arise. While the measures here proposed can provide a very useful starting point, most probably, and most fortunately, they will also change and derive as new challenges arrive.

Acknowledgements

This work was supported by the Portuguese Foundation for Science and Technology funded by QREN - POPH - Tipologia 4.1 - Formação Avançada, comparticipado pelo Fundo Social Europeu e por fundos nacionais do MCTES, under individual doctoral grant (SFRH/BD/76010/2011); and by the Research Centre for Architecture, Urbanism and Design (CIAUD), University of Lisbon, Portugal.

References

ADAM, 2009. *ADAM Digital Compendium — Home* [online]. Available from: http://adam-digital-compendium.pik-potsdam.de/ [Accessed 6th July 2012].

ADAPT, 2005. *Towards an integrated decision tool for adaptation measures. Case study: floods* [online]. Available from: http://dev.ulb.ac.be/ceese/ADAPT/home.php [Accessed 11th June 2012].

AMICA, 2006. *Matrix of Adaptation Measures* [online]. Available from: http://www.amica-climate.net/online_tool.html [Accessed 4th June 2012].

Brandão, P., 2011. *O Sentido da Cidade. Ensaios Sobre o Mito da Imagem Como Arquitectura.* Lisboa: Livros Horizonte 978-972-24-1704-4.

CAKE, 2010. *About CAKE* [online]. Available from: http://www.cakex.org/about-cake [Accessed 5th June 2012].

Carmona, M., *et al.*, 2010. *Public Places - Urban Spaces: The Dimensions of Urban Design* 2nd, 1st ed. 2003 ed. UK: Architectural Press, Elsevier ISBN: 978-1-85617-827-3.

CcSP, 2004. *Climate 'changes' Spatial Planning programme* [online]. Available from: http://www.climatechangesspatialplanning.nl/ [Accessed 2th June 2012].

ci:grasp, 2008. *The Climate Impacts: Global and Regional Adaptation Support Platform* [online]. Available from: http://pik-potsdam.de/cigrasp-2/ [Accessed 1th July 2012].

CIRCLE-2, 2013. *Adaptation Inspiration Book - 22 implemented cases of local climate change adaptation to inspire European citizens.* The Netherlands: Drukkerij Tienkamp.

Climate-ADAPT, 2012. *About us* [online]. Available from: http://climate-adapt.eea.europa.eu/about [Accessed 28th June 2012].

ClimWatAdapt, 2010. *Why this project?* [online]. Available from: http://www.climwatadapt.eu/ [Accessed 1st July 2012].

EA, 2011. *Temporary and Demountable Flood Protection Guide.* Ogunyoye, F., Stevens, R. and Underwood, S. eds. Bristol, UK: Environment Agency. 282 pp. ISBN: 978-1-84911-225-3

Eco, U., 1989. *The Open Work.* Cambridge, Massachusetts: Harvard University Press. 285 pp. ISBN: 06-74-63976.6.

EEA, 2009. *Report on good practice measures for climate change adaptation in river basin management plans.* Cornelius Laaser*, et al.* eds. http://icm.eionet.europa.eu/ETC_Reports: European Environment Agency, Report No EEA/ADS/06/001. 116 pp.

EEA, 2011. *Green infrastructure and territorial cohesion: The concept of green infrastructure and its integration into policies using monitoring systems.* Luxembourg: Publications Office of the European Union: European Environment Agency, Report No 18/2011. 138 pp. doi: 10.2800/88266

EEA, 2012. *Urban adaptation to climate change in Europe: Challenges and opportunities for cities together with supportive national and European policies.* Copenhagen: European Environment Agency, Report No 2/2012. 300 pp. doi: 10.2800/41895

ESPACE, 2007. [online]. Available from: http://www.espace-project.org/ [Accessed 3rd June 2012].

Gehl, J., 1987. *Life Between Buildings: Using Public Space* New York: Island Press.

GRaBS, 2008. *Green and Blue Space Adaptation for Urban Areas and Eco Towns* [online]. Available from: http://www.ppgis.manchester.ac.uk/grabs/ [Accessed 10th July 2012].

Hecq(coord.), W.*, et al.*, 2008. *ADAPT - Towards an integrated decision tool for adaptation measures - Case study : floods. Final report (phase 1).* Bruxelles: Belgian Science Policy. 129 pp.

Jacobs, J., 1992[1961]. *The Death and Life of Great American Cities.* New York: Random House. ISBN: 0-679-74195-X.

Jacqueline Hoyer*, et al.*, 2011. *Water Sensitive Urban Design. Principles and Inspiration for Sustainable Stormwater Management in the City of the Future. Manual.* HafenCity Universität, Hamburg, Germany, Deliverable 5.1.5. 115 pp.

Lennon, M., Scott, M. and O'Neill, E. 2014. Urban Design and Adapting to Flood Risk: The Role of Green Infrastructure. *Journal of Urban Design,* 19(5), 745-758.

LNEC, 1983. *Contribuição para o estudo da drenagem de águas pluviais em zonas urbanas. Vol. 2.* Abreu(coord.), M. R. P. d. ed.: Laboratório Nacional de Engenharia Civil,

Loftus, A.-C., 2011. *Adapting urban water systems to climate change. A handbook for decision makers at the local level.* ICLEI European Secretariat GmbH. 53 pp. ISBN: 978-3-943107-10-4.

Neue Ufer, 2013. *Home* [online]. Available from: http://www.neue-ufer.de [Accessed 16th July 2016].

Novotny, V., Ahern, J. and Brown, P., 2010. *Water centric sustainable communities: planning, retrofitting,an building the next urban environment.* Hoboken, New Jersey: John Wiley & Sons, Inc. 606 pp. ISBN: 978-0-470-47608-6.

Philip, R., 2011. *SWITCH Training Kit - Integrated Urban Water Management in the City of the Future.* Freiburg, Germany: ICLEI European Secretariat GmbH | Gino Van Begin. 51 pp. ISBN: 978-3-943107-06-7.

Prominski, M.*, et al.*, 2012. *River.Space.Design: Planning Strategies, Methods and Projects for Urban Rivers.* Berlin, Switzerland: Birkhauser ISBN-10: 3034606877.

Ruddell, D.*, et al.* 2012. Scales of perception: public awareness of regional and neighborhood climates. *Climatic Change,* 111(3-4), 581-607.

SWITCH, 2006. [online]. Available from: www.switchurbanwater.eu [Accessed 4th June 2012].

TCPA, 2001. *Climate Change Adaptation By Design: a guide for sustainable communities* Shaw, R., Colley, M. and Connell, R. eds.: Town and Country Planning Association 49 pp.

UKCIP, 2012. *About us* [online]. Available from: http://www.ukcip.org.uk/about-ukcip/ [Accessed 28th June 2012].

weADAPT, 2011. *About weADAPT* [online]. Available from: http://weadapt.org/knowledge-base/guidance/overview-of-weadapt [Accessed 4th June 2012].

White, I. and Howe, J. 2004. The mismanagement of surface water. *Applied Geography,* 24(4), 261-280.

Whyte, W. H., 1980. *The Social Life Of Small Urban Spaces.* USA: Project for Public Spaces Inc.

Assessing and coping with the urban heat island effects in major cities

Walter Leal Filho 1, Luiz Priori Jr 2, Victoria Omeche Emanche 3

1 Hamburg University of Applied Sciences, walter.leal@haw-hamburg.de

2,3 Universidade Federal de Pernambuco, Hamburg University of Applied Sciences luizpriori@gmail.com victoriaomeche.emanche@haw-hamburg.de

Abstract

Cities are among the major drivers of global climate change. The majority of the world's population already lives in urban areas, a trend bound to increase, with global urban population projected to have increased to 66% by 2050. The growth of urban agglomerations combined to population migration from rural to urban/suburban areas will exacerbate the problem. Cities consume up to 80% of total global energy production, and account for 71% to 76% of global CO2 emissions. Cities are also severely affected by climate impacts. The study describes one of the consequences of climate change, namely urban heat. Due to their geographical characteristics such as low albedo, high impermeability and favorable thermal properties for the energy storage and heat release, and as a result of the ways their infrastructure - which is often of sub-standard quality- function, cities are highly vulnerable to climate change as a whole and to urban heat in particular, especially (but not only) in developing countries. The paper defines the scope of the problem, its consequences and outlines some of the ways it may be addressed.

Keywords: climate change, urban heat, urban infrastructure.

Post-disaster Mental Health: An Exploratory Study on Typhoon Haiyan Survivors in Tacloban City, Philippines

Angeli Guadalupe 1, Chiho Watanabe 2, Makiko Sekiyama 3

1 The University of Tokyo, Rm 334, Building of Environmental Studies, 5-1-5 Kashiwanoha, Kashiwa City, Chiba 277-8563 JAPAN. angeliguadalupe@edu.k.u-tokyo.ac.jp

2 Department of Human Ecology, The University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo 113-0033 JAPAN. chiho@humeco.m.u-tokyo.ac.jp

3 Graduate Program of Sustainability Science, The University of Tokyo, Rm 334, Building of Environmental Studies, 5-1-5 Kashiwanoha, Kashiwa City, Chiba 277-8563 JAPAN. sekiyama@k.u-tokyo.ac.jp

Abstract

Climate change nowadays has increased the frequency and severity of extreme weather events. Aside from bringing physical havoc, natural disasters have left countless of survivors with psychological distress, which sometimes lead to Post-traumatic Stress Disorder (PTSD) or even to Major Depression. It is reported that the incidence of mental disorders double after emergencies. However, disaster preparedness programs rarely address mental wellness of survivors. Economic and environmental rehabilitation is usually the priority. It is observed that in disaster settings, mental health services are fragmented, unstable, short of staff, affected by language barriers, involves misdiagnosis and applies culturally inappropriate treatment methods. This is a wasted opportunity for if mental disorders are detected and addressed at an early stage, patients are more likely to recover fully. In Tacloban City in the Philippines, one of the countries most vulnerable to natural disasters, a Category 5 supertyphoon named Haiyan struck last November 2013 killing at least 6,300 people. After this tragedy, it is reported that at least one in ten survivors was advancing into depression. Sadly, there were no community-based mental health services rendered in the city. The WHO started a program called Mental Health Gap Action Program wherein they trained 70 health professionals and almost 300 community workers to link primary care with mental healthcare. However, almost the same patients before and after Typhoon Haiyan avail of these free services from health centers despite the increased number of persons reported and expected to be mentally ill. Thus this study aimed to determine which demographic factors and barriers affect the health-seeking behavior of Typhoon Haiyan survivors. Key person interviews were performed then an administered questionnaire survey was conducted of a random sample of adult residents (n= 129) in three different communities in Tacloban City. It was determined that the most significant factor to their health-seeking behavior is the attitudinal barrier of wanting to handle the problem on their own. This was followed by structural barriers, e.g. lack of doctors, poor quality facilities, distance from facilities, limited finances and lack of time. Stigma was the lowest reported barrier. Sociodemographic characteristics, except for educational attainment, have not shown significant correlation with their health-seeking behavior. Educational attainment is inversely proportional to the use of mental health services, a trend opposite to those observed in developed countries. Most of those who used the services availed from non-governmental organizations and not health centers. These findings could be utilized to improve and promote community-based mental health services in Tacloban City, Philippines.

Keywords: disaster mental health care, exploratory study, Typhoon Haiyan, mental health service use, Philippines

What can Brazilian power companies learn from the French experience when developing their climate change adaptation strategy?

Katia Cristina Garcia [1], Gilles Debizet [2]

[1] CEPEL/Eletrobras, garciak@cepel.br

[2] PACTE/ Université de Grenoble, gilles.debizet@ujf-grenoble.fr

Abstract

Since the launch of the latest report of Working Group II of the Intergovernmental Panel on Climate Change in March 2014, called the AR5 (Assessment Report), the discussions on climate change have been expanded, moving from a view focused only on mitigation to a broader one, considering also the need to adapt to climate changes that are already underway. This movement has impacted not only on the strategies and actions of national, regional and local governments, but also on different sectors of the economy. The electricity sector is notoriously one of the main actors of global climate change and it now begins to present another important role: the role of a sector that is also vulnerable to the consequences of climate change. As so, some new important questions arise: How the sector must be prepared to minimize the consequences of temperature increases, changes in precipitation and more frequent occurrence of extreme weather events on the energy offer, on the energy demand and on the energy assets and infrastructure? What are the key aspects to be considered by a power company when building a strategy for climate change including both mitigation and adaptation issues? How companies can prepare themselves to the climate changes already underway as to have a minimal impact on their business? It is in this challenging context that this paper takes place. It presents the results of a research project developed by researchers of CEPEL/Eletrobras (Electrical Energy Research Center) and PACTE (Social Science Research Laboratory of Grenoble-Alpes University) which aims to bring to Brazil greater expertise in the subject of climate change governance and climate change adaptation. The paper shows the first results of a campaign of interviews realized in France with key stakeholders, that tried to address how the French electricity companies and territories are preparing to minimize the consequences (or profit from them) of climate change. From the analysis of positive and negative points of that experience at different action levels (policies, plans, programs, strategies) it is discussed the key aspects of an effective Adaptation Strategy to Climate Change in the Brazilian electricity companies, in a way to enable the consideration of the possible impact that climate changes may bring to electricity generation, transmission and distribution.

Keywords: Adaptation Strategy, Climate Change, Brazil, France

Track 3b. Mitigating Climate Change: Renewable Energy and Energy Efficiency

The sustainability of future scenarios of the Portuguese power system

Patrícia Fortes[1], Luís Dias[2], Júlia Seixas[3]

[1]CENSE, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, p.fs@fct.unl.pt

[2]CENSE, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, luisdias@fct.unl.pt

[3]CENSE, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, mjs@fct.unl.pt

Abstract

A shift to a low-carbon energy system, particularly for electricity generation, has been identified as a key strategy to mitigate climate change. A wide range of energy models have been used to support policy decisions. However, such models mostly focus on the cost-effectiveness of energy technologies to reduce greenhouse gas (GHG) emissions, ignoring other aspects of sustainability. Low-carbon power plants, as wind or solar PV farms, may require more materials and land-use than fossil-fuelled plants with other environment impacts. Also, some emergent renewable energy sources (RES) technologies, e.g., wave, have significant capital costs which may be unbearable on a financial point of view. A sustainable power system must contribute to climate change mitigation but also needs to promote economic and social development, without prejudicing other environmental aspects. Most of the electricity generation planning does not take into account a wide range of sustainability aspects, which require tools and approaches with expanded abilities. This paper aims to evaluate the sustainability of the Portuguese power sector as foreseen by three scenarios within the Portuguese National Climate Change Programme (NACCP) up to 2030: REF (electricity mix according to the policy goals of the Renewable Action Plan, including mandatory emergent RES capacity), REFaj (equal to REF but with lower hydro capacity and without mandatory emergent RES) and REFaj+ (equal to REFaj but with wind onshore and solar PV installed capacity up to the maximum cost-effective national potential). A business-as-Usual (BAU) scenario, which considers an average electricity technology generation mix over the last three years is also analysed. We apply sustainability metrics comprising three groups of sustainability indicators: environmental (GHG emissions, water consumption and land-use); economic (capital costs, electricity production cost); and social (number of new jobs). An equal weighting of the sustainability criteria is considered for each of the indicators. The assessment shows that despite the lowest requirement for capital investment and electricity price, the BAU scenario shows the poorest overall sustainability score in 2030. The lower RES installed capacity and the continuous operation of coal power plants are translated in higher GHG emissions, water and land-use. This scenario is also the worst option from the social perspective. The REFaj+ and REF scenarios have the best environment sustainability performance. The main drawback of the former is associated with higher land-use due to solar PV farms, while for the latter is the larger water consumption as a result of higher hydro capacity. Within the three NACCP scenarios, REFaj has the last attractive sustainable power mix in 2030. Besides a higher electricity price, this scenario leads to the biggest GHG emissions and lowest jobs creation, translated in lowest ranking regarding economic, social and environmental criteria. Overall, the most sustainable scenarios are those with higher penetration of RES. However, although different technologies enable mitigate climate change, some options present additional sustainable aspects. Contrary to current energy models, the sustainability assessment allows to explore a wide range of additional important aspects, which makes it a relevant tool in decision-support framework, contributing to more informed and comprehensive policy making.

Keywords: sustainability assessment, low carbon future scenarios, Portuguese power sector

Greenhouse gas inventory of a Brazilian electricity distribution company

Cássia Ribeiro 1, Célio Andrade 2

[1] Federal University of Bahia - Brazil; causribeiro@gmail.com

[2] Federal University of Bahia - Brazil; jcelio.andrade@gmail.com

Abstract

In order to respond to climate change and mitigate its Greenhouse Gas (GHG) emissions, companies must first develop GHG emission inventories. The GHG inventory practice is still unusual in developing countries. For example, among the Brazilian companies of electric power distribution, only 4 out of 63 companies develop and disclose their GHG inventories following the GHG Protocol. None of these four companies is located in Northeast Brazil. This study aims to estimate GHG emissions in 2014 from the activities of Coelba, an electric power distributor located in the Northeast of Brazil, and to make a comparative analysis using the GHG emissions data published in the inventory of AES Sul, which is located in the South of Brazil. In order to do that, secondary data were collected from institutional documents (sustainability and management reports) and information systems of the companies (SAP-R3) and primary data were obtained through interviews with employees from different areas of the companies (Management, Human Resource, Environment, Supply, Market and Loss Recovery). The results show that the purchase of energy to be distributed to end users responds to the largest amount of GHG emissions (84.77% in Coelba and 90.40% in AES Sul). Secondly, the electricity losses represent 14.64% of Coelba's GHG emissions and 9.33% of AES Sul's. This result is influenced by the increase, in recent years, of the Brazilian electric system's emission factor, due to the activation of some fossil fuel plants to ensure national energy supply. It is argued that the initial inventory of Coelba's GHG emissions may help the company to develop GHG reduction strategies, identifying opportunities for improvements in operational efficiency as well as cost reduction. Besides, it is also a benchmark for other companies in the electric sector to prepare their inventories and include more categories in addition to scopes 1 and 2.

Keywords: GHG Emission Inventory, GHG Protocol, Electricity Distribution Company, Brazil.

1. Introduction

There is a growing discussion worldwide on climate change caused by greenhouse gas emissions. The Intergovernmental Panel on Climate Change - IPCC shows in its reports that the emission of gases from human activities are responsible for the observed increase in temperature in recent decades and only human beings' actions can reduce such impacts (IPCC, 2014).

The IPCC (2014) also shows that climate changes caused by global warming have already had significant impacts on people's lives and the natural environment, such as loss of agricultural productivity, accelerated extinction and species displacement, increasing damage to infrastructure and economy due to extreme rainfall and drought. The IPCC states that the most effective way to reduce risk is to reduce GHG emissions, also impacted by the accumulated historical emissions. If GHG emissions continue to grow at current rates over the next few years, the planet's temperature might increase to 4.8ºC in this century.

According to estimates of the Emissions Database for Global Atmospheric Research (2015), in 2014, global GHG emissions totalled approximately 53 billion tons of carbon equivalent (Gt CO2e), out of which, 3% (1.58 Gt CO2e) was Brazil's contribution. In terms of GHG emissions per capita, in 2014, each Brazilian emitted an average of 2.4 t CO2e, about 7 times less than an American does and 3 times less than an European or a Chinese emits.

Despite the predominance of oil and the growing use of natural gas, the Brazilian energy matrix still has a high share of renewable sources. Table 1 shows that, in the country, in 2014, 39.5% of all energy production came from renewable sources (hydro, biomass, wind, solar and geothermal) against 13.7% in the world average.

The global power sector produces electricity primarily from non-renewable sources (oil, natural gas, coal and nuclear), which represented, in 2014, more than 75% of the electricity produced in the world, as shown in Table 1. Coal stands out, because it is responsible for approximately 40% of the total amount.

The electric matrix in Brazil is predominantly composed by renewable sources (74.6%), however, the analysis of the evolution of emissions shows that the share of non-renewable sources has grown significantly, representing, in 2014, 25.4 % of the total, as opposed to 12.9% in 2011, according to the National Energy Balance (BEN, 2015).

Table 1. Share of sources within Brazilian and Global Energy and Electric Matrices

Sources	Energy Matrix		Electric Matrix	
	Brazil	World	Brazil	World
Not renewable	**60.50**	**86.30**	**25.40**	**76.40**
Oil	39.40	31.10	5.10	4.80
Natural gas	13.50	21.50	14.90	22.00
Coal	6.30	29.00	2.90	39.20
Nuclear	1.30	4.70	2.50	10.40
Renewable	**39.50**	**13.70**	**74.60**	**23.60**
Hydro	11.50	2.50	65.20	17.10
Biomass	27.60	9.90	7.40	1.90
Wind	0.40	0.50	2.00	3.20
Solar	-	0.30	0.003	1.10
Geothermal	-	0.50	-	0.30

Source: EPE, 2015

Figure 1 shows the evolution of GHG emissions in the different sectors in Brazil over the past decade. We can observe emission reduction due to changes in land use (9.7%) between 2013 and 2014, however, all other sectors, especially the energy one, showed an increase. Of the total emissions, there was a reduction of 0.9%. Since 2009, the country's emissions are stable, at around 1.5 GtCO2e.

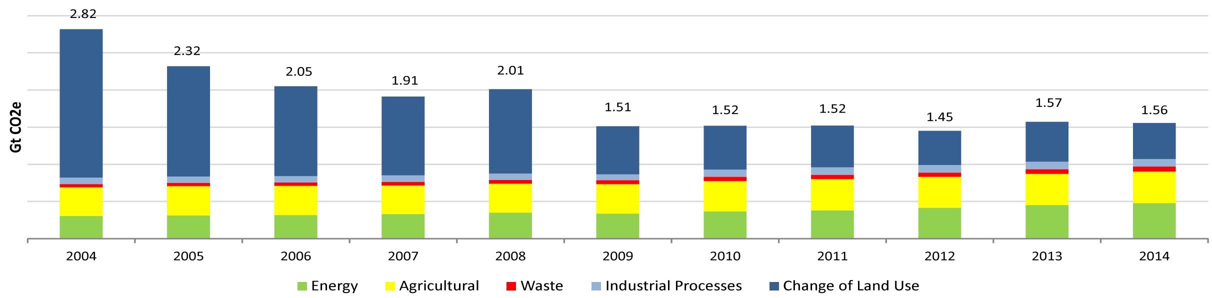


Figure 1. GHG Emission in Brazil by Sector 2004 – 2014
Source: Designed by the authors, based on SEEG (2015)

The energy sector emitted, in 2014, 0.479 GtCO2e, representing an increase of 6% as compared to the previous year, and it shares, together with the land use change sector (0.486 Gt CO2e), the ranking of the leading sources of GHG in Brazilian economy.

There is a prospect that the energy sector is the most important one in terms of GHG emissions. For the third consecutive year, due to unfavourable hydrological conditions, there was a reduction of hydraulic power supply. In 2014, the decrease represented 5.6%. The lower water supply explains the decline in the share of renewable sources in the electric matrix, from 84.5% in 2012 to 79.3% in 2013 and 65.2% in 2014, despite the increase of 3.177 MW in the installed capacity of the hydroelectric plants. Wind power reached 4.903 MW, which provided an 85.6% increase in this source of electricity generation. The final consumption of electricity in the country in 2014 displays an increase of 2.9%, provided by the expansion of thermal generation, especially from coal, natural gas and biomass plants (EPE, 2014).

The increase of GHG emissions in the energy sector was generated by the subsectors of transport, which emitted 3% more than in 2013; of electricity generation, which increased 23%, mainly due to activation of fossil power plants to cope with the drought that has run out the hydroelectric reservoirs in the Northeast and Midwest/Southeast Regions of the country; and of fuel production, which increased its emissions at 6.8%, due to the production and refining of oil and gas - which includes the exploration of pre-salt layer. Figure 2 shows the evolution of emissions of these subsectors.

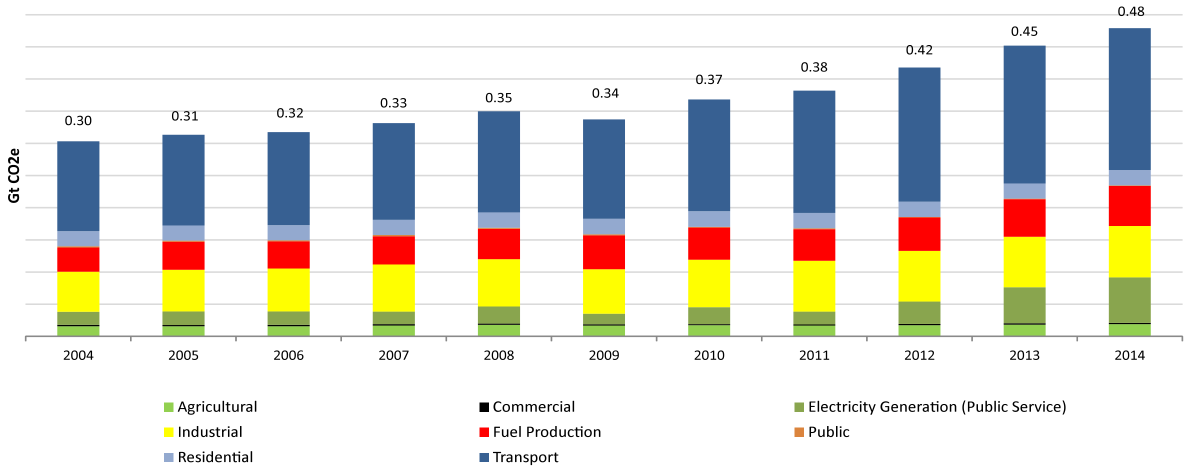


Figure 2. GHG Emission in Brazil by Subsector (2004-2014)
Source: Designed by the authors, based on SEEG (2015)

Brazil has a National Policy on Climate Change (NPCC), which defines the national voluntary commitment to adopt mitigation actions to reduce GHG emissions between 36.1% and 38.9%, being 2005 the base year, and a projection for 2020 estimated at 3,236 Gt CO2e (MMA, 2009). In 2015, Brazil and the United States agreed to increase bilateral collaboration, in accordance with the United Nations Framework Convention on Climate Change (UNFCCC), through joint efforts of both countries to meet the challenges set by climate change. Also in 2015, during the 21st UN Conference on Climate Change (COP21), Brazil committed itself to reduce GHG emissions up to 43% by 2030, and to achieve 45% of renewable sources in its energy matrix.

In order to meet the voluntary commitment, Sector Plans were designed in areas such as agriculture, combat f deforestation, industry, energy, transport and mining, including specific actions, indicators and goals to reduce emissions and mechanisms for verification of compliance. Brazil also intends to ban deforestation in the Legal Amazon and restore 12 million hectares of forests by 2030. According to EPE (2012), Brazil is expected to reach 226 million inhabitants in 2050. Of this total, nearly 90% shall live in urban areas, in more than 39 million new houses. It is expected that the Brazilian hydroelectric potential will not meet such demand.

The Ten-Year Plan for Energy Expansion 2023 establishes a reduction in the percentage of hydropower in Brazil's electric matrix from 65% to 59%. Despite the proposal to use renewable sources, it is expected the need to use more thermal energy - natural gas, nuclear and coal. (PDE, 2012).

The Brazilian energy policy already provides for the diversification of energy sources, taking advantage of regional characteristics, such as the construction of hydroelectric plants in the Amazon; wind plants in the Northeast; development of biomass out of sugarcane bagasse in the Southeast; use of natural gas in the Southeast and South (Sauer, 2013).

The first step to reduce GHG emissions in the energy sector is the development of emission inventories by companies belonging to this sector. One of the most used methods worldwide for the development of corporate emission inventories is the GHG Protocol. Besides being the most widely used method for preparation of inventories in organizations, the GHG Protocol Corporate Accounting and Reporting Standard adopts a methodology adapted to the national scenario. The initiative was implemented in Brazil by the Study Center for Sustainability of the Getúlio Vargas Foundation (FGV) and the World Resources Institute (WRI), with support from the Brazilian Business Council for Sustainable Development (CEBDS), World Business Council for Sustainable Development (WBCSD) and the Ministry of Environment (MMA) (GHG Protocol Brazil, 2008). The guideline provides information for the preparation of GHG emission inventories in different companies and organizations. The GHGs present in its scope are the same as in the Kyoto Protocol: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), sulphur hexafluoride (SF6), hydro fluorocarbons (HFCs), per fluorocarbons (PFCs). The method is compatible with ISO standards and the methodologies of the IPCC.

The methodology considers three scopes for measurement of emissions: a) Scope 1 - direct emissions, from sources owned or controlled by the organization; b) Scope 2 - indirect emissions, from energy consumption and c) Scope 3 – GHG indirect emissions, whose report is seen as optional, deriving from the activities of the company, but which come from sources that do not belong or that are not controlled by the company. There is no standardization of operational limits reported in scope 3, being it up to the companies to choose which sources to report. The GHG also has a number of tools to calculate emissions.

In the first year of implementation of the Brazilian GHG Protocol Program, in 2008, 23 inventories were published. In 2014, 132 inventories. Such growth was not found in the electricity and gas sector, despite the need to reduce GHG emissions, due to increased emissions from this sector, as shown in Figure 3 (GHG Protocol Brazil, 2015).

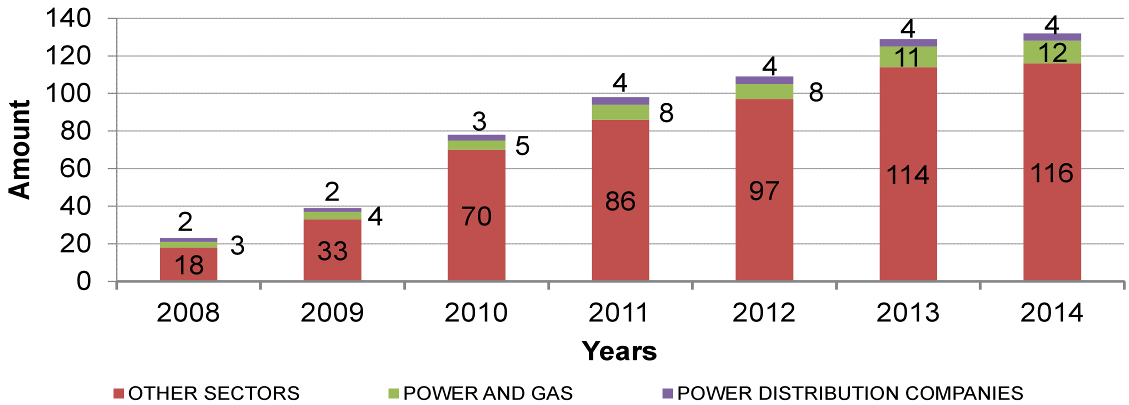


Figure 3. Number of companies participating in the GHG Protocol
Source: Designed by the authors, based on GHG Protocol Brazil (2015)

Brazil has 63 electricity distribution companies, responsible for providing energy to 75 million consumer units in 2014. Out of these companies, only 4 design the GHG inventory following the GHG Protocol, however, they consider as an organizational boundary all subsidiaries and units, including different segments. Only AES Sul has a disclosed inventory whose organizational limit is the operations of the company in the distribution segment.

Thus, in order to contribute to the increase of GHG inventories in the Brazilian energy sector, this paper aims to estimate GHG emissions in 2014 from the activities of an electricity distribution company located in the Northeast of Brazil and make a comparative analysis with the GHG emission data published in the inventory of AES Sul, located in Southern Brazil.

2. Methods

The Brazilian electricity sector is divided into four segments: generation (responsible for producing electricity), transmission (responsible for transporting electricity to large urban areas) and electricity distribution (responsible for receiving the energy from the transmission companies and transporting it to the final consumer), which have become independent business areas, and commercialization (responsible for the purchase and sale of energy).

For this work, the following data sources were considered:

For Coelba - Electricity Company of the State of Bahia - secondary data were used, collected from institutional documents of the company (sustainability report and management report), as well as the SAP-R3 information system. Primary data were obtained through interviews with eleven employees from different areas of the company (Management, Human Resource, Environment, Supply, Market and Loss Recovery).

As to the AES Sul, the secondary data used were collected from institutional documents of the company (sustainability report and GHG inventory published in the GHG Protocol framework), and the primary data were obtained through interviews with an employee of the General Production Board, responsible for preparing the inventory of the entire group of companies of which AES Sul is part.

2.1 Coelba Corporate Profile

Coelba is a distributor of energy, part of the Neoenergia Group, which operates in the generation, transmission, distribution and commercialization sectors, holding 87.84% of its shares. It also has a stake of 8.50% of the Spanish Iberdrola Group, 2.29% of the Pension Fund of the Bank of Brazil (Previ) and 1.37% of other shareholders, as shown in Figure 4.

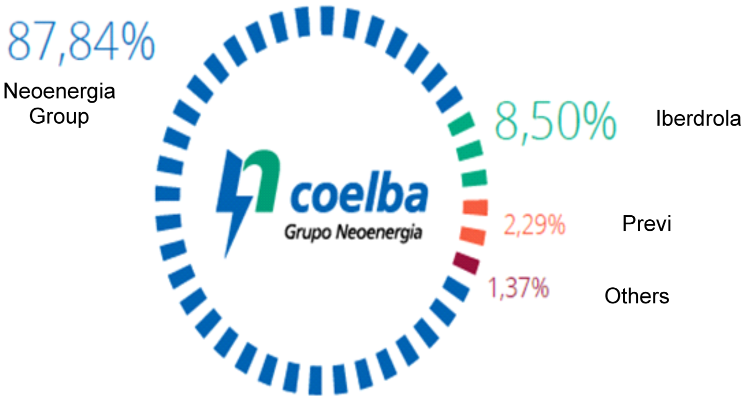


Figure 4. Coelba Shareholders' Participation
Source: Coelba Sustainability Report (2014)

Coelba is located in the state of Bahia, northeastern Brazil. The state occupies the 8th position in the national ranking of emissions, 0.0741 Gt CO2e. Of this total, 35.24% was emitted by the energy sector, with the largest shares of the sub-sectors of transport and electricity generation, in accordance with the results found in the country's emissions.

The company holds the concession for power distribution in 415 of the 417 municipalities in Bahia (99.5% of the total), covering an operation area of 563 thousand square kilometers. The total installed capacity is 5,600 MVA. In 2014, the company distributed 18,380 GWh - an increase of 4.7% as compared to 2013 - to 5.5 million customers. It is the country's third largest energy company in number of customers (ABRADEE, 2015) and the sixth one in amount of provided energy (ANEEL, 2015).

To mitigate the impacts of climate change on the operation, the company invests in adaptation strategies through research and development programs that improve the assertiveness of time review and the risks they pose to power supply. However, it does not have any action focused on the monitoring, control and reduction of its GHG emissions.

Table 2 shows some figures of Coelba.

Table 2. Coelba figures in 2014

Data	2014
Consumers	5.5 million
Municipalities	415.00
Concession area	559,951 km2
Employees	2,517.00
Outsourced employees	9,157.00
EBTIDA	1.43 billion
Installed power	5,640 MVA
Distributed power	18,380 GWh
Global power losses	3,154 GWh
Distribution transformers	219,187.00
Distribution lines	258,850 km
Transmission power lines	9,313 km
Substations	331.00

Source: Coelba Sustainability Report (2014)

2.2 AES Sul Corporate Profile

AES Sul is an electricity distribution company, member of AES Brazil Group, composed by companies in the segments of generation, distribution and services.

AES Sul is located in the state of Rio Grande do Sul, southern Brazil. The state ranks fifth in the national emission ranking, 0.0937 Gt CO2e. Of this total, 49% were emitted by agriculture and 28% by the energy sector, with the largest shares of the sub-sectors of transport and electricity generation, in accordance with the results found in the country's emissions.

The company holds the concession of 118 municipalities out of the existing 497, in the metropolitan regions and the Midwest of the state, covering an operation area of 99.5 thousand square kilometers. The total installed capacity is 1,900 MVA. In 2014, the company distributed 9,530 GWh - an increase of 6.2% as compared to 2013 - to 1.3 million customers.

Since 2013, GHG emission management has become part of the Governance System of the Impacts of Climate Change developed by AES Brazil, in order to evaluate the points of vulnerability and propose climate adaptation measures for all Group members. According to the commitment made by the Sustainability Platform, AES Brazil Group aims at a 10% reduction of GHG emissions by 2016, based on 2011.

Table 3 shows some figures of AES Sul.

Table 3. AES Sul figures in 2014

Data	2014
Consumers	1.3 million
Municipalities	118.00
Concession area	99,512 km2
Employees	1,635.00
Outsourced employees	1,372.00
EBTIDA	0.40 billion
Installed power	1,920 MVA
Distributed power	9,530 GWh
Global power losses	1,092 GWh
Distribution transformers	61,586.00
Distribution lines	64,711 km
Transmission power lines	19.91 km
Substations	62.00

Source: AES Sul Sustainability Report (2014)

Table 4 shows the total GHG emissions of the AES Sul, as well as divided by scope, presented in the company's emission inventory:

Table 4. GHG Emissions of AES Sul in 2014

	Equivalent CO2 emissions in metric tons (tCO2e)			
GHG (t)	Scope 1	Scope 2	Scope 3	Total
CO_2	3,450.90	131,573.79	1,274,991.50	1,410,016.19
CH_4	12.31	-	0.06	12.37
N_2O	71.39	-	1.09	72.48
HFCs	-		-	-
PFCs	-		-	-
SF_6	95.76		-	95.76
NF_3	-		-	-
Total (tCO2e)	3,630.36	131,573.79	1,274,992.65	1,410,196.80

Source: Designed by the authors, based on the GHG Protocol Brazil (2016)

Figure 5 shows the representation of the three scopes in the GHG inventory of AES Sul and the categories that make up scope 3. Most of the emissions classified in scope 3 refer to activities related to fuel and energy, not included in scopes 1 and 2 (99.40% of the total and 99.99% of scope 3).

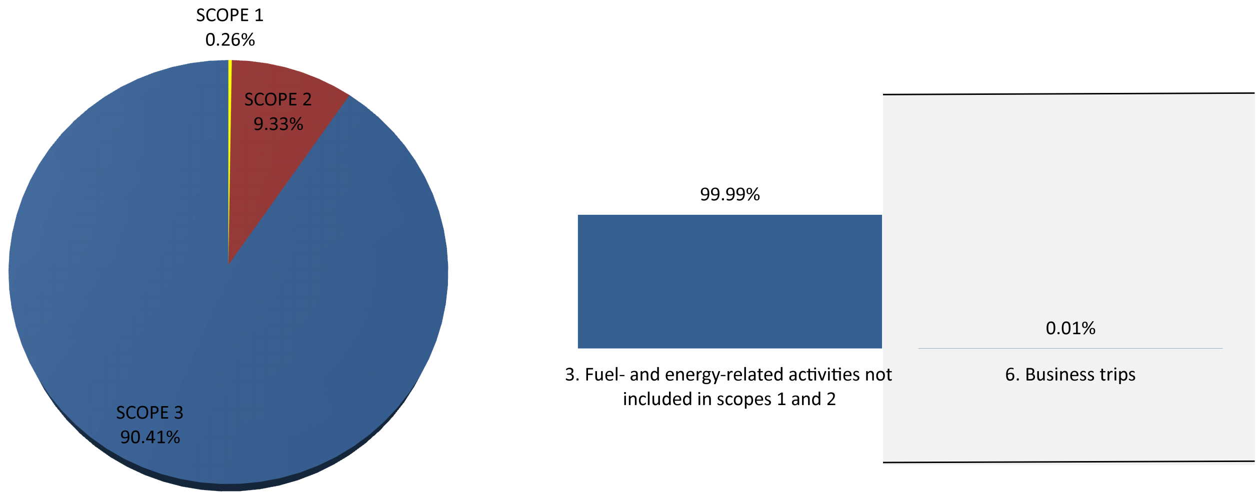


Figure 5. Representation of GHG Emissions (2014) of AES Sul by Scope
Source: Designed by the authors, based on the GHG Protocol Brazil (2016)

Figure 6 shows the location of the electricity distributors Coelba and AES Sul, in the Northeast and South of the country, respectively.

Figure 6. Location of Coelba and AES Sul
Source: CFF (2016)

3. Results and Discussion

Following a worldwide trend, and to allow the comparison with other companies in this segment, we used the 2016 version calculation tool, available on the GHG Protocol website and adapted to the national scenario, to estimate the emissions generated by Coelba activities in 2014.

3.1 Scope 1

3.1.1 Mobile Combustion

The mobile combustion of scope 1 is derived from the transportation of the company's own fleet. For the sake of the calculation, the total annual fuel consumption was taken into account, considering the type of road transport, since most of the company's transportation is done by motor vehicles (see Table 5).

Table 5. Estimated emission by mobile combustion – 2014

Type of fuel	Annual consumption (L)	Emissions (t)			Total emissions
		CO_2	CH_4	N_2O	(t CO_2e)
Ethanol	5,017.00	0.00	0.00	0.00	0.07
Gasoline	782,754.00	1,298.59	0.52	0.15	1,357.54
Diesel	1,195,490.00	2,935.52	0.18	0.16	2,986.95
Total	**1,983,261.00**	**4,234.11**	**0.70**	**0.31**	**4,344.55**

Source: Designed by the authors, based on the GHG Protocol Brazil (2016)

3.2 Scope 2

3.2.1 Indirect GHG emissions from energy

This category includes GHG emissions caused by the generation of the electricity consumed by the company, and by the loss of energy during distribution (see Table 6).

The electricity consumption of Coelba was 16 GWh in 2014. However, the largest impact on the increase of the total CO2 emissions in this category is due to electrical losses (3,154 GWh in 2014), and the increase in the electric energy emission factor of the National Interconnected System (SIN).

Table 6. Estimated indirect GHG emissions from energy – 2014

Source record	Electricity (GWh)	Total emissions (t CO_2e)
Own consumption	16.00	2,167.73
Global power losses	3,154.00	427,401.96
Total	**3,170.00**	**429,569.69**

Source: Designed by the authors, based on the GHG Protocol (2016)

The SIN is calculated based on the average emissions from electricity generation, considering all existing plants in the National Interconnected System, operating in a given period of time.

The increase over the previous year is mainly due to the increase in the activation of the thermoelectric plants to ensure the national energy supply.

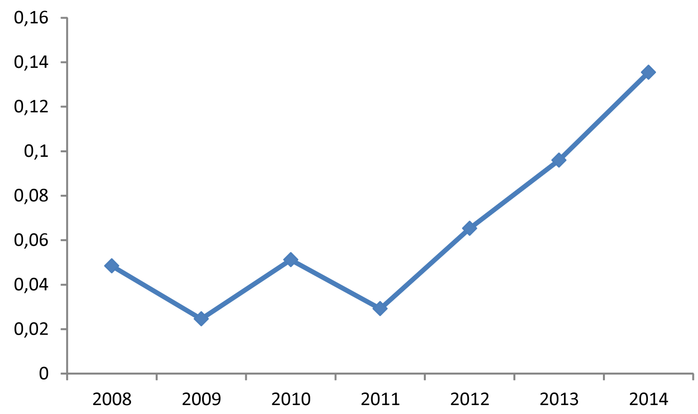


Figure 7. Evolution of the average emission factor of SIN

Source: MME (2015)

3.3 Scope 3

3.3.1 Purchased Goods and Services

In this category, only the emissions caused by the transportation and distribution of goods and services purchased by Coelba in 2014 are taken into account. For the calculation of these emissions, we were analyzed all material purchases made by the company: the mileage from the origin to the delivery of the product in the warehouse, weight of the material, number of trucks/trips (see Table 7).

Coelba receives the material and distributes it to the service providers who work in its 23 business units throughout the state of Bahia. This material is redistributed to be used in the construction sites of the company. All that transportation was considered for the sake of mileage calculation.

Type of fleet	Annual distance (km)	Emissions (t)			Total emissions
		CO_2	CH_4	N_2O	(t CO_2e)
Heavy diesel truck	14,369,661.12	10,377.84	0.86	0.43	10,527.86
Light diesel truck	332,186.00	145.66	0.02	0.01	149.13
Average-size diesel trucl	268,924.00	117.92	0.02	0.01	120.73
Light gas-powered comer	1,632,287.00	273.53	0.01	0.04	285.45
Total	**Total**	**10,914.95**	**0.91**	**0.49**	**11,083.16**

Table 7. Estimated emission of goods and services – 2014

Source: Designed by the authors, based on the GHG Protocol Brazil (2016)

In this category, we did not consider the emissions of services consumed by the company, such as telephone, water etc. The methods of calculations for service emission are being analyzed for this item to be covered in the next version of the inventory.

3.3.2 Fuel- and energy-related activities, not included in scopes 1 and 2

We considered all the energy acquired for distribution to final consumers, excluding the company's own consumption (see Table 8). This item is also influenced by the variation of the SIN emission factor.

Table 8. Estimated emission of fuel- and energy-related activities, not included in scopes 1 and 2 - 2014

Source record	Electricity (GWh)	Total emissions (t CO_2e)
Power distribution	18,364.00	2,488,015.93
Total	**18,364.00**	**2,488,015.93**

Source: Designed by the authors, based on the GHG Protocol Brazil (2016)

3.3.3 Business trips

The business trips made by employees were divided into air and land, because they use different emission factors.

For air travel, we used the 2016.0 version auxiliary tool of the GHG Protocol to calculate fractional transport emissions, which already informs emissions based on information from the airport of origin and of arrival, and the number of parts (see Table 9).

Land travel might occur using the company's own fleet, a taxi or a bus. The trips made by its own fleet were considered within scope 1, in the mobile combustion category, because it was not possible to target the fuel used by the fleet to perform service and to travel. For trips made by taxi, it was computed the mileage used in the year (see Table 10). This information was available in the SAP R3 system, in the monitoring of the service contract. The other trips taken by bus were not included in this version of the inventory. The company is trying to gather this information, because there is no specific control.

Table 9. Estimated emission of air business trips – 2014

Type o fair travel	Passanger mileage (km)	Emissions (t)			Total emissions
		CO_2	CH_4	N_2O	(t CO_2e)
Short distance (d < 500 km)	623,319.28	97.23	0.00	0.00	98.22
Medium distance (500 ≤ d < 3.700 km)	5,861,310.91	520.89	0.00	0.02	525.53
Long distance (d ≥ 3.700 km)	351,646.98	36.48	0.00	0.00	36.84
Total **Total**		**654.60**	**0.00**	**0.02**	**660.58**

Source: Designed by the authors, based on the GHG Protocol Brazil (2016)

Table 10. Estimated emission of land business trips – 2014

Type of vehicle	Type of fuel	Total distance (km)	Emissions (t)			Total emissions
			CO_2	CH_4	N_2O	(t CO_2e)
Car (taxi)	Gasoline	5,515,252.80	53.78	0.01	0.01	56.31
Total		**5,515,252.80**	**53.78**	**0.01**	**0.01**	**56.31**

Source: Designed by the authors, based on the GHG Protocol Brazil (2016)

3.3.4 Employees commuting

This category corresponds to the emissions associated with the employees commuting from their residence to the workplace during the year.

Coelba had 2,517 employees in 2014, with 1,417 residents of the metropolitan area and 1,100 in the countryside.

Adopted criteria for the choice of vehicle:

• Buses: for all employees who received transportation assistance;

• Car and motorcycle: for all employees who were in the company's vehicle registration;

• No motor vehicle: for everyone who lived within 2.5km from the company.

For the commuting calculation, we checked the distance between the home and the workplace using Google Maps, considering commuting to and from work. For those employees who commuted by car, we adopted a percentage of 20% more for the lunch time (see Table 11).

The 9,157 employees of service companies were not considered in this version of the inventory. The company is trying to find ways to gather information to enable the calculation or the adoption of criteria.

Table 11. Estimated emission of employees commuting – 2014

Type of vehicle	Type of fuel	Total distance (km)	Emissions (t) CO_2	CH_4	N_2O	Total emissions (t CO_2e)
Car	Gasoline	5,515,252.80	809.72	0.14	0.12	847.82
Motorcycle	Gasoline	294,216.00	13.12	0.01	0.00	13.52
Bus	Diesel	3,917,866.00	330.28	0.02	0.02	335.96
Total	**Total**	**9,727,334.80**	**1,153.12**	**0.17**	**0.13**	**1,197.30**

Source: Designed by the authors, based on the GHG Protocol Brazil (2016)

3.4 Total Emission

Table 12 shows the total GHG emissions of Coelba that was calculated and sorts out by scope:

Table 12.GHG emissions of Coelba in 2014

	Equivalent CO2 emissions in metric tons (tCO2e)			
GHG (t)	Scope 1	Scope 2	Scope 3	Total
CO_2	4,234.11	429,569.69	2,500,792.38	2,934,596.1
CH_4	0.70	-	1.09	1.79
N_2O	0.31	-	0.65	0.96
HFCs	-		-	-
PFCs	-		-	-
SF_6	-		-	95.76
NF_3	-		-	-
Total (tCO2e)	4,344.55	429,569.69	2,501,013.29	2,934,927.53

Source: Designed by the authors, based on the GHG Protocol Brazil (2016)

Figure 8 shows the representation of the three scopes in the Coelba GHG inventory. Most of the emissions classified in scope 3 is regards fuel- and energy-related activities not included in scopes 1 and 2 (84.77% of the total and 99.48% of scope 3). Even though it is not compulsory, we observe the relevance of the calculation of emissions in scope 3.

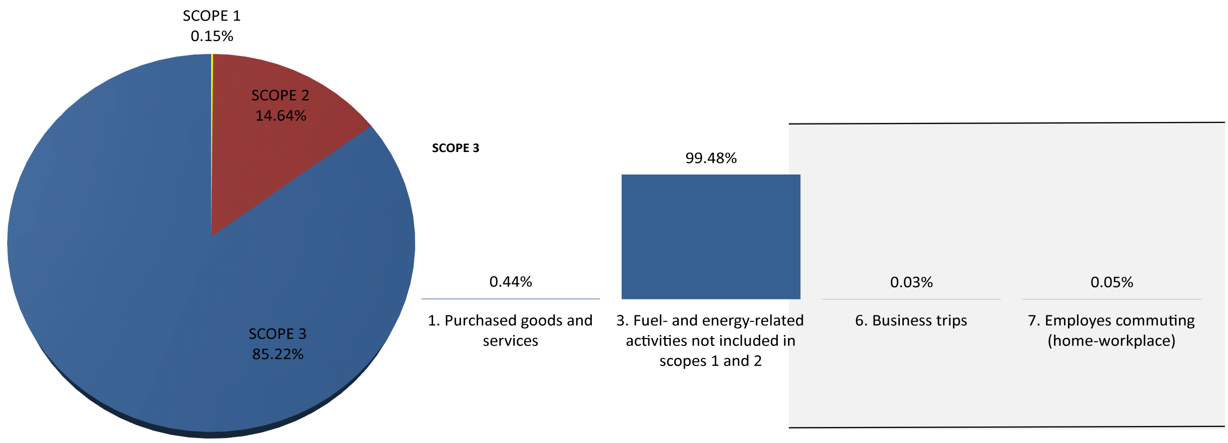


Figure 8. Representation of Coelba GHG emissions by scope

Source: Designed by the authors, based on the GHG Protocol Brazil (2016)

3.5 Comparative analysis of Coelba and AES Sul

Table 13 shows GHG emissions from activities of Coelba and AES Sul, segmented by scope and by categories. The boxes with ND have not been calculated by the corresponding company. This fact leads to comparison constraints, because, as can be seen in Table 16, in the AES Sul inventory, there are not any data on emissions from transportation of purchased goods and services nor on employees commuting (home-workplace). As to Coelba, it was not possible to calculate fugitive emissions.

Table 13. GHG emissions (tCO2e) in 2014: Coelba and AES Sul

SCOPE	CATEGORY	COELBA	AES SUL
SCOPE 1	Mobile combustion	4,344	3,534
SCOPE 1	Fugitives	NA	96
SCOPE 2	GHG indirect emission of energy	429,570	131,574
SCOPE 3	1. Purchased goods and services	11,083	NA
SCOPE 3	3. Fuel- and energy-related activities not included in scopes 1 and 2	2,488,016	1,274,876
SCOPE 3	6. Business trips	717	116
SCOPE 3	7. Employes commuting (home-workplace)	1,197	NA

Source: Designed by the authors, based on the GHG Protocol Brazil (2016)

To enable the comparison of the emissions of the two companies in the same segment, but with very different characteristics in terms of scale, we defined some criteria, presented in Table 14.

Table 14. Criteria for index calculation: Coelba and AES Sul

N°	Criterion	Unit	Coelba	AES
1	Number of consumers	In million	5.50	1.30
2	Concession area	Km2	559,951	99,512
3	Number of employees	Amount	2,517	1,635
4	Workforce (including outsourced employees)	Amount	11,674	3,007
5	Total distributed power	GWh	18,380	9,530
6	Power losses	GWh	3,154	1,092

Source: Designed by the authors

Table 15 shows the index results:

Table 15. Calculated indices of Coelba and AES Sul

SCOPE	CRITERION	INDEX	COELBA	AES SUL
SCOPE 1	2	**tCO2e / km2** = tCO2 emitted by the company's fleet by each km2 of concession area	0.01 tCO2e / km2	0.04 tCO2e / km2
SCOPE 2	1	**tCO2e / Consumer in million** = emitted tCO2e, refering to Coelba's own power consumption by each million	78,104 tCO2e / consumer in million	101,211 tCO2e / consumer in million
SCOPE 3	1	**tCO2e / consumer in million** = emitted tCO2e, refering to distributed power by each million consumers	452,367 tCO2e / consumer in million	980,674 tCO2e / consumer in million
SCOPE 3	3	**tCO2e / employee** = emitted tCO2e, refering to business trips by each employee	0.28 tCO2e / employee	0.07 tCO2e / employee
TOTAL	4	**tCO2e / workforce** = total emitted tCO2e by each employee (including outsourced ones)	251 tCO2e / workforce	469 tCO2e / workforce
TOTAL	5	**tCO2e / GWh** = tCO2e total emitted tCO2e by each distributed GWh	160 tCO2e / GWh	148 tCO2e / GWh
TOTAL	6	**KWh / tCO2e** = lost KWh by each generated tCO2e	1.07 KWh / tCO2e	0.77 KWh / tCO2e

Source: Designed by the authors, based on the GHG Protocol Brazil (2016)

The mobile combustion index varies due to the type of fuel and amount of kilometers covered or consumed liters. Coelba displayed a better index than AES Sul, even using diesel and gasoline in 99.75% of its fleet. This raises the hypothesis that Coelba better optimizes the use of vehicles for the provision of services than AES Sul does.

The indices of indirect GHG emissions of energy (Scope 2) and fuel- and energy-related activities not included in scopes 1 and 2 (scope 3) of AES Sul are much higher than the ones of Coelba. These categories are calculated based on the amount of energy distributed to consumers.

Despite the fact that Coelba has a number of consumers over four times greater than AES Sul does, the consumers of AES Sul have much higher average consumption than the consumers of Coelba. Among residential consumers of AES Sul, in 2014, only 8.8% were classified as low-income consumers. In Coelba, this percentage increases to 42.07% (ANEEL, 2016).

Coelba presents the business trip index 4 times greater than AES Sul. The biggest impact is related to air travel. This can be explained by the fact that Coelba is part of a group of companies presented in different regions of the country. Whereas AES Sul is part of a group of companies concentrated in the South and Southeast.

Three criteria for analysis of total emissions were used: workforce, distributed power and energy losses.

The workforce involves all employees, including the outsourced ones, providing service to the company. Coelba's workforce is almost four times greater than AES Sul's, contributing to the fact that the amount of tCO2e per workforce is very much reduced when compared with AES Sul. However, Coelba total emissions do not include the emissions related to the activities of outsourced employees, such as commuting and business trips.

The tCO2e/GWh index demonstrates how much GHG the companies emit to distribute 1 GWh of energy. AES Sul shows greater efficiency (148 tCOe/GWh) than Coelba (160 tCOe/GWh). However, this result is incomplete, because the inventories of the two companies still have several limitations, especially regarding the computation of emissions of scope 3.

As to the KWh/tCO2e index, it shows how many kWh are lost for each generated tCO2e. AES Sul (0.77 KWh / tCO2e) also showed greater efficiency in the process of losses than Coelba (1.07 KWh / tCO2e). The total amount of technical and commercial losses of AES Sul is smaller than Coelba's. It can be related to differences between the consumer profiles of each company.

4. Conclusions

The GHG inventory allows us to identify opportunities for improvement in operational efficiency as well as cost savings, because it allows companies to understand their GHG emission profile and the impacts on the environment, besides encouraging the adoption of sustainable practices throughout the market.

In addition, companies that already produce the GHG inventory are anticipating a market trend, since Brazil has already committed itself to a voluntary GHG reduction and it has developed sectoral plans.

The preparation of the GHG inventory of the activities of Coelba and the comparison with AES Sul inventory show the importance of such monitoring process by the companies.

This study has some limitations that prevent further comparative analysis, including: the scale economies between the two companies are very different, and the limitations arising from not estimating GHG emissions of some categories, more specifically those relating to scope 3. Since scope 3 is not mandatory, many companies do not calculate the emissions from all categories of this scope, often due to lack of information or to the cost to obtain the necessary information for the calculation of some categories of this scope.

For instance, for this article, some issues were not considered in the calculation of Coelba inventory: a) emissions of some services consumed by the company, such as telephone, water etc. b) bus trips made by employees, since there is no specific control of that information by the company; c) emissions caused by employees of service providers were not considered, because the company is still trying to find ways to gather information; d) fugitive emissions etc.

To continue this work, it is recommended: i) the calculation of Coelba GHG emissions from all categories not considered in this article; ii) the realization of a further comparative analysis of Coelba with other power distribution companies in Brazil that have GHG inventories, rather than AES Sul.

References

ABRADEE, 2015. Power industry. http://www.abradee.com.br (accessed 02.01.2016)

AES SUL. 2014. Sul Sustainability Report 2014. http://www.aessul.com.br (accessed 02.05.2016)

ANEEL. 2015. Information consumers. http://www.aneel.gov.br (accessed 02.01.2016)

CFF. 2016. Mapas. http://www.cff.org.br/ (accessed 03.10.2016)

COELBA. 2014. Coelba Sustainability Report 2014. http://www.coelba.com.br (accessed 02.05.2016)

Emissions Database for Global Atmospheric Research. 2015. Indicators. http:// http://www.eea.europa.eu/ (accessed 01.30.2016)

EPE. 2012. National Energy Balance 2012. https://ben.epe.gov.br/ (accessed 07.17.2012).

EPE. 2014. National Energy Balance 2014. https://ben.epe.gov.br/ (accessed 01.20.2016).

EPE. 2015. National Energy Balance 2015. https://ben.epe.gov.br/ (accessed 01.20.2016).

GHG Protocol Brazil, 2008. Specifications of the Brazilian GHG Protocol Program.

Second edition. FGV

GHG Protocol Brazil, 2015. Participants. http://www.ghgprotocolbrasil.com.br/ (accessed 02.10.2016)

GHG Protocol Brazil, 2016. Intersectoral tool (versão 2016.1.1). http://www.ghgprotocolbrasil.com.br/ferramenta-de-calculo (accessed 10.01.2015)

IPCC. 2014. Guidelines for National Greenhouse Gas Inventories, Intergovernmental Panel on Climate Change. (accessed 10.01.2015)

National Energy Balance. 2014. Synthesis report, Rio de Janeiro, Brazil

MMA. 2015. National Policy on Climate Change. http://www.mma.gov.br/clima/politica-nacional-sobre-mudanca-do-clima/ (accessed 11.02.2015)

MME. 2015. average emission fator of SIN. http://www.mme.gov.br/ (accessed 11.02.2015)

PDE. Decennial Plan for Electric Energy Expansion. 2012. National Energy Plan, Rio de Janeiro

Sauer, I. 2013. Política Energética. Estudos Avançados 27(78), 239-264. https://dx.doi.org/10.1590/S0103-40142013000200015

SEEG. 2015. Energy. http:// http://seeg.eco.br/en/panorama-energia/ (accessed 02.02.2016)

Multiple benefits of energy efficiency – the case of Austrian Energy Regions

Morgane M.C. Fritz[1], Rupert R.J. Baumgartner[2], Romana Rauter[3], Schöggl, J.-P.[4]

[1] Morgane M.C. Fritz, Institute of Systems Sciences, Innovation and Sustainability Research, University of Graz, Austria, morgane.fritz@uni-graz.at

[2,3,4] Rupert J. Baumgartner, Romana Rauter, Schöggl, J.-P., Institute of Systems Sciences, Innovation and Sustainability Research, University of Graz, Austria, rupert.baumgartner@uni-graz.at, romana.rauter@uni-graz.at, josef.schoeggl@uni-graz.at

Abstract

A recent publication from the IEA (OECD/IEA, 2014) shows that initiatives, programme or projects aiming at enhancing energy efficiency (EE) can provide multiple benefits to the economy and society in addition to energy savings. These benefits can for instance be an improvement of inhabitants' health in the case of building renovation. Publications on the topic are so far very limited since the focus of researchers in this field is rather set on quantifying energy savings, i.e. mainly economic and environmental impacts. Such approaches do not enable to assess the full economic, environmental or social impacts of energy efficiency improvements since not all impacts are quantifiable. Additionally, the multiple benefits of energy efficiency can also originate from initiatives that do not have energy savings as a primary goal. This is the case for instance of initiatives at a city or region level that aim at reaching energy autonomy and ensure a secured supply of energy to the inhabitants and companies of the city or region. Such a context is typical in Austria where more than a hundred so called "Energy Regions" were created in the past few years (Klima- und Energie-Modellregionen, 2015). The aim of this research is to show what multiple benefits can be expected from Energy Regions in Austria and analyse if these are similar to the ones identified by the IEA or if Energy Regions can expect any other multiple benefits of EE. This research is conducted via the qualitative content analysis of case-studies in Austria (project reports and scientific papers) according to Mayring and Gläser-Zikuda (2008). A focus is set on project and papers aiming at deriving policy recommendations or creating new business models for Energy Regions. Such analysis is complemented by a literature review (Fink, 2005) on the topic of multiple benefits of EE in Austria. The results show that Austrian Energy Regions can expect to benefit from the same benefits as the one identified by the IEA such as energy security, job creation or resources management. Additionally, the Energy Regions can also benefit from aspects that are specific to the Austrian context such as more motivation for cities that are not yet part of Energy Regions based on best practice examples of successful Energy Regions; an increased social value of the regions via the stimulation of networking between energy experts, the public administration and researchers or else; a stronger identification of inhabitant to their city and region and a higher acceptance for technological changes. The analysis also reveals that some EE initiatives may be counterproductive and hence bring "negative benefits" to the overall transition of Energy Regions towards energy independence. The results show that beyond the multiple benefits of EE identified by the IEA, there is also a need to identify country and region specific benefits. These benefits may indeed support project leaders, public utilities and inhabitants towards EE or non-EE related initiatives and hence contribute to economic, environmental and/or social value creation for cities and regions in Austria.

Keywords: Energy efficiency, energy regions, multiple benefits, Austria

References

Fink, A., 2005. Conducting research literature reviews: from the Internet to paper, 2. ed. SAGE Publications, Inc. doi:10.1111/j.1365-2648.2006.04033.x

Klima- und Energie-Modellregionen, 2015. Übersichtskarte der Klima- und Energie-Modellregionen. Retrieved from: http://www.klimaundenergiemodellregionen.at/start.asp?ID=242147&b=5121 (accessed 14 December 2015).

Mayring, P., Gläser-Zikuda, M., 2008. Die Praxis der Qualitativen Inhaltsanalyse, Beltz-UTB, Weinheim, p.299.

OECD/IEA, 2014. Capturing the Multiple Benefits of Energy Efficiency. IEA Publications, 2nd Edition, Paris, France.

Sustainable Development and the Climate Change Act 2008 – The UK's residential sector as a case study

K. S. Getvoldsen, T. E. Butt, C. House, M. R. Phillips

School of Architecture, Built & Natural Environments (SABNE), Faculty of Architecture, Computing & Engineering (FACE), University of Wales Trinity Saint David (UWTSD), Mount Pleasant Campus, Swansea. PostCode: SA1 6ED. Wales, UK Tel: 0044(0)7817139170; Email: t_e_butt@hotmail.com

Abstract

The Sustainable Development philosophy can be regarded as the most multi-, inter-, cross- and trans-disciplinary field of study. Sustainable Development has three principal dimensions which are the social / ethical, economic and environmental, and there are numerous implications which emerge from varying degree of interpolations and extrapolations of these dimensions. On the other hand, Climate Change, which is also a relatively new field of study, has been evolving as yet another significantly multi- and inter-disciplinary field of study. This field covers not only drivers and impacts of Climate Change but also Climate Change Mitigation and Adaptation which touch across a whole host of other fields of study ranging from the environment to socio-economic factors. So in the context of diversity of constituting subject areas, both Sustainable Development and Climate Change have substantial commonality. However, this commonality has so far been studied insufficiently, and therefore, there is a need of furthering the knowledge specifically on how the two with such a high degree of diversity and commonality can be related to each other in a supporting manner – 'hitting two birds with the same stone'. This paper is to advance knowledge in this direction, specifically employing the UK's Climate Change Act 2008 as a vehicle, which legally binds the country to cut emissions of greenhouse gasses by at least 34% by 2020 and by 80% by 2050 compared with 1990 levels. This paper investigates the UK's housing sector as a case study and carries out explicit mathematical calculations to demonstrate that even partly insulating the existing housing stock of the UK, how the aforesaid legal targets of the Act can be met. In doing so, the clear links are drawn between Climate Change and Sustainable Development that how come steps taken to tackle Climate Change can directly and indirectly be helpful to meet the national sustainability agenda.

Keywords: Sustainability; Sustainable Development; Green House Gases (GHG); Carbon Emissions; Energy Efficiency; Energy Management; and Climate Change Act 2008.

Biofuels face the current energy paradigm

Luzia Mendes Oliveira, Nelson Correia, and Egas Mascarenhas

Abstract

The discussion on biofuels had great relevance in the wake of successive increases in oil prices and later, with the emergence of problems surrounding global warming, a phenomenon resulting largely from the use and transformation of energy in various human activities, mainly in the transport sector. Biofuels can be a solution for building a low-carbon society and decreasing dependence on fossil fuels. The current energy paradigm, shows a trend for a decreasing for oil price and exploration of new forms of unconventional fuels (e.g. shale gas, oil sands), paradoxically to the future trend, where countries will have to take steps to make the compromises of Paris COP 21, meaning necessarily an energy transition. Both 4th and 5th reports of IPCC highlights, the importance of biofuels in the mitigation of greenhouse gases. They predict for 2030 an availability of technologies on the market for the production of 2nd generation biofuels to use in the transportation sector. Nowadays, renewable energy is about 19% in world energy matrix in which, biofuels, according to the International Energy Agency, represent a little more than 0.5%. If during a period, biofuels were seen as something profitable from an environmental economic and political point of view, since 2008 from now, they began to be highly contested in several ways such as: the threat to food security; low capacity in reducing emissions of greenhouse gases; contributing to reduction and loss of biodiversity and to soil and water contamination. On the other hand, new approaches have been explored the tradeoffs and synergies between different components of sustainability and climate change, highlighting the positive impact of biofuels on improving the living conditions of populations. The scope of this research was to analyze the controversies and arguments in favor of biofuels and growth prospects facing new climate challenges. Therefore, basing on literature review of various documents including developed policies in the producers countries; the increasing of strategy in the market and their impact on people's life and the environment. As conclusion, we emphasize: due to the controversy, producers countries have adopted policies consistent including legislation to guarantee a sustainable production and have invested in the research of technology for greater projection in the market; towards new developments in global climate policy and the necessity to change the current energy paradigm, biofuels have an important role to decarbonize the transport sector. Finally to overcome the critical side of biofuels production, all its policies should always be considered the economic, social and environmental balance.

Keywords: biofuels; climate change; energy paradigm.

The energy transition in Portugal: business strategies, policy and context shifts

Isabel Salavisa , Cristina Sousa and Teresa Calapez

Abstract

Portugal is an interesting case study in energy transition, due to its successful and rapid move towards renewable energy. A new sector has been formed at the confluence of technological opportunities and strong policy incentives, with the creation of a large number of new technology-intensive firms and the entry of some major incumbents into the business. This paper focus on the strategies deployed by the firms, taking advantage of the evolution of technologies, scale economies and more favourable market conditions, while also facing policy shifts, macroeconomic constraints and uncertainty. With the Portuguese budgetary crisis, severe restrictions impacted the sector, combining the decrease of incentives with a substantial rise of uncertainty. However, favourable shifts have also been at work. In fact, technologies have become more cost-effective, albeit at a differential pace in the various technological areas. Innovation and market strategies have played a major role in the way companies have dealt with these contextual shifts. These strategies have had distinct degrees of success due, among other aspects, to the heterogeneity of technological areas within the renewable sector. In addition, other policies have affected the sector such as European anti-dumping measures. We adopt a framework that: a) addresses context shifts (domestic and European policy, operating in domains such as the development of technologies, business supportive schemes, R&D support, and fiscal and trade policy; world competition; public acceptance) and their impact on the companies' strategies; b) takes into account the distinctive evolution path of the various renewable energy technologies; c) addresses the interplay between firms' innovation and market strategies. The framework is applied to 60 Portuguese renewable energy technologies firms. Data were collected through detailed interviews, based on a semi-structured questionnaire, with the founders or CEOs, complemented with extensive documentary information. The analysis permitted to identify: 1) the existence of distinctive strategies according to dimensions such as the technological area or the company´s origin; 2) the adequate matches of innovation and market strategies; 3) the impact of perceived obstacles and opportunities on the companies' strategies and achievements; 4) the evolution prospects. Conclusions draw on the Portuguese case aiming to contribute to the general debate on energy transition.

Keywords: renewable energy technologies; energy transition; business strategies; innovation strategies; renewable energy policies.

Curbing the Paradox: The challenges of achieving sustainable energy access in Namibia, Southern Africa

François Diaz-Maurin[a,*], Zivayi Chiguvare[b], Gideon Gope[c], Lukas Wayiti[c], Miguel Castro Gómez[d], Felipe Yunta Mezquita[d]

(a) Institute of Environmental Science and Technology (ICTA), Universitat Autònoma de Barcelona, Bellaterra 08193, Barcelona, Spain.

(b) Namibia Energy Institute (NEI), Namibia University of Science and Technology, Windhoek, Namibia.

(c) Department of Electrical and Computer Engineering, Namibia University of Science and Technology, Windhoek, Namibia.

(d) Department of Agricultural Chemistry and Bromatology, Universidad Autónoma de Madrid, Spain.

*: (Corresponding author) Tel. +34 935 86 86 36. E-mail address: Francois.Diaz@uab.cat

Abstract

The vast majority of the 2.4 Million population in Namibia does not benefit from sustained access to modern energy. This concerns both rural and urban populations although unevenly affected. In rural areas, where population is scattered over a large territory, communities are mainly relying on biomass fuelwood and paraffin uses for cooking and lighting, and have very scarce access to imported gasoline for transportation. In addition, the vast majority of rural households are disconnected from the electric grid and renewable energy systems, like photovoltaic (PV) systems, remain marginal. In urban settings, although access to transportation fuels and services is made easier, about a third of the households do not have sustained access to electricity. Overall, lack of electricity access concerns about half the population of Namibia. Despite these issues, communities suffer from the paradoxical situation of scarcity in abundance that characterizes most countries of the Southern Africa region. Namibia's territory benefits from an abundance of resources with one of the highest rates of annual solar radiation on the planet, high wind energy potential especially in the coastal areas, and one of the largest uranium deposits worldwide. Yet, achieving sustainable energy access in Namibia faces many technical and societal challenges on the supply side. The paper focuses on the challenges posed to the generation of electricity in Namibia. The study intends to support policies on energy access, efficiency and security providing an integrated assessment of alternative energy systems at national level. The integrated analysis of the energy metabolism in Namibia is based on the MuSIASEM approach (Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism). MuSIASEM is capable of keeping coherence of information referring to different dimensions and different scales of analysis. This accounting method can be used as: (i) a diagnostic tool – describing the current energy matrix in Namibia; and (ii) a simulation tool – characterizing the desirability, viability and feasibility of some scenarios based on policy options considered as relevant by the Government of Namibia. We investigate the potential for three energy scenarios: nuclear power, concentrated solar power (CSP) and wind power. These scenarios refer to the deployment of large-scale energy systems. Looking at environmental, economic and societal constraints, we compare the potentials of these three alternative energy technologies on the domestic supply of electricity generation. The integrated analysis shows that the development of large-scale energy projects is limited by economic costs, spatial constraints, resources availabilities and/or insufficient institutions. The study reveals that the supply of large-scale energy technologies alone cannot lead to sustainable energy access in Namibia. Rather, the potential of disconnected small-scale renewable energy systems should be assessed, especially in remote areas. Consequently, rather than focusing on alternative energy systems, we claim that more attention should be given in energy policies to alternative development pathways. This requires revisiting the conventional paradigms of clean energy and development typically adopted by governmental and international institutions. Curbing the paradox of sustainable energy access in Southern Africa calls for more holistic approaches.

Acknowledgement: This study was carried out under the EDULINK II project "Participatory Integrated Assessment of Energy Systems to Promote Energy Access and Efficiency" (PARTICIPIA), contract DCI-AFS/2013/320-333.

Keywords: integrated analysis, energy security, nuclear power, concentrated solar power, wind power

Carbon reductions through composting food waste for food production: Understanding people's experiences, drivers and challenges of composting in different urban settings

Belinda Christie and Vivienne Waller

Abstract

Due to population growth and the increase in single person households, food waste is rising in many nations. One-third of the food produced globally is wasted every year, much of it entering landfill. As one of the largest emitters of methane, landfill directly contributes to climate change. The efficient diversion of food waste from landfill through composting can therefore help abate global emissions. Large scale, and high density, cites (such as New York, Portland, San Francisco, and Vancouver) have proven the success of using offsite composting to divert food waste from landfill. What is unknown however is how different systems for onsite composting compare with offsite composting in reducing greenhouse gas emissions, producing quality compost for growing food, and encouraging people's engagement in the compost process. As cities throughout world consider alternatives to landfilling food waste, the need to understand the experiences, attitudes, drivers and challenges to people's engagement with composting is critical. Without such understanding, efforts to divert food from landfill will be ineffective. Therefore an Australian Cooperative Research Centre (CRC) for Low Carbon Living study is currently being undertaken by Swinburne University, Melbourne, and the University of South Australia, Adelaide. The project pilots various models for composting household and commercial food waste, for the purposes of growing food. In particular, it compares different models of on-site composting (such as worm farms and 'in-vessel' 24 hour composters) and off-site composting (kerbside collection) in different urban settings (offices, multistorey apartment buildings, suburban houses, cafes and commercial kitchens, among others). The study investigates three domains: which systems are most effective in reducing greenhouse gas emissions, which produces the better compost product, and which are the most successful in engaging people in composting processes. This presentation will present the preliminary findings from the latter social research domain of the study. Results from case study interviews, focus groups, questionnaires and observations conducted with people involved in food separation and composting at the various sites will be discussed. In doing so, the presentation will explore questions such as, how do people understand and experience food separation and composting, what are the drivers and challenges toward people's engagement in food separation, composting, use of compost itself and in growing food, and how does composting food waste for food production contribute to community building? The lessons learnt from this study will be of interest to those wishing to identify opportunities, constraints and solutions to creating sustainable cities and reducing urban greenhouse gas emissions.

Keywords: greenhouse gas emissions, sustainable practices, cities, landfill, food systems

Electricity saving potential in the small business service sector – case-study Telheiras, Portugal

Miguel Sequeira[1], João Joanaz de Melo[2]

[1] Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa (c/o. Dept. Environment), 2829-516 Caparica, Portugal, m.sequeira@campus.fct.unl.pt

[2] CENSE, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, 2829-516 Caparica, Portugal; jjm@fct.unl.pt

Abstract

Energy is a crucial challenge for sustainable development. Among the options to reduce consumption and greenhouse gas emissions, energy efficiency is recognized as the most promising one. In the EU, a number of studies have identified an economic saving potential between 20% and 30% for the service sector, which remains mostly untapped. Although the topic of energy efficiency has been explored in depth before, there is little organized information about the service sector and, in particular, about its small and medium enterprises. In 2013, this sector was responsible for 34% of the final electricity consumption of Portugal. In this context, the main objective of the present study is to explore the electricity saving potential in the small business service sector. The selected case-study was Telheiras, a neighborhood of Lisbon, where 13 establishments were subjected to detailed energy audits and 37 to simpler walk-through audits. This information was extrapolated for a total of 107 similar establishments in the neighborhood. The detailed energy audits indicate an average cost-effective saving potential of 39% of current energy consumption. If only measures with payback period under three years are accepted, the saving potential is of 27% of current consumption, with an average investment of 317 € per establishment. In the 107 establishments of Telheiras, this translates to annual savings of 218 MWh. The extrapolation of this high profitability potential to the national scale suggests a reduction of 1% to 2% of Portugal's electricity consumption. One way to achieve this potential is to contract energy efficiency services. However the owners of these establishments seem to prefer the involvement of local actors in detriment of large energy utilities. The main driver of action is the need to cut costs and the main barriers are the low priority given to energy and insufficient knowledge. The introduction of an energy audit program could provide the needed support for the adoption of energy efficiency measures.

Keywords: energy efficiency, service and commerce sector, small and medium enterprises, local case study, drivers and barriers

1. Introduction

Energy is the vital force of human society. However the scale of its consumption is causing serious negative consequences in earth's atmosphere, hydrosphere and biosphere (Bilgen, 2014). In this context, it is crucial to transform the current energy system with a transition to renewable sources and efficient use (Leijten & Bolderdijk, 2014).

Energy efficiency is widely recognized as the most cost-effective and readily available option to deal with the problems associated with energy, with multiple benefits to society (IEA, 2014). The World Energy Council (WEC, 2013), among many other authors, states that there is a significant potential for improvement in energy efficiency, which remains mostly untapped. Although energy efficiency improvement appears to be an attractive goal, progress has been slow. This energy efficiency gap is caused by a series of barriers that hinder the implementation of cost-effective measures (IEA, 2012).

Buildings account for 40% of final energy consumption in the European Union (EU) and present the largest energy saving potential among major energy consuming sectors (Eurostat, 2015).

PwC *et al*. (2014) have estimated an economic saving potential of 28% for the final energy consumption of the service sector in the EU until 2030, in comparison with a reference scenario (the service sector includes all the activities associated with commerce, finance, public administration, health, food services, lodging, education and other services).

Since 2005, Portugal's final energy consumption has been decreasing, due to the combined effects of economic crisis, efficiency policies and technological progress. However, the energy intensity of productive sectors in Portugal is still 27% above the average value for the EU (Government of Portugal, 2014). In 2013, buildings accounted for 30% of final energy consumption and the service sector was the second largest electricity user with 34% of total consumption (DGEG, 2016). In particular, the low voltage electricity consumption of the service sector (mostly at 230 V) constitutes 15% of Portugal's total consumption (DGEG, 2015b).

In comparison with industry and transports, the service sector is less energy intensive. However, in recent years it showed the largest growth among economic activities in the EU, prominently in electricity consumption (Eurostat, 2015). In Portugal, services final electricity consumption more than doubled between 1990 and 2013. In 2013, electricity satisfied around 75% of the sector energy needs. More importantly, energy intensity deteriorated in comparison with 1995 levels (DGEG, 2016). In 2013, the energy intensity of services was 5.5 MWh/employee/year (Odyssee, 2016). The specific consumption per area for non-domestic Portuguese buildings was 237 kWh/m^2/year in 2008 (Entranze/Enerdata, 2013).

Several authors (*eg*. Gruber *et al*., 2008; PwC *et al*., 2014) state that the main end uses of electricity in the EU's service sector are lighting, HVAC systems, and other equipments. Data from Portugal (DGE, 1994) and the USA (D&R International, 2012) indicate that food services, food sales and healthcare are the most energy intensive subsectors. As the consumption patterns differ significantly among subsectors, it is necessary to gather information on individual activities (IEA, 2014).

In several large services buildings in European countries, Gruber *et al*. (2008) identified achievable electricity savings potentials of around 20% of current consumption, with few differences between subsectors. The present levels of energy efficiency adoption vary between subsectors and enterprises, with office activities and larger corporations taking the lead (WSBF & Carbon Connect, 2013). The main driver for improvement of energy efficiency in the service sector (as elsewhere) is reduction of operational costs (Retail Forum, 2009).

In the service sector, Schleich & Gruber (2008) suggest that the main barriers to energy efficiency are split incentives (investment and operations do not have the same decision-makers), insufficient knowledge about current consumption and lack of information about specific measures. In particular, many barriers remain in small and medium enterprises (SME) where energy has a low priority and no resources are allocated for its management (Fleiter *et al*., 2012). Also, SME of the service sector often suffer financial difficulties and do not consider investments with a return period greater than three years (WSBF & Carbon Connect, 2013); similar results were found for industrial SME in Portugal (Brazão & Melo, 2012). Experiences in Germany show that the existence of an energy audit program focused in this sector can help to overcome some of the barriers to energy efficiency (Schleich & Gruber, 2008).

An energy audit is an important tool for exploring the energy saving potential of a building or activity (EC, 2013). However the implementation of the proposed energy efficiency measures is also crucial. Specific measures include the upgrade or renovation of equipments, the management and operation of systems and the behavior of individuals.

2. Methods

The main goal of the study was to explore the energy saving potential in the small business service sector. The selected case-study was Telheiras, a neighborhood of Lisbon, with an area of 51 ha (figure 1).

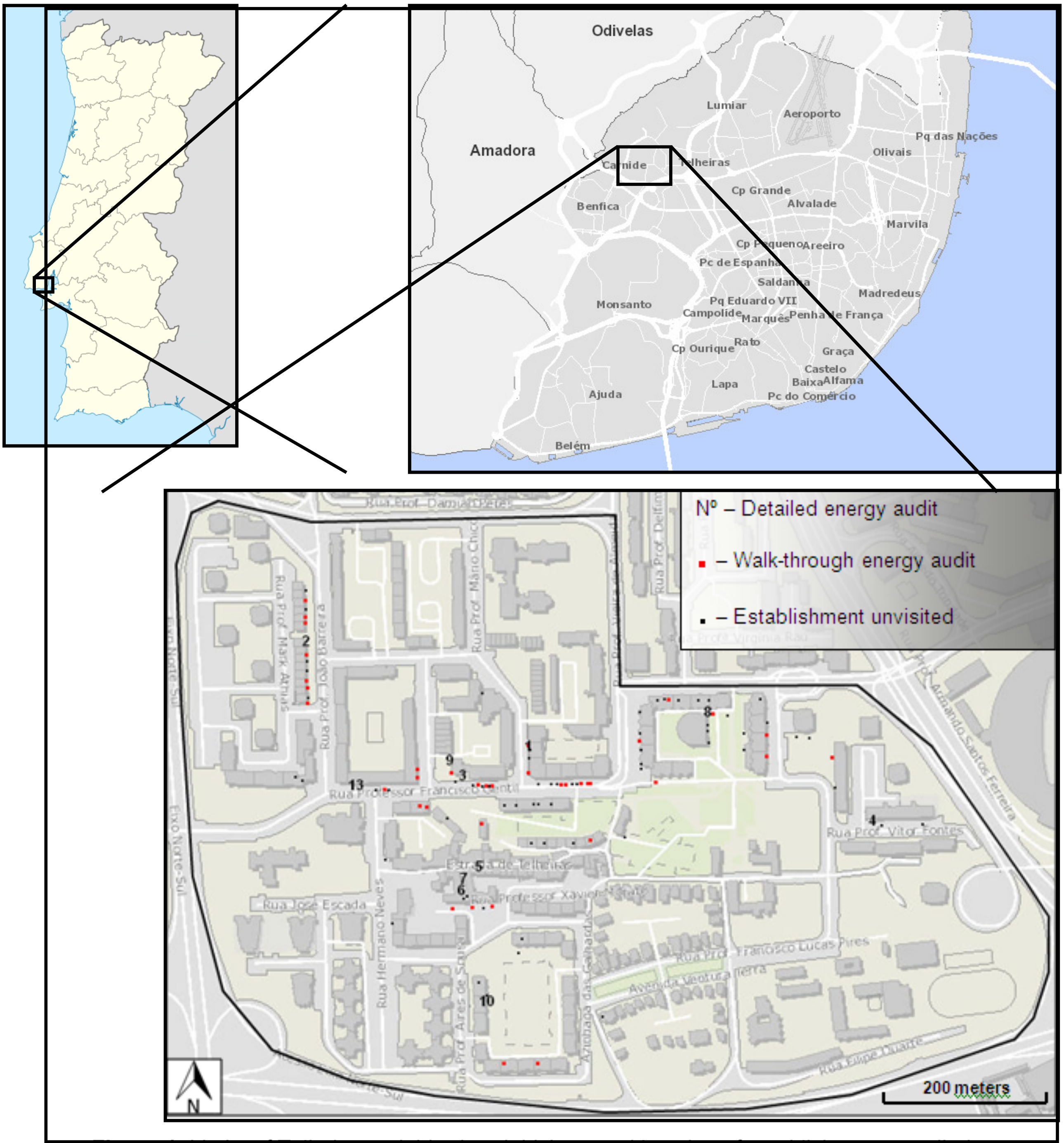


Figure 1. Limits of Telheiras neighborhood, Lisbon, and location of establishments studied

The first step was a census of all commerce and services establishments in the area, conducted in March 2015. The establishments were divided according to size (large or small) and type of activity (general shops, refrigerated products, food services, health and beauty, cultural association, print shop, offices, and others). In March 2015, there were 160 service and commerce entities in the neighborhood, of which 148 were small establishments. As a matter of priority, establishments classified as offices and as others were excluded from the scope of the study (offices have been the object of many other studies, and "others" were too diverse for a meaningful analysis), leaving 107 establishments as the study universe. Of these, 50 establishments were subjected to energy audits (13 detailed audits and 37 walk-through audits).

Thirteen establishments were subject to detailed energy audits in order to identify their energy consumption patterns, specific efficiency measures and investment costs, saving potentials, and specific energy consumption indicators. Electricity consumption data were collected through direct measurements, technical specifications of equipments and patterns of use provided by the owners. Energy efficiency measures were identified with information from the literature and from market research. Selected measures are presented in table 1.

Table 1. Energy efficiency measures recommended in the scope of the detailed energy audits

Electricity end use	**Description of the energy efficiency measure**
Lighting	Upgrade to LED light bulbs
	Installation of movement sensors and light sensors
Cooking	Elimination of phantom load
Refrigeration	Purchase of efficient equipment
	Proper maintenance
	Installation of glass doors in open displays
Hygiene and cleaning	Purchase of efficient equipment
Office equipment	Elimination of unnecessary consumption and of phantom load
Water heating	Installation of solar thermal systems
	Deactivation during holidays
Climatization	Purchase of efficient HVAC equipment
	Good practices in the operation of air conditioning units
	Rehabilitation of constructive elements

The energy saving potential was calculated depending on the payback time on investment, with a discount rate of 7% and with 2015 energy prices (ERSE, 2015). The savings potential was separated in four types: technical potential (no restrictions), economic potential (payback time shorter than 15 years), medium profitability potential (payback time shorter than 6 years) and high profitability potential (payback time shorter than 3 years). The cost of avoided consumption was computed for the lifetime of the measures (ERSE, 2013). The information from individual audits was aggregated by category of activity. An average retail category and an average small establishment category were created on the basis of the number of establishments in the neighborhood. Specific energy consumption indicators were calculated for shop area, number of employees, number of working hours, and number of clients.

For the other 37 establishments, a simpler walk-through audit was performed to verify the opportunities and difficulties recognized before. This allowed for an extrapolation of the results obtained in the detailed audits to the neighborhood scale.

Finally, the combination of case-study data with national statistics supported a tentative extrapolation of the results to the national scale. This procedure was executed for the relevant activities on the basis of the low voltage electricity consumption statistics (DGEG, 2015a) and the number of workers in enterprises with less than 10 persons employed (INE, 2016).

3. Results and discussion

The results of the 13 detailed audits were aggregated according to the activity of the establishments and are shown in table 2. The most energy intensive categories are refrigerated products commerce and food services and the less energy intensive is general commerce.

These results concur with those previously reported by DGE (1994) for Portugal and D&R International (2012) for the USA, in terms of hierarchy of specific consumption, although actual values vary widely. The comparison with the specific consumption per area (Entranze/Enerdata, 2013) and per employee (Odyssee, 2016), reported for Portugal's service sector as a whole, indicates that the small business service sector is less energy intensive.

Table 2. Average specific energy consumption in fully audited establishments

Activity	Cost per establ. (€/year)	Consumption per establ. (MWh/year)	Specific energy consumption indicators			
			$\frac{kWh}{m^2.year}$	$\frac{MWh}{employee.year}$	$\frac{kWh}{working\ hour}$	$\frac{kWh}{client}$
Retail	1 262	5.9	106	3.4	2.0	1.1
- General	570	2.3	39	1.4	1.0	0.9
- Refrigerated	5 788	28.4	531	15.8	8.3	2.0
Food services	3 263	15.5	271	10.2	5.8	3.3
Health and beauty	680	2.9	92	1.6	1.2	1.4
Cultural association	691	3.2	45	3.2	1.0	0.9
Print shop	1 045	3.4	50	1.7	1.1	1.1
Average	1 609	7.3	138	4.6	2.7	1.7

During the energy audits, energy consumption was divided by type of use, with the results shown in figure 2. For the average establishment, the main end use is the HVAC system, with heating and cooling presenting similar shares, followed by lightning and refrigeration.

The comparison with data concerning the service sector of the EU (Gruber *et al*., 2008; PwC *et al*., 2014) confirms the importance of the HVAC system and lighting, although in reverse order. This difference may be explained by better availability of sunlight during office hours in Portugal, warmer climate, and different architecture and construction standards (poor construction often prevailing in Portugal).

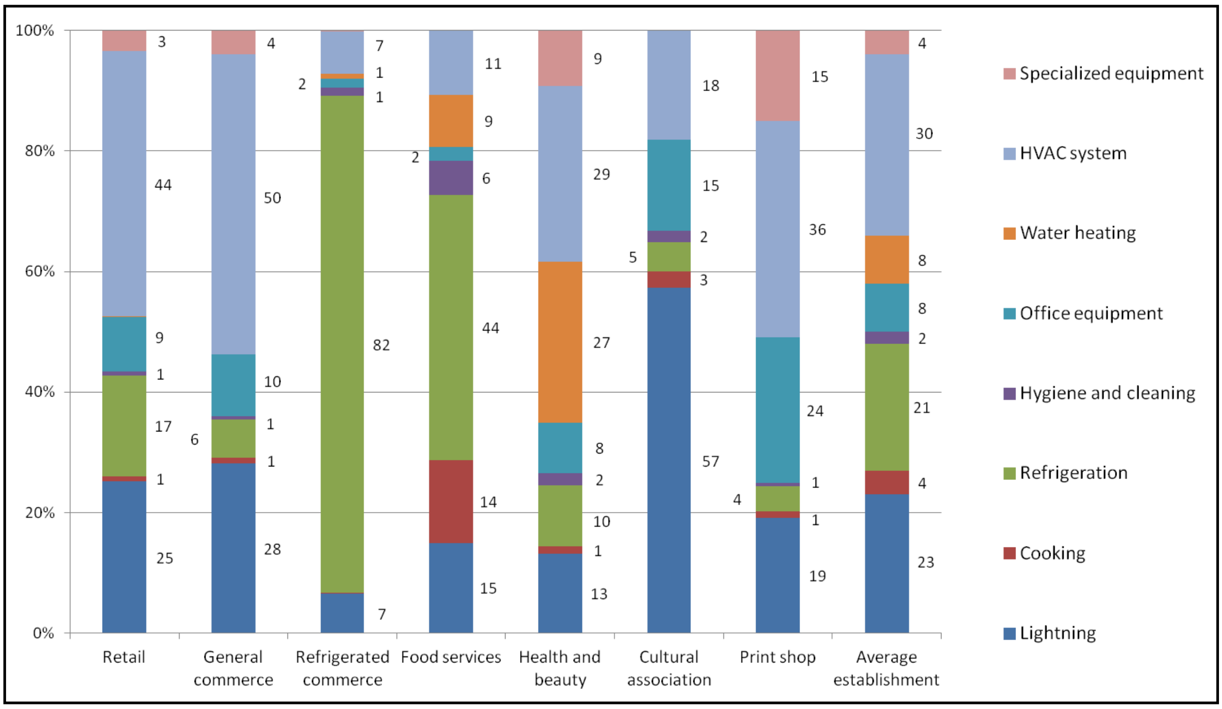


Figure 2. Average energy consumption by end use and category of activity

The implementation of the suggested energy efficiency measures allows the energy savings presented in figure 3, in comparison with current consumption. The average investment cost per establishment to attain these electricity saving potentials is presented in table 3 for each category of activity. A reduction of an average of 6% of current consumption is attainable through behavioral measures with no investment costs.

The comparison between the saving potentials presented in this study and the ones calculated by Gruber *et al*. (2008) and by PwC *et al*. (2014) for the service sector in various European countries confirms the plausibility of results obtained. In fact, the economic saving potential identified through energy audits in small establishments of the service sector appears to be superior to the values identified by Gruber *et al*. (2008) through energy audits in large service buildings.

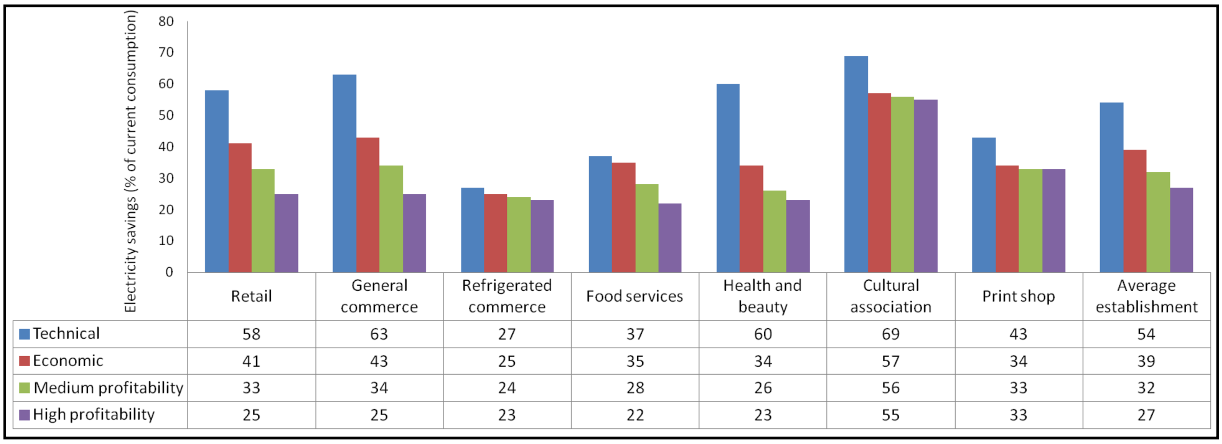


Figure 3. Average savings potential in comparison to current consumption for the different activities

Table 3. Average investment per establishment to attain energy saving potentials

Activity	Investment to attain energy saving potentials (€/establishment)			
	Technical potential	Economic potential	Medium profitability pot.	High profitability potential
Retail	7 220	871	490	346
- General	7 539	612	225	82
- Refrigerated	5 199	2 512	2 164	2 023
Food services	4 983	2 383	1 224	526
Health and beauty	7 509	622	175	109
Cultural association	1 813	240	184	175
Print shop	3 292	133	96	96
Average	6 156	1 123	568	317

Recommended energy efficiency measures focus in the various electricity end uses. For the average establishment, the saving potentials for each end use are presented in table 4.

The greatest cumulative savings with high profitability for the average establishment are available in refrigeration, followed by lightning and the HVAC system. Climatization presents the greatest technical cumulative savings potential; however the costs of the whole package of measures are often high, because they involve rehabilitation of construction elements. Typically construction rehabilitation is performed with the major goal of improving comfort, with the bonus of saving energy in the long run.

Table 4. Energy saving potentials by end use for the average fully audited establishment

Electricity end use	Saving potential (% of current consumption)			
	Technical	Economic	Medium profitability	High profitability
Lightning	72	72	69	67
Cooking	35	34	34	34
Refrigeration	55	34	21	13
Hygiene and cleaning	6	0	0	0
Office equipment	43	43	43	43
Water heating	74	26	5	1
Climatization	58	28	22	17

The exploration of the identified potentials produces cumulative energy savings during the lifetime of the energy efficiency measures. Table 5 shows the cost of avoided consumption during the lifetime of the energy efficiency measures.

For the economic saving potential, the results show that the cost of avoiding the consumption of one kWh is smaller than the cost of purchasing one kWh. In addition, it is cheaper than producing electricity through both renewable and conventional sources, contributing to the perspective that energy efficiency should be the priority in Portugal's energy policy.

Table 5. Cost of avoided consumption in the lifetime of the measures in fully audited establishments

Activity	Cost of avoided consumption (€/avoided kWh)			
	Technical potential	Economic potential	Medium profitability pot.	High profitability potential
Retail	0.364	0.037	0.021	0.012
- General	0.407	0.039	0.021	0.010
- Refrigerated	0.046	0.025	0.023	0.021
Food services	0.063	0.030	0.022	0.013
Health and beauty	0.278	0.036	0.017	0.013
Cultural association	0.080	0.015	0.012	0.012
Print shop	0.177	0.010	0.008	0.008
Average establishment	0.252	0.033	0.019	0.013

Crossing information from detailed energy audits, walk-through energy audits and the census of commerce and services establishments allowed an estimation of the annual energy consumption for 107 establishments that formed the study universe (table 6).

Table 6. Estimate of annual energy consumption of 107 service establishments in Telheiras

Activity \ Extrapolation method	Energy consumption (MWh/year)				
	Nº of establishments	Area	Nº of employees	Nº of working hours	Average
General commerce	87	86	86	93	88
Refrigerated commerce	170	190	213	175	187
Food services	418	461	760	545	546
Health and beauty	69	90	81	69	77
Cultural association	29	31	29	21	28
Print shop	10	9	10	9	10
Total	783	867	1 179	912	936

The extrapolation of the identified energy saving potentials to the neighborhood scale is presented in table 7. The exploration of the high profitability saving potential, where the long term benefits are 13 times larger than the initial costs in the perspective of the enterprises, seems to be particularly attractive. The annual savings associated with this potential in the 107 establishments of Telheiras could provide enough energy to satisfy the annual needs of 28 Portuguese families.

Table 7. Estimate of annual energy savings potential in 107 service establishments in Telheiras

Activity	Annual energy saving potentials (MWh/year)			
	Technical	Economic	Medium profitability	High profitability
General commerce	55	38	30	22
Refrigerated commerce	50	46	45	43
Food services	187	169	143	117
Health and beauty	47	27	20	18
Cultural association	19	16	15	15
Print shop	4	3	3	3
Total	362	299	256	218

Because most of the energy used in audited establishments was electricity, it was decided to compare it with electricity consumption at national level. The results, shown in table 8, indicate that the type of establishments analyzed use between 4% and 8% of Portugal's total electricity.

Table 8. Estimate of national annual electricity consumption of selected small business services

Method \ Activity	Electricity consumption in 2014 (GWh)				
	Retail	Food services	Health and beauty	Cultural association	Total
Estimated based on number of employees	735	792	228	110	1 865

Energy statistics (DGEG, 2015a)	1 603	632	1 017	250	3 502

Table 9 shows a rough estimate of the savings potential at national level as a percent of national consumption. Although precision is low given the method of estimation, the results suggest it is possible to reduce Portugal's electricity consumption by 1% to 2% through high profitability actions in the small business service sector.

Table 9. Electricity saving potentials of selected services as % of national consumption

Method	**Electricity saving potentials (% of Portugal's total consumption)**			
	Technical	Economic	Medium profitability	High profitability
Estimated based on number of employees	2	1	1	1
Estimated based on energy statistics	4	3	2	2

4. Conclusions

In the audited establishments the energy consumption patterns vary significantly, illustrating the diversity of activities included in the service sector. The implementation of high profitability measures allows a reduction of 9% to 55% in current energy consumption.

In the small business service sector the main driver for the improvement of energy efficiency is the need to cut operational costs. The main barriers are the low priority attributed to energy and insufficient knowledge. The importance of the split incentives barrier was also confirmed by the high percentage of rented spaces.

The average establishment has a specific consumption of 138 kWh/m^2/year and 4.6 MWh/employee/year. The comparison with the literature indicates that the small business service sector is less energy intensive than the service sector as a whole. The desegregation by end use shows that the most significant energy uses are climatization, lightning and refrigeration, although this varies widely with the activity and establishment. These same uses have the highest potential for energy savings.

For the average establishment, the technical saving potential is of 54% of current consumption. Cost-effective measures have a saving potential of 39% of current consumption. High profitability saving potential is 27% of current consumption. With the implementation of behavioral measures alone it seems possible to save an average of 6%. This saving potential can be explored through the implementation of community-based initiatives.

In Portugal, the activities included in the scope of the study consume between 4% and 8% of total electricity. The extrapolation of the high profitability saving potential suggests that the improvement of energy efficiency in the small business service sector may allow a reduction of 1% to 2% in Portugal's electricity consumption.

The identified energy saving potential could be explored through the introduction of an energy audit and counseling program focused in small businesses. The implementation of energy efficiency measures could then be enabled by the creation of economic incentives.

References

Bilgen, S. (2014). Structure and environmental impact of global energy consumption. Journal Renewable and Sustainable Energy Reviews, v 38, pp 890-902.

Brazão, A. & Melo, J.J. (2012). Barriers to energy efficiency improvement in industrial small- and medium-sized enterprises: the Portuguese case. 1st International Conference on Energy, Environment and Sustainability (EES 2012). Instituto Politécnico do Porto, 26-27 September 2012.

DGE (1994). Caracterização energética do setor dos serviços: relatório síntese. Direcção-Geral de Energia, October 1994. ISBN 972-9030-77-4.

DGEG (2015a). Consumo de energia elétrica por sector de atividade em 2014 (provisório). Version of 15-12-2015. Direção-Geral de Energia e Geologia.

DGEG (2015b). Consumo de energia elétrica por tipo em 2014. Version of 15-12-2015. Direção-Geral de Energia e Geologia.

DGEG (2016). Principais indicadores energéticos – Portugal. Version of 29-01-2016. Direção-Geral de Energia e Geologia.

D&R International Ltd. (2012). 2011 Buildings energy data book.

Entranze/Enerdata (2013). Total unit consumption per m^2 in non-residential.

ERSE (2013). Parâmetros do PPEC 2013-2014, no âmbito dos artigos 21.º e 22.º das Regras do PPEC. Entidade Reguladora dos Serviços Energéticos.

ERSE (2015). Preços de referência no mercado liberalizado de energia elétrica e gás natural em Portugal Continental, última atualização: 7 de dezembro de 2015. Entidade Reguladora dos Serviços Energéticos.

EC (2013). Commission Staff Working Document guidance note on Directive 2012/27/EU on energy efficiency – Article 8: Energy audits and energy management systems. European Commission.

Eurostat (2015). Energy balance sheets 2013 data – 2015 edition. Eurostat statistical books.

Fleiter, T., Gruber, E., Eichhammer, W. & Worrell, E. (2012). The German energy audit program for firms – a cost-effective way to improve energy efficiency? Journal Energy Efficiency, v 5, pp 447-469.

Government of Portugal (2014). Portugal 2020 – Acordo de Parceria 2014-2020.

Gruber, E., Plesser, S., Dusée, R., Sofronis, I., Lima, P., Rivière, P. & Rialhe, A. (2008). EL-TERTIARY Monitoring Electricity Consumption in the Tertiary Sector – Deliverable D 26: Report on the Project Results.

IEA (2012). World Energy Outlook 2012. International Energy Agency.

IEA (2014). Energy Efficiency Indicators: Essentials for Policy Making. International Energy Agency.

INE (2016). Sistema de Contas Integradas das Empresas. Instituto Nacional de Estatística. www.ine.pt, consulted on February 2016.

Leijten, F. R. M. & Bolderdijk, J. W. (2014). Factors that influence consumers' acceptance of future energy systems: the effects of adjustment type, production level, and price. Journal Energy Efficiency, vol 7, pp 973-985.

PwC, Fraunhofer ISI & TU Vienna (2014). Study evaluating the current energy efficiency policy famework in the EU and providing orientation on policy options for realising the cost-effective energy-efficiency/saving potential until 2020 and beyond.

Odyssee (2016). Unit consumption of electricity per employee in tertiary.

Retail Forum for sustainability (2009). Issue paper on the energy efficiency of stores. Issue Paper No 1, September 2009.

Schleich, J. & Gruber, E. (2008). Beyond case studies: Barriers to energy efficiency in commerce and the services sector. Journal Energy Economics, v 30, pp 449-464.

WEC (2013). World Energy Resources – 2013 Survey. World Energy Council.

WSBF & Carbon Connect (2013). Building efficiency: reducing energy demand in the commercial sector.

A MULTI2C application to assess the sustainability of energy efficiency scenarios

Luis Cruz[1], Eduardo Barata[2], Pedro Ramos[3], João-Pedro Ferreira[4]

[1,2,3,4] Faculty of Economics - University of Coimbra, Portugal, lmgcruz@fe.uc.pt, ebarata@fe.uc.pt, pnramos@fe.uc.pt, joao.ferreira@fe.uc.pt

Abstract

Energy efficiency is at the heart of the European Union (EU) 2020 Strategy for smart, sustainable and inclusive growth (COM/2010/2020). The EU Energy Efficiency Plan and the Energy Efficiency Directive set a 20% energy savings target by 2020. The EU 2020 Strategy goes beyond and also seeks to reduce the dependence on imported fossil fuels and to increase to 20% the share of renewable endogenous resources, as well as to achieve a 20% reduction in EU greenhouse gas emissions (GHG). Thus, to assess energy efficiency policies, it is critical to consider modelling frameworks able to account for energy-economy-environment interactions. Indeed, this research aims to contribute for the development of a modelling framework able to account for (inter)regional energy-economy-environment interactions. Then, the modelling approach is empirically applied to the Portuguese case, with the aim of assessing the socio-economic and environmental impacts resulting from energy efficiency gains. Accordingly, this work proposes an Input-output (IO) model for the Centro region, a NUT II matching the central part of mainland Portugal. This is a closed rectangular bi-regional model, at domestic flows and basic prices, comprising beyond the Centro also the Rest of Portugal, derived from the MULTI2C (multi-sectoral multi-regional Coimbra model). MULTI2C is a general flexible approach, developed by a group of researchers, mainly from the University of Coimbra (Portugal) that allows for the construction of input-output tables for different geographic configurations and empirical applications. The MULTI2C framework has a great level of detail concerning both the products and the industries that produce them. Further, this research recognizes that electricity production and distribution encompasses a set of activities with different technologies, either by main energy source or by region. To account for this we consider the division of the original electricity industry into one industry of “electricity distribution” and 9 industries of “electricity production” according to the following sources: 1) wind; 2) geothermal; 3) hydro; 4) photovoltaic; 5) coal; 6) fuel oil; 7) natural gas; 8) diesel; and 9) cogeneration. Next, we use this modelling approach to assess the socio-economic and environmental impacts, in both regions, resulting from energy efficiency scenarios. Results reveal that the analysed energy efficiency gains would generate a (small) net contractionary effect on the Portuguese economy, following the electricity production reduction, which is not fully compensated by the second-order expansionary effects. However, if one extends the assessment of the impacts resulting from the energy efficiency gains to the environmental dimension (both at the level of primary energy resources use and related GHG emissions), effects are being counterweighed by environmental improvements. Further, the assessment of the products whose production would change the most, as a consequence of this efficiency gain, contributes to an improved knowledge of the regional specificities. Finally, it is possible to claim that this research shows that energy-economy-environment IO analysis can be crucially helpful in supporting policy making within a perspective of sustainable development, and particularly relevant in the discussion, supported by ex-ante assessments, on the possible trade-offs among several 2020 EU targets.

Keywords: Energy Efficiency, Energy use; Energy-related CO2 Emissions; Input-Output Analysis

A Global study of the carbon strategy assessment for the steel, cement and energy utility sectors

Arijit Paul , Christian Unterberger , Rupert J Baumgartner

Abstract

Industries and energy sectors together accounts for more than half of the global GHG emissions (IPCC, 2014). Among the industries cement and steel sectors are the largest contributors (Bloom, 2012). Among the energy sectors, utilities producing electricity and heat has the largest share. .. Hence, strategies to mitigate GHG emissions (hereinafter referred to as carbon strategies) in these three sectors will play a very important role in meeting the target of limiting the global temperature rise to 2oC as decided in the Paris Agreement. Irrespective of this major importance, a systematic longitudinal study of the carbon strategies adopted in these three sectors is missing from the literature. Our paper aims at filling this research gap. We have developed an assessment instrument comprising of five categories of strategic activities. These are: 1) product and process improvement; 2) voluntary initiatives; 3) lobbying; 4) risk and opportunity management; and 5) new market and product development; based on the five principles of integration of environment into the business strategies of organizations as proposed by Reinhardt (1999). Companies will be graded across each of these categories by a five point Likert scale ranging from zero to four, based on their level of sophistication. A score of zero indicates the absence of this category and a four suggests the formulation of an advanced and sophisticated elaboration of this particular strategic activity. Scores from one to three will correspond to the various intermediate stages of sophistication between these two extremes. We will perform a longitudinal study of about 30 companies from around the world for the period of 2008 to 2013, hence an assessment of about 180 company years in total. The geographical coverage will include all continents of the world. The primary source of information will be the proprietary database of Carbon Disclosure Project (CDP). In addition annual- and corporate sustainability reports of the companies will be assessed. Content analysis will be applied for grading the companies using the assessment instrument, followed by a cluster analysis to identify differences in strategic orientation among the companies. This combination of content and cluster analysis has been found to be useful for similar exercises (e.g., Kolk & Pinkse, 2005; Lee, 2012) and hence selected for our assessment. The results of this assessment will provide crucial insights into the carbon strategies currently practiced among the global steel, cement and utility companies. In doing so it will contribute to understanding the strategic responses to climate change for the two most GHG and energy intensive sectors of the world. The results will be of importance both for the academics as well as for the policy makers.

Keywords: climate change, carbon strategy, steel, cement, energy utilities

References

Bloom, A. (2012). Iron, Steel and Cement Production. Retrieved from http://www.eoearth.org/view/article/161510

IPCC (2014). Climate Change 2014: Mitigation of Climate Change . Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Kolk, A., & Pinkse, J. (2005). Business responses to climate change: Identifying emergent strategies. California Management Review, 47(3), 6–20.

Lee, S.Y. (2012). Corporate carbon strategies in responding to climate change. Business Strategy and the Environment, 21, 33-48.

Reinhardt, F. L. (1998). Bringing the environment down to earth. Harvard business review, 77(4), 149-57.

Sustainable Energy or Renewable Energy – some innovative insights for sustainability and climate change.

T. E. Butt*1; L. M. Rudd1; M. R. Phillips1; M. Camilleri2

*1,1 School of Architecture, Built & Natural Environments (SABNE), Faculty of Architecture, Computing & Engineering (FACE), University of Wales Trinity Saint David (UWTSD), Mount Pleasant Campus, Swansea. PostCode: SA1 6ED. Wales, UK. Tel: 0044(0)7817139170; Email: t_e_butt@hotmail.com

2 Data Insight NZ (Property and customer data specialists) 31 Dacre Street, Eden Terrace, Auckland 1010, New Zealand.

Abstract

Energy is the 'blood of life' for our built environments, as without it, the built environment simply can not exist. However, the irony is that the same energy causes environmental stress in many ways, not only on the natural environment but even the built environment, equally. Therefore, the renewable energy and/or sustainable energy become the focus of the current modern world so that we sustain the built environment without (or as less as possible) anthropogenic climate change and environmental impacts for the current and future generations. This is where the energy strongly relates to the sustainable development philosophy. However, in general, the terms renewable energy and sustainable energy are found to be interchangeably used both in industry and academe. One main reason is that remits of the two are neither clearly defined, and therefore, nor appreciated as such. Furthermore, the two concepts appear to be generally focusing more on the 'mass' generation aspect of energy, and not as much on the other two facets which are energy distribution and energy consumption. This paper, based on literature review and investigation of computer-aided models, will establish domains of the two terminologies and their use. With varying exemplary scenarios, the paper will define their remits as individual terms, and also highlight common denominators and uncommon factors. Definition and implications of the philosophy of 'sustainability' will also be engaged in doing so. Moreover, the two terms will be related not only to the generation end of energy, but also to the other two main aspects of the energy 'pipeline', that is, the distribution and the consumption end. Thus, a holistic picture of the energy phenomenon in the built environment will be painted. In addition, some innovative insights will be introduced based on theoretical as well as real-world case studies. This way, specifically in the context of energy for the old and new worlds, the paper will contribute towards environmental communications; climate change mitigation and adaptation; and rethinking of sustainability models and practices.

Keywords: Sustainability; Sustainable Development; Climate Change; Sustainable Energy; Renewable Energy; Energy Efficiency; and Energy Management.

Effectiveness of wind energy support policies in the European Union: an empirical assessment

María Teresa García-Álvarez[1], Laura Cabeza-García[2], Isabel Soares[3]

[1] University of Coruna (Spain), mtgarcia@udc.es

[2,3]University of Leon (Spain), Research Centre in Economics and Finance and University of Porto (Portugal), laura.cabeza@unileon.es, isoares@fe.up.pt

Abstract

The development of renewable energies is an essential issue in the 2020 Energy Strategy of the European Union. However, important differences in both renewable development and the characteristics of renewable energy support policies between member states and over time have been observed. In this context, key issues for policy-makers are to know: a) if renewable energy support policies have actually increased renewable generation capacity, b) what renewable energy support policy (based on quantities or prices) has involved more renewable generation capacity and c) the impact of policy design in renewable generation capacity. Our contribution to the literature is to give an empirical assessment to those three issues in the case of onshore wind power in the European Union over the period 2000-2014. The choice of this production technology is given by being the largest install base of any renewable energy source in the European Union. Likewise, quota system (also known as renewable portfolio standard) and feed-in tariff are chosen as research focus because they represent the dominant policies to promote wind energy in the European Union. This paper involves not only to study the type of renewable energy support policy but to analyze their design elements too. It is essential because the literature has focused on the study of renewable energy support policies although the choice of design elements in each support policy is as least as important to promote renewable energies as the choice of specific policies. The methodology is based on pooled Ordinary Least Square Regressions Clustered on the Country Level. Results show that feed-in tariff policies represent greater wind installed capacity than quota policies. Moreover, the duration set in feed-in tariff policies is obtained as an essential concept in the development of onshore wind energy in the European Union. However, quota policies and their design elements do not seem to have a significant influence on onshore installed capacity. As conclusions, we can establish the importance of feed-in tariff policies and their design elements in the development of wind capacity in the European Union. Likewise, policy-makers should include stability, the reduction of project risks as well as the establishment of regular adjustment of support conditions to market progress as essential issues to get an effective renewable energy support policy based on prices.

Keywords: renewable energy, sustainable development, feed-in tariff policies, renewable porfolio standard, empirical assessment

Integrative Smart City Planning – Energy system modelling at city scale

Luís Dias[1], Júlia Seixas[2], João Pedro Gouveia[3], Sofia Simões[4]

[1] Luís Dias, CENSE - Center for Environmental and Sustainability Research, Department of Science and Environmental Engineering, Faculty of Science and Technology, Universidade NOVA de Lisboa, Portugal, luisdias@fct.unl.pt

[2] Júlia Seixas, CENSE - Center for Environmental and Sustainability Research, Department of Science and Environmental Engineering, Faculty of Science and Technology, Universidade NOVA de Lisboa, Portugal, mjs@fct.unl.pt

[3] João Pedro Gouveia, CENSE - Center for Environmental and Sustainability Research, Department of Science and Environmental Engineering, Faculty of Science and Technology, Universidade NOVA de Lisboa, Portugal, jplg@fct.unl.pt

[4] Sofia Simões, CENSE - Center for Environmental and Sustainability Research, Department of Science and Environmental Engineering, Faculty of Science and Technology, Universidade NOVA de Lisboa, Portugal, sfcs@fct.unl.pt

Abstract

Urban areas are home to half of the world's population and account for two thirds of final global energy consumption and this will be intensified as populations increasingly concentrate in cities and towns, pushing the urbanization rate up from 53% in 2013 to 63% in 2040. For a sustainable urban development new approaches are needed for urban design, city planning, and production and management of energy. The so-called smart city concept is an opportunity to deal with mitigation, through the highest efficiency and resource optimization, the problems generated by rapid urbanization and population growth, such as energy supply, waste management, and mobility. However, city planning and management is typically addressed through a fragmented approach, focusing in individual city systems (e.g. public lighting, residential buildings), and therefore a holistic and integrated should be implemented and supported by robust tools to capture the connections between measures. INSMART project addresses this issue through the design of a city (in this case Évora) framework tool combining different models and simulation tools that characterize each city sector in terms of technical and economic parameters (e.g. activity and energy consumption). At the core of the framework is a technology-rich optimization model: TIMES_Évora. This model is the application at city scale of the TIMES (The Integrated MARKAL-EFOM System) model generator developed as part of the IEA-ETSAP collaboration, an international community which uses long term energy scenarios to conduct in-depth energy and environmental analyses. The objective of using this type of model is its capacity of characterize current and future city energy system, covering all its phases: from energy supply sectors (e.g. electricity production technologies and natural gas network) to end use sectors (e.g. residential and transport). The model also has an important environment component as it accommodate combustion and process emission factors of the main greenhouses gases and air pollutants. The model incorporates other important city services/sectors components, namely the municipal solid waste chain, water treatment and distribution and wastewater treatment system. The model is fed with a range of new technologies for each system, like for example LED lamps for public lighting, characterized in terms of economic and technical parameters (e.g. investment cost and efficiency). This database provides the options to choose from in order to comply with defined city sustainable targets, as for example 50% reduction of greenhouses gases emissions in 2030 of the municipality when comparing with 1990 values. TIMES_Évora is use to develop a set of medium long-term sustainable scenarios and the assessment of the more cost-effective configurations of the city energy system and the necessary measures. This tool supports city decision makers on the cost-optimal spatial and sectoral specific portfolio of measures to assist the transition to a decarbonized energy system.

Keywords: Smart city planning; Decarbonized energy system; Scenarios

Coal or Green Energy? A Real Options Approach to Renewable Energy Investments in the Philippines

Casper Agaton

Ruhr University of Bochum, cbagaton@iuj.ac.jp

Abstract

With the recent rate of economic development, the Philippines' electricity demand is drastically increasing in the past decades. Despite its natural reserves of coal, oil, and natural gas, the country's electricity sector is still highly dependent on imported. This has made the country's energy security and sustainability susceptible to unstable prices of fossil fuels in the world market. To become energy self-reliant country, the government invests in developing more domestic fossil fuel resources and introduces localized renewable energy sources into national energy mix. However, investment on renewable energy is challenged by high startup cost and very competitive prices of fossil fuels. These give an impetus to make a study that clearly suggests a strategy to invest in renewable energy. This study employs the Real Options Approach to investment under coal price uncertainty. The main goal is to evaluate the comparative attractiveness of either investing in renewable energy or continuing the use of coal as a source of electricity. Specifically, this study analyzes the trigger price of coal for switching technologies from coal to renewable. To represent different investment environments in energy switching decision making process, this study considers various scenarios including technology innovation in renewable energy and negative externality for using coal. The results show that switching energy is a better option than continuing the use of coal. The results also present some possible welfare losses from delaying or waiting to invest in renewable energy. These findings suggest that switching energy source should be done earlier to avoid welfare losses. As the price of coal is increasing while technology price for renewable energies is decreasing, investment on the latter not only benefits the country's economy but the environment and the society as well. To make renewable energy more attractive, the government may impose externality tax for using coal or subsidize the investments on renewable energy.

Keywords: real options approach, renewable energy investment, coal price uncertainty, dynamic optimization

Exploring the Timing Differences of CDM Project Registration

Liguang Liu

Abstract

Clean Development Mechanism (CDM) is a project-based climate mitigation scheme under the Kyoto Protocol. The approval of implementing CDM activity has been one of the most significant climate change mitigation initiatives in developing countries. The CDM pipeline project is developed and processed by the UNFCCC for validation, registration and the final carbon reduction credit issuance. The certified credits can be traded in the international carbon market. The timelag starting from the developers' submitting the project for validation till the final registration decision results reflects the competitiveness of the CDM projects and also acts as an indicator of host countries' regulatory capacity. The CDM projects have confronted risks of not successfully registered and subsequently discharge from the pipeline. There are a number of reasons that potentially relate to the dropout: types of projects; project development capacity, maturity of methodology, etc. This paper aims to compare the timing differences of CDM project registration among top four CDM host countries, namely China, India, Brazil and Mexico, and seeks to identify the driving factors that cause these differences. A novel nonparametric method of survival analysis will be applied to study the CDM project registration time, by integrating the failed projects with successful projects into consideration. Further, several factors will be tested to see it they can contribute to explanation of the differences. Expected results include: to describe the pipeline time differences among countries with the Kaplan-Meier Curves; to compare the processing time with regard to different categories, i.e. illustrating the processing time differences among projects of different types, sizes or countries; and to reveal the capacity differences among host countries after adjusting covariate factors.

Keywords: Clean Development Mechanism, Survival Analysis, Capacity

Supporting renewable energy in electricity market: experiences of South Korea

Tae-Hyeong Kwon[1]

[1] Hankuk University of Foreign Studies, Seoul, South Korea, tkwon@hufs.ac.kr

Abstract

Two popular policies for fostering electricity from renewable energy sources (RES-E) are FIT (feed-in tariffs) and RPS (renewable portfolio standards). Under FIT, prices are first determined by a regulatory agency and then, the quantity of RES-E is determined through market processes. RES-E producers supply RES-E as long as their marginal cost is less than (or equal to) the FIT, which is guaranteed by the government. Under RPS, the quantity of RES-E is first determined by a regulatory agency, and then, the price of RES-E is determined through market processes. The government first allocates a required portion of RES-E to electricity suppliers. Subsequently, certificates (renewable energy certificates: RECs) are issued for all RES-E produced. Therefore, electricity suppliers can fulfill their allocation by producing it themselves or by purchasing RECs from other RES-E producers. Although governments intervene in the renewable energy market to support its growth, an information asymmetry problem between the government and renewable energy suppliers can distort policy outcomes. This study examines the information asymmetry problem of renewable energy policies by exploring the policy experiences of South Korea. South Korea's experience with both FITs and the RPS over the past decade makes for an interesting case study. The government determines FITs on the basis of cost information about each RES-E technology. However, because regulators have only limited information on the cost structure of RES-E and in addition, there can be rent-seeking behaviors by RES-E producers, FITs can be set higher than the real generation cost, which then becomes a source of rents or excess profits for RES-E producers. The quantity of RES-E and the subsidy budget exceed the government's initial expectations. In fact, excessive budget expenditures for FITs have been common in South Korea and many other countries. In RPS, information asymmetry may seem to no longer be a problem because the government does not need information on RES-E costs. The RPS market mechanism determines how much electricity is produced from each renewable energy source. However, a problem with RPS is that non-marginal technology can earn rent because a standard RPS has only one common price. To reduce rents given to non-marginal technologies, banding or set-aside is needed. The ratio of multipliers in a banding scheme must be proportional to the generation cost of each technology, less the average electricity price. Rent-seeking behaviors are highly probable in a decision process of banding ratios. The South Korean experience confirms that multipliers in the banding scheme have been key elements in determining winners in the RES-E market. Therefore, the information asymmetry problem is still an issue with RPS. Although market support policies for RES-E are essential to stimulate its growth, more elaborate policy designs are required to overcome information asymmetry problems.

Keywords: Renewable energy, Renewable Portfolio Standards, Feed-in Tariffs, South Korea

Interplay between ethanol and electric vehicles as low carbon mobility options for passengers in the municipality of São Paulo

Evaldo Costa, Júlia Seixas, Gustavo Costa, Thomas Turrentine

Abstract

The Brazilian cities as well as many of the large urban centers in the world, continue to expand, increasing the demand for mobility and transport, while, at the same time, are investing in greenhouse gases mitigation to avoid climate change. Brazil's urbanization rate increased from 26% in 1940 to almost 70% in 1980, since the urban population has multiplied by seven while the Brazilian population has tripled during this period. By 2010, in São Paulo the transport sector was responsible for 71% of emissions related to the energy consumption, due to the increasing of vehicle fleet. To meet growing mobility demand while mitigating CO2 emissions, Brazil adopted ethanol as a fuel for road vehicles providing significant reduction of emissions in transport. However, the production of ethanol would have to double in order to meet the expected number of vehicles in the next decade. Moreover, the problem of CO2 emissions from road transport would persist. The hybrid plug-in and pure electric vehicle, much more efficient than their peers powered by fossil fuels and markets of EVs are expanding around the world. Large urban centers such as São Paulo, Brazil's largest municipality, could take advantage of such low-carbon transport. However, it is important to identify whether the adoption of electrified vehicles will bring more benefits than vehicles powered by ethanol. In addition, it is necessary to examine the impact on CO2 emissions of the increased electricity consumption on power generation, and if the energy matrix of São Paulo is compatible with an expansion of electrified passenger cars. In this context, the present study used the bottom-up approach to investigate energy consumption by Tank-To-Wheel (TTW) modeling and CO2 emissions of passenger cars fleet in the municipality of São Paulo. To perform the analysis we have used the simulation tool Long Range Energy Alternatives Planning System (LEAP) through which five scenarios were created to simulate large-scale introduction of battery electric vehicles and plug-in electric vehicles between 2015 and 2030, replacing gasoline-powered and ethanol cars. The highest penetration of battery electric vehicles to replace the gasoline-powered cars showed the highest reduction of energy consumption (17%) and CO2 emissions (36%) of passenger cars in 2030 when compared with 2011. In spit of a high substitution share of electric cars (representing 25% of passenger fleet in 2030), they represent only 6% of the total energy consumption of passenger cars, representing a relatively small impact on the São Paulo's power grid, which we assume will remain predominantly clean (the share of renewable in the Brazilian electricity grid in 2014 was more than 65%). Generally, we may conclude that, from an energy consumption system perspective, electric mobility has a higher positive impact in climate change mitigation than ethanol. However, other components, as the expected evolution of power sources in São Paulo and the land use practices supporting ethanol production, should also be considered for a complete overview of climate mitigation potential of mobility options.

Keywords: electric vehicles, plug-in, CO2 emissions, ethanol, Sao Paulo.

The financial impact of residential distributed generation on local governments in South Africa: A case study into Stellenbosch Municipality

Nikkie Korsten, Ben Sebitosi, Alan Brent, and Karin Kritzinger

Abstract

Worldwide, the uptake of residential solar rooftop PV has increased dramatically over the past few years as the investment in the technology became increasingly attractive. Although this is a great progressive development in terms of sustainability, it is not without implications for electricity utilities that experience sales drop as a result and see their revenues declining. Also in South Africa, an increased uptake of solar rooftop PV is being experienced. As South African local governments are responsible for the network, electricity delivery and sales within their border of jurisdiction, they might face similar challenges as electricity utilities across the globe. In South Africa, there is a concern that allowing rooftop PV connection to the grid will reduce electricity sales of local governments and therewith reduce their revenue on electricity. Many South African municipalities use the surplus on electricity to supplement municipal services that are underfunded and therefore the electricity surplus is seen as critical for the financial health of the municipality. Local governments are left with the question how to develop appropriate policies that do not hamper the development of decentralized solar rooftop energy whilst at the same time not jeopardizing the financial balance of municipalities. The aim of the research is contributing to informing policy development through investigating the potential financial impact of increased grid-connected rooftop PV at a household level on South Africa municipalities. The research looks specifically at the residential areas with high electricity use in Stellenbosch Municipality, determined by an examination of the electricity use in the different suburbs. Two different approaches are used that result in two outcomes. In the first approach the point of departure is the maximum grid capacity for distributed generation as set by South African NRS standard. Second, an approach is used based on monetary criteria of individual households to invest in rooftop PV. If the first approach would be applied, this leads to a net loss of approximately 2,4% on the total electricity revenue of Stellenbosch Municipality. If the approach based on financial criteria of citizens is used this leads to a net loss of approximately 0,6% on the total electricity revenue. This research suggests three points that should be critically looked at. Firstly, one should examine decoupling as a tool to break the link between the utility's recovery of fixed costs and volumes of kWh sales. Secondly, a fair and sustainable rate design for distributed generation owners for the electricity they provide should be reviewed. The last point looks at possibilities for ownership of renewable energy assets by the municipality.

Keywords: renewable energy, revenue impact, electricity utility, South African municipalities

Sustainability of electricity generation sector in Brazil: Hydro vs Solar

Juliana Barbosa[1], Luís Dias[2]

[1]Juliana Barbosa, CENSE - Center for Environmental and Sustainability Research, Department of Science and Environmental Engineering, Faculty of Science and Technology, Universidade NOVA de Lisboa, Portugal, Juliana.barbosa@campus.ul.pt

[2]Luís Dias, CENSE - Center for Environmental and Sustainability Research, Department of Science and Environmental Engineering, Faculty of Science and Technology, Universidade NOVA de Lisboa, Portugal, luisdias@fct.unl.pt

Abstract

Historically the Brazilian electricity matrix was one of the most sustainable in the world due its high disposable of hydroelectricity. Unfortunately, a deeper analysis reveal that in the recent years the Green House Gases (GHG) emissions intensity has doubled from 6.3x10-5 MtCO2e/GWh in 2006 to 12.4x10-5 MtCO2e/GWh in 2013. This was due to the energy demand increase at a rate higher than the supply of hydroelectricity, causing the necessity to use the fossil thermal capacity. Until 2030, is expected an increase of 122% in energy consumption in Brazil, though an imperative question rises on how this demand will be satisfied in a sustainable way. The official plan for future electricity supply is based on hydro expansion, manly in Amazon region raising environmental impacts that are not addressed. In addition, solar technology is not included, although the high level of available solar resource in the country and also large available areas for PV installation. In this way, we assessed the sustainability of current situation of the Brazilian electricity generation portfolio and two different scenarios for its future development through a multicriteria analysis considering different environmental aspects, namely: carbon footprint, resources use, morbidity due to pollution and reliability (product of capacity factor and availability of power generation plants) and energy efficiency and a proxy for biodiversity: Net primary productivity (NPP). The use of NPP in the assessment of the sustainability of current and future Brazilian electricity generation sector is vital as it provides the inclusion of its impacts on biodiversity that is typical not included. For this, it was considered the average of Net Primary production (NPP) of the Brazilian municipalities with top ten larger utilities for each energy source multiplied by the average area occupied by the corresponding technology. The multicriteria analysis assumes the weakness sustainability hypothesis, where the substitutability between different capitals forms. The different electricity generation technologies analyzed were: hydroelectricity, coal, natural gas and oil thermalpowerplants, nuclear, solar power, wind power and biomass thermalpowerplant. In addition to the analysis base year (2010) situation, the two scenarios for future Brazilian electricity generation mix correspond to: the official defined electricity supply expansion (Hydro-based scenario), and an alternative scenario considering a possible inclusion of solar photovoltaic in the mix in substitution of hydro power (Solar scenario). The results show that the general sustainability index for the base year situation is 0.470. In the official scenario (Hydro-based scenario) the index can reach 0.5149 as an consequence of the deployment of more hydro power. In the alternative scenario (Solar scenario), where is considered the possibility of part of the expansion of the hydropower, namely two plants at Tapajós River with installed capacity expected of 8500GW, were substituted by solar power, the index rises to 0.508. This concludes that, although the increase of hydro power in the electricity mix can provide benefits in the sustainability of future Brazilian power sector, it can be significantly improved if the some future hydropower utilities are substituted with solar technologies.

Keywords: Sustainability of electricity generation; solarpower; hydropower

Climate Change and Sustainable Energy in Rural Bangladesh – An Innovative Approach

Shahana Afrose Chowdhury*, James Ohlmacher

* Corresponding author, email: shahana.ac@gmail.com

Abstract

Being a densely populated country with limited natural resources, Bangladesh is severely suffering from the energy crisis since the past few decades. Due to the limitation in fossil fuel reserve, the only way to minimize the supply-demand gaps in the energy sector is switching towards the alternative renewable energy sources. Kazi Shahid Foundation (KSF) has been working in partnership with rural villagers for over 15 years. In order to make rural people's lives healthier and more productive, KSF has developed "Biogas Program". The continuous burning of biomass fuels leads to long term health issues, predominantly among women. The amount of wood consumed, also contributes to an increase of green house gas emissions and partly responsible for deforestation. Bangladesh has a long standing tradition of utilizing dung exclusively as the feedstock for biogas plants where as India has focused mainly on food waste. This project has taken mixed approach, using both dung and waste food to produce cooking fuel by allowing the Biogas Plant to operate more efficiently. Attempting another first for Bangladesh, KSF is utilizing the same "no cash" microfinance repayment system, where KSF will be reimbursed the cost of the Biogas Plant through the effluent slurry, as well as, excess cow dung or milk. KSF hopes to continue the Biogas Program by bringing biogas to the rural villages of Panchagarh district. In order to make biogas a viable alternative to the current biomass fuels used in cooking, this multi-purpose approach was developed through careful research into the latest technologies available in Bangladesh. In depth understanding of the needs and concerns of the village people; a comprehensive training program was developed, provided full support structure able to deal quickly with both simple and complex problems and finding innovative methods to use the bio slurry as a regular income generating asset.

Keywords: climate change, low carbon emission, biomass energy, sustainable approach

Introduction

Energy Need of Bangladesh

Bangladesh is a developing country with a population of 160 million in an area of only 147,570 sq. km. About 85% of the population lives in rural areas where agricultural is the dominant occupation. In densely populated rural Bangladesh energy scarcity is already an acute problem and will worsen as the population continues to increase. It is widely accepted that the availability of energy is a necessary condition for sustainable economic and human development. For countries such as Bangladesh, which have relatively low per capita energy consumption, small increases in energy consumption are associated with substantial improvements in education, life expectancy and income levels (GCM resources, 2014). Biomass energy is the oldest type of fuel used by humanity and still an important energy source in Bangladesh, especially in rural areas. Bangladesh's rapidly increasing population has led to unsustainably use of the countries forests by the rural poor for fuel-wood, bamboo, fodder, medicines, herbs and roof materials. Deforestation has gradually upset the natural recycling system, as well as, led to an increase in the cost of fuel wood, both in terms of financial cost and time spent, creating a vicious circle and further deforestation. Enormous amount of labour time is spent in gathering fuel wood and agricultural residues, with the work mainly being done by women and young children.

Relevance of Biogas

Over 2 billion people worldwide lack access to clean, safe and sustainable domestic energy services. Lack of access to adequate, affordable, reliable, safe and environmentally sustainable energy sources is a severe constraint on development. A lack of access to clean and affordable energy can be considered a core dimension of poverty. Biogas technology has clear economic, social and environmental benefits for rural households, such as reducing environmental pollution by safely recycling manure and providing households with a clean cooking fuel alternative to fossil fuels or firewood. The technology is simple and construction materials are readily available. The biogas can be used for a range of purposes including cooking, household lighting, heating, running a television or radio and even operating small machines. Energy from commercial sources accounts for only 8.6% of all energy used in the domestic sector (Ahmmed and Chaudhury, 2000). Promotion of biogas technology is motivated by the need to address the following problems in rural areas: lack of clean cooking fuels; indoor air pollution from burning solid biomass (such as firewood) in poor cooking stoves; water pollution and water-borne infection from human and animal waste; soil degradation due to the wide application of inorganic fertilisers; and forest deterioration caused by the over-collection of firewood, among others.

In the context of energy demand homestead biogas as cooking fuel is a crucial step by rural women who benefit the most directly from it. Infrastructure Development Company Limited (IDCOL), (2006) surveys have found that users in Bangladesh save, on average, depending on the size of the plant, between 65 and 80 minutes per day compared with burning biomass. Most of the time saved is due to shorter cooking and cleaning time as well as the reduced time spent collecting biomass. In saved time, women potentially can spend this on education, productive and other activities (SNV, 2010). Biogas users also benefit from improved indoor air quality and health outcomes as biogas is smokeless (Dasgupta, 2004). The bio-slurries amassed as a by-product of a biogas plants is an effective and organic plant fertilizer and can be used or sold by Biogas users as a cheap and safe alternative to manure and in-organic fertilizers, contributing towards better food safety of citizens.

Improved health, increased crop productivity, saved time for women are some of the major benefits to the users. It also provides economic benefit to the country through reduced deforestation and carbon trading. In addition, by reducing green house gas emission, the technology helps in mitigating global warming and climate change. Thus biogas is a renewable, sustainable and clean source of energy that provides multiple benefits; locally and globally. Cattle dung has been used primarily as an input and the technology is limited to households only. Biogas project in large scale livestock farms will generate not only local environmental benefits, but also international greenhouse gas mitigation benefits. In this paper, the benefits of biogas project towards the greenhouse gas (GHG) mitigation as well as the additional economic benefits, organic farming, improved livelihoods of the rural people are described.

General Constraints in the Biogas Systems of Bangladesh

As reported by Biogas Audit of Bangladesh 2011-13, the major constraints in biogas systems which are barring biogas plants from being efficient and more widespread are construction flaws, operations irregularities, and problem of appliances, energy inefficiency and lack of after-sales services. What adds further to these issues is the general lack of sustainable investment and an effective payment method by the users. The lack of quality control, institutional transparency in subsidy disbursement, price uniformity of materials and rates of interest for loans also make the biogas plant sector of Bangladesh inefficient and unfriendly to users.

KSF Biogas Program

Kazi Shahid Foundation (KSF) is currently running a homestead biogas project in Panchagarh district. The objectives of the project are to provide a clean, healthy and environmentally sustainable source of energy for cooking, lighting and small to medium size power generation. It also had a community empowerment agenda where besides increased productivity and health/ environmental benefits, the users of the technology would be able to generate some income out of selling by-products of the operation (bio-slurry). The payment for buying and using the technology was made efficient through KSF Dairy Cooperative Program's non-traditional form of micro-credit as a barter system-- the household would repay KSF the cost of the plant through bio-slurry, dung, milk and so on.

Program Area and Biogas Plant Implementation

Panchagarh District is situated in the extreme north of Bangladesh and is part of the Rangpur Division. The area has one of the highest poverty rates in Bangladesh according to the Bangladesh Bureau of Statistics (BBS) with acute need of energy initiatives Panchagarh District is well covered by vegetation with widespread availability of fruit bearing trees such as jackfruits in addition to large tea estates, farming area, such as, paddy, corn and sugarcane production. Along with using household waste materials above available organic waste could be tested in this proposed project for enhanced biogas production which could be sustainable.

Figure 1: Panchagarh District

Reviewing the technological efficiency and user-friendliness of the traditional biogas plants, one of the major constraints identified was low portability/ transferability and rigidity of their structure. KSF has looked into best practices elsewhere in the world and found that one possible opportunity can be building biogas plants in a floating dome model (instead of a fixed dome model) which would be made of plastic/ jute/ fibreglass (instead of brick and mortar). The flexibility of this technology coupled with easier handling, repairing and mobility is assumed to be most useful and applicable to the unpredictable circumstances of the Panchagarh District. Its soil is sandy, alluvial and bears close affinity with the soil of the old Himalayan basin. On the northern part of the district there exists underground layer of pebbles. It is 150 feet high from the sea level. The proposed scientific research in question will either affirm this hypothesis, or potentially drive KSF to an alternative avenue of applied technology.

There is an opportunity for training and development in after-sales service and quality assurance, which is proposed to be taken up by KSF to substantially increase the usage efficiency of its plants. KSF places a lot of importance on providing end-to-end solutions to its user groups, and its community involvement through its parent company's agro and dairy projects strengthens its role as an integrated biogas solution provider rather than a one-off biogas plant seller. Both the KSF experience and Biogas Audit 2011-13 indicate that smaller biogas plants are substantially more energy efficient than larger ones. Generally, only 40%-60% of anticipated average gas production is obtained, whereas smaller plants show better results than bigger plants. With the experience of some of its previous biogas plant projects, KSF has noted that scarcity of cow-dung is a big constraint in operating larger plants.

Methodology

Selection of the Study Area and Household survey and individual interview

There are six unions in Atwari Upazilla and the study was concentrated only in four unions. There are five Upazilla in Panchagarh district namely: Panchagarh sadar, Tentulia, Boda, Debiganj and Atwari (Map of the study area, Figure 1). In this study 600 households were surveyed. A semi-structured interview was organized with the selected respondents. There was a guided interview with the KSF beneficiaries both having homestead biogas plant owner and without biogas plant; different aspect of bio-gas plant, perception of bio-gas, current cooking system, fuel types with sources, use of cow dung and bio-fertilizers and as well as their socio-economic status.

Collection of qualitative data

Following tools (PRA) including Focus Group Discussion (FGD), group interview, key informants interview were carried out in getting in depth information related to the study.

Additionally, few cases were mapping for citing as a success story and or drawbacks of intervention.

Key Informants Interview

Key Informant Interview were carried out with the Agriculture Extension Officer, Upazilla Livestock Officer, prospective farmers, Bio-gas plant owners, a person from Grameen Shakti and KSF staff. This was to elicit details information problem and prospects of bio-gas and bio-fertilizers in the study area.

Focus Group Discussion

Focused Group Discussions (FGDs) were carried out separately with male and female participants. Details information on traditional cooking, fuel type cooking time, prospect and perception of bio-gas plant, current uses of cow dung, incidence related to traditional cooking were collected.

Results and Discussion

The current episode of global warming is attributed to increasing emissions of CO_2 and other greenhouse gases into Earth's atmosphere. The global annual mean concentration of CO_2 in the atmosphere has increased by more than 40% since the start of the Industrial Revolution, from 280 ppm in the mid-18th century to 402 ppm as of 2016 (Dlugokencky, 2016). The GHGs are responsible for increase in earth temperature. There is a need to develop GHG mitigation strategies to reduce the adverse impacts of climate change. Biogas technology provides an excellent opportunity for mitigation of GHG and reducing global warming through,

(i) replacing firewood for cooking,

(ii) replacing kerosene for lighting and cooking,

(iii) replacing chemical fertilizers, and

(iv) saving trees from deforestation.

A family size biogas plant (3 m^3 capacity), operated with dung produced by four cattle, commonly reared in a household, was calculated using the relationship of 0.5 m^3 biogas with per kg of dry dung (Khendelwal and Mahdi 1986). It was assumed that 80% of generated biogas would be used for replacing firewood and 20% for replacing kerosene as fuel. This implied that a family size biogas plant would save the calculated quantities of kerosene and firewood, which would otherwise emit GHG to the atmosphere upon burning as fuel. Carbon dioxide emissions from burning of kerosene and firewood were taken as 2.41 kg/L (w/v) and 1.83 kg/kg (w/w) respectively. Firewood burning also emits CH_4 and per kg of CH_4 produces 3.0 g of C.

Biogas slurry, a by-product of biogas plant, is applied as manure to substitute chemical fertilizer. As there is negligible mass loss of substrate (cattle dung) as biogas, it was assumed that 1 t of cattle dung would generate similar amount of biogas spent slurry containing 1.4% N, 0.5% P and 0.8% K on dry weight basis (Subrian et al. 2000; Tandon

and Roy 2004). Substitution of chemical fertilizer with spent slurry reduces CO_2 emission, which would emit for production of fertilizer. Saving of N fertilizer due to replacement by biogas slurry would also reduce emission of nitrous oxide at a rate of 0.7% of the applied N (Bhatia et al. 2004; Malla et al. 2005).

Demonstration of Cost-Benefits

Kazi Shahid Foundation (KSF) has been working in partnership with rural villagers for over 15 years. In that time it has developed many successful programs including its Dairy Cooperative Program for female entrepreneurship. A first of its kind in Bangladesh, this cashless microfinance program provides its members with cows with the ownership transferred in exchange for milk and cow dung instead of cash.

In order to help its membership live healthier and more productive lives, KSF has developed its Biogas Program. The continuous burning of Biomass fuels such as wood or dung leads to long term health issues, predominantly among the women of the household. The amount of wood consumed, also contributes to an increase of carbon emissions and is in part responsible for deforestation. Burning dried cow dung is a cheap alternative compared to other Biomass fuels. However, the process is labour intensive, unsanitary, and the fumes from burning contain carcinogens. The use of improved cook stoves helps with the efficiency but doesn't address the health related issues.

Other than the use for cooking or burning, the biogas can be used for lighting and fuel for vehicle involving farming. Once the demonstration phase is completed with positive results a full-fledged future intervention of “Biogas Model” and up scaling plans will benefit the users as well as the people of the country using waste converted energy.

The production and use of biogas from waste management will reduce natural pollution and deforestation and overall costs compared to the present cost of Liquefied Petroleum Gas (LPG). The “Biogas Model” will increase energy efficiency by about 25% or more. The homemaker’s significant time saving can be employed for additional production which will inject increasing Gross Domestic Production (GDP) and ultimately it will generate a positive impact on Per-Capita Income. The benefits can be quantified and compared to the cost involvement. Initially, cost saving for the member of household in the working area of Panchagarh District will be calculated and based on the description given below, using which we can determine total saving across the country.

The cost-benefit analysis is stated below-

#	Benefited Item/Field	Time Saved/ Month (hr)	Hourly Rate BDT	No. of KSF Member/ User (6,000)	Current Cost/ Unit BDT	Biogas Intervention Cost/Unit BDT	Monthly Cost-Saved for Target User BDT
1	**LP Gas Vs Biogas each Household/Month**	**-**	**-**	**516**	**1,200**	**1,079**	**62,350**
2	**Biogas Vs Fuel & Power/Month (Kerosene/Diesel/Firewood /Electricity)**	**-**	**-**	**5,484**	**1,200**	**1,079**	**6,62,650**

3	**Homemaker Time (hr) Saving & Productivity/Month**	**75**	**20**	**6,000**	**-**	**-**	**90,00,000**
4	**Health-Treatment (@4 member/family)**	**-**	**-**	**6,000**	**100**	**30**	**16,80,000**
5	**Bio-Slurry/Bio-fertilizer for Organic Farming**	**-**	**-**	**6,000**	**-**	**2,250**	**1,35,00,000**
	Total BDT						**2,49,05,000**
* Environmental pollution & deforestation will save and it is not quantified/calculated in terms of money.							

Conclusion

Although Bangladesh is a developing country and emits only very little amount of the GHGs in atmosphere, many practices here in Bangladesh are contributing for mitigating and adaptation of the climate change, that may be potential for the Clean Development Mechanism (CDM) in Bangladesh and Reducing emissions from deforestation and forest degradation (REDD). Biogas technology is considered as the one of the best clean energy sources that is economically affordable for the rural people, also reduce the emission of the GHGs. It is one of the effective and appropriate mitigation effort in Bangladesh.

The reduction in global warming should encourage the policy makers to promote biogas technology to combat climate change and integration of carbon revenues will help the farmers to develop biogas as a profitable activity. With the large number of existing and potential biogas plants, Bangladesh has a good opportunity to solve its energy crisis, reduce global warming and earn substantial revenue under the new regime of carbon marketing. The mechanism of carbon market should be used to promote installation of biogas plants by making these financially viable.

Acknowledgement

We would like to thank Ms. Momtaz Chowdhury, CEO, KSF. A special thanks for the whole KSF Panchagarh field team members, without their help this study would not be possible.

Reference

Alam, S. 2006. Production of organic manure in Bangladesh, Bangladesh Livestock Re-

search Institute's Report, Savar, Dhaka, Bangladesh.

Ball, J. (2007). Cows, climate change and carbon credits. The Wall Street Journal-Online, B1 (June 14, 2007).

BBS. 2011. Bangladesh Bureau of Statistic - Population Census 2011.

Bhatia, A., Pathak, H., &Aggarwal, P. K. (2004). Inventory of methane and nitrous oxide emissions from agricultural soils of India and their global warming potential. Current Science, 87(3), 317–324.

Biogenic Methane Potential Method: DIN 38414 and VDI 4630.

Chaudhury, A.H. and Ahammed, S. 2000. Diffusion of biogas technology: a community

based approach. Khulna University Studies, 2(1): 7-22.

Dasgupta, P. 2004. "World poverty: causes and pathways." In B. Pleskovic and N. H.

Stern (eds). World Bank Conference on Development Economics. Washington, DC: World Bank

Dlugokencky, E (5 February 2016). Annual Mean Carbon Dioxide Data. Earth System Research Laboratory. National Oceanic & Atmospheric Administration. Retrieved 12 February 2016.

Gautam, R., Baral, S. and Heart, S. (2009). Biogas as a sustainable energy source in Nepal:

Present status and future challenges. Renewable and Sustainable Energy Reviews 13(1): 1248–252.

Grameen Shakti .Website: http://www.gshakti.org/ics.html

http://web.b.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=eddfe4a6-e872-4e91-aa09-7a5091dfc761%40sessionmgr114&vid=2&hid=103

http://extension.psu.edu/natural-resources/energy/waste-to energy/resources/biogas/projects/biogas-from-manure

IDCOL. Official Website of Infrastructure Development Company Limited.

http://www.idcol.org/

Imam, B., (2013). Energy Resources of Bangladesh, Published by University Grant Com-

mission of Bangladesh, Dhaka, pp. 283-297.

IPCC. (2001). Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the IPCC. Intergovernmental Panel on Climate Change. Cambridge University Press, UK.

Katuwal, H. & Bohara, A.K. (2009). Biogas: A promising renewable technology and its

impact on rural households in Nepal. Renewable and Sustainable Energy Reviews. Volume13(9): 2668–2674.

Khendelwal, K. C., & Mahdi, S. S. (1986). In biogas technology: A practical technology (pp. 128). New Delhi: Tata McGraw-Hill.

Kumar, S., Malav, L.C., Malav M.K. and Khan, S.A. (2015). Biogas Slurry: Source of Nutrients for Eco-friendly Agriculture. International Journal of Extensive Research

2:42-46.

Karim, K., Hoffman, R., Klasson, T., Al-Dahhan, M.H. (2005). Anaerobic Digestion of Animal Waste: Effect of Mode Mixing, Water Research. 39.

Malla, G., Bhatia, A., Pathak, H., Prasad, S., Jain, N., & Singh, J. (2005). Mitigating nitrous oxide and methane emissions from soil under rice-wheat system with nitrification

and urease inhibitors. Chemosphere 58(2), 141–147.

Meher, K. K., Ranade, D. R. and Gadre, R. V. (1990). Res. Ind., 1990, 35, 115–117

Mohan B. Chand, Bidur P. Upadhyay, Rejina Maskey, (2012). Biogas option for mitigating and adaptation of climate change. Rentech Symposium Compendium, Volume 1, March 2012.

Pathak, H., Jain, N., Bhatia, A., Mohanty, S., Gupta, N. (2009). Global warming mitigation potential of biogas plants in India. Environ Monit Assess (2009) 157:407–418

DOI 10.1007/s10661-008-0545-6.

Puyuelo, B., Ponsá, S., Gea, T., Sánchez, A. (2011). Determining C/N ratios for typical organic wastes using biodegradable fractions. Chemosphere.85(4): 653-9. doi: 10.1016/j.chemosphere.2011.07.014. Epub 2011 Aug 6.

Rasi, S. (2009). Biogas composition and upgrading to biomethane. Dissertation. University of Jyväskylä

SNV. (2010). Biogas Support Programme Fuels Rural Household Energy Supply in Nepal. Paper for UNCTAD Expert Meeting on Green and Renewable Technologies as Energy Solutions for Rural Development, Geneva, 9-11 February 2010. Geneva. Netherland Development Organization.

Subrian, P., Annadurai, K., & Palaniappan, S. P. (2000). Agriculture: facts and figures. pp. 133–134. New Delhi: Kalyani.

Tandon, H. L. S., &Roy, R. N. (2004). In integrated nutrient management — A glossary of terms. New Delhi: Food and Agriculture Organization of the United Nations, Rome and Fertiliser Development and Consultation Organization.

Uddin, M. M. and Mojumder,M. S. S. (2011). Biogas Production From Municipal Waste: Prospect in Bangladesh. Cyber Journals: Multidisciplinary Journals in Science and Technology, Journal of Selected Areas in Renewable and Sustainable Energy (JRSE).

Ullah, M.H., Hoque, T. and Hasib, M.M. (2012), Current Status of Renewable Energy sector in Bangladesh and a proposed Grid Connected Hybrid Renewable energy system, International Journal of Advanced Renewable Energy Research, Vol. 1, pp. 618, 621-624.

UN. (2010). Renewable Energy Technologies for Rural Development. A Paper Presented in the United Nations Conference on Trade and Development. United Nations.

Vavilin, V.A. (2010). Anaerobic degradation of organic waste: An experience in mathematical modeling. Microbiology 79:334-341

Wadud, Z., Graham, D. J.,and Noland, R. B. Gasoline, (2010). Demand with Heterogeneity in Household Responses, The Energy Journal, Vol. 31, No.1, pp 47–73, 2010.

Yadvika; Santosh; Sreekrishnan, T.R.; Kohli, S.; Rana, V. (2004). Enhancement of biogas production from solid substrates using different techniques—A review. Bioresour. Technol. 95, 1–10

Zuzhang, Xia, (2013). Domestic biogas in a changing China Can biogas still meet the energy needs of China's rural households?, International Institute for Environment and Development (UK), ISBN: 978-1-84369-955-2

Walkability City Tool (WCT): measuring walkability

Miguel Zuza Aranoa[1], Cristina Rivas Allo[2], Isabel Pérez-Ilzarbe Serrano[3]

[1] Miguel Zuza Aranoa, suma-USC, correo@suma-usc.com

[2,3] Cristina Rivas Allo, Isabel Pérez-Ilzarbe Serrano, suma-USC, correo@suma-usc.com

Abstract

Public space is the essence of the city but almost 70% of this public space is occupied by surfaces meant for cars. And yet citizens who walk are the ones who give meaning to this public space. The habit of walking benefits both the individual and the community to which they belong, both of which are widely documented. The needs of the roadway networks have been repeatedly analyzed but, what about the pedestrian network? Prints of the streets that work the best or worst are often examined without analyzing pedestrians' reasons for choosing different streets to walk on. Likewise, interventions on the pedestrian network are not made using clear criteria. There is a significant body of scholarly work that has researched this topic, with prominent figures in urban planning (Jane Jacobs, Jan Gehl...), sustainable urban planning certification systems (BREEAM, LEED, CASBEE) and even indexes that work on some of the factors that influence walkability (PERS, WalkScore...). The development of WalkabilityCityTool emerged in response to the needs detected stemming from the lack of compiled, precise, objective information on the walkable network when taking strategic decisions on the city that affect pedestrian mobility (and its influence on the model of city, retail, tourism...). WCT examines the factors studied via five topics: Modal Distribution: division of space between the different means of transportation (number of lanes, parking, public transportation...); Urban Grid: characteristics of the sidewalks (width, condition of pavements, obstacles...); Urban Scene: information on the environment around us as we walk (activities on street level, trees...); Safety: perception of safety when walking (street lighting, presence of people...) and Environment: factors that influence walkers (noise level, pollution...). The methodology of the tool starts with gathering a wide range of information on the street from each of the sidewalks and intersections (accessibility, danger...) in order to get a geo-referenced weighted WCTscore, yielding a walkability "heat map" that allows city managers to draw from extraordinarily valuable analytical information. Application: One of the most recent applications of the WCT was in the financial district in Panama as part of the Emerging and Sustainable Cities Initiative (IDB). Using the WTC allowed the city managers to have precise, objective information on the state of the network of sidewalks and intersections in one of the city's most centrally-located, emblematic neighborhoods in order to make decisions and establish priorities on the investments to be made. Conclusions: Current mobility policies are encouraging citizens to use their private vehicles less, restricting access and lowering the amount of surface area devoted to vehicle circulation and parking. However, pedestrian spaces should not be characterized solely by the absence of cars, since there is a host of factors that affect their quality and make them true public spaces in the broadest sense of the term. The application of WCT helps the pedestrian network to be regarded not only as a leftover from the roadway network but more as a grid in itself which should be improved in order to support modal change policies towards non-motorized means.

Keywords: pedestrian network, sidewalks, pedestrians, analysis, Geographic Information Systems.

1. Introduction

1.1 Cities and public space

Today the physical city where we interact is made up of our squares, parks and streets: public space is the essence of the city. Almost 70% of this public space is occupied by surfaces that serve cars. But walking citizens are the ones who give meaning to public space, where they walk, look, interact, shop, meet, have fun, rest, travel, work… they perform an endless series of activities that should be encouraged by providing them with appropriate spaces.

1.2 Cities and mobility

The design of our cities and the steady increase in the number of inhabitants means an increase in the use of private vehicles, leading to the usual congestion of the streets. Zoning, low intensities, poor strategic design and poorly planned public transportation are just some of the factors that contribute to aggravating these mobility problems within the city and everything they entail.

1.3 Why encourage walkability?

Cities should work on measures that encourage modal shift to non-motorized means and collective transportation. The fact that walking should bring benefits to both the individual and community in which they live is both well-grounded and amply documented.

1.4 Why analyze walkability?

The needs of vehicle roadways have been extensively analyzed: the number of vehicles circulating on the street are tallied, wait times at traffic are studied, the traffic situation is reported, work is done on lane width and speeds, etc. This allows us to evaluate the road network and act on the points where it is most needed in the most appropriate way.

But what about the pedestrian network? It is often dealt with using impressions on which streets work better or worse without analyzing the reasons pedestrians choose one street over another. The interventions, such as the creation of pedestrian zones, ramps, parking, etc., are not performed with clear criteria.

In recent years, a great deal of effort has been invested in the quality of the urban space and walkability, or how friendly an area is to walking. Numerous factors come into play in the experiences of citizens who walk around the city.

1.5 Current state of the technique in this field

Below is a description of the current state of the technique from three of its vantage points:

1.5.1 Development of scholarly research

As a landmark figure in the shift in how we view cities, particularly from the standpoint of the pedestrian, we should cite Jane Jacobs (1916-2006), a popular Canadian scientist, urban planning theoretician and socio-political activist who was born in the United States. Her most influential work was “The Death and Life of Great American Cities” (Jane Jacobs, 1961). Contrary to the schematic city models that lead to the destruction of public space and communities, she asserts that dense neighborhoods and mixed uses make for vibrant places to live and work.

In his work “Tivoli Gardens” (John Lyle, 1969), John Lyle analyzes which benches are used the most on paths. Subsequent studies have further plumbed this kind of issue, such as “Seating Preferences on Kongens Nytorv” (Louise Kao, 1968), “Pedestrians” (Jan Gehl, 1968) and “The

Livable Environment: Psychological Aspects of Homes" (Jan Gehl, 1971a).

In his book "Life between Buildings" (Jan Gehl, 1971b), Jan Gehl introduces the relationships between the shape of the urban space and social behavior.

These authors cited have transformed our way of understanding urban space in relation to citizens, but there is a host of scholarly studies that analyze how the characteristics of the urban space influence the people who walk there. Many of these studies come from the world of medicine, regarding the health benefits of walking. Others relate the price of housing and therefore quality of life with an area's ease of walking.

1.5.2 Vision of sustainability certification systems

Currently, the most influential sustainable urban planning certification systems are BREEAM, LEED and CASBEE.

BREEAM (Building Research Establishment Environmental Assessment Methodology) was conceived in the United Kingdom in 1990. There are different schemes of BREEAM certification; BREEAM Communities is the one applied in urban planning.

BREEAM assesses factors like accessibility, the distance to green areas, the design of safe spaces (in terms of the characteristics of the building facades, lighting, the existence of furniture, etc.), whether façade design encourages street activity (number of shops, number of gaps, blind zones, etc.).

LEED (Leadership in Energy & Environmental Design) is a certification system developed by the U.S. Green Building Council in 1998, in which projects earn points for meeting specific criteria. There are different kinds of LEED certification; LEED for Neighborhood Development is the one applied in urban planning.

LEED assesses factors that directly affect walkability, such as sidewalk width, building facades (number of entrances, glassed-in areas, etc.), the accessibility of parks, recreational facilities, etc.

CASBEE (Comprehensive Assessment System for Built Environment Efficiency) is a Japanese certification system that started being developed in 2001. A variety of different tools have been developed; CASBEE for Cities and CASBEE for Urban Development are the ones applied in urban planning.

CASBEE assesses what it calls social aspects such as traffic safety and crime safety, environmental quality aspects like shade and universal accessibility, and other factors.

In Spain, Salvador Rueda from the Urban Ecology Agency of Barcelona has developed a system of sustainability indicators which evaluates the degree of city model fit both at the start of the urban development (planning) and once the action has been implemented and is running (use and management) (Certification of Ecological Urban Development, Urban Ecology Agency of Barcelona, 2014). It studies factors related to the quality of urban space within the following areas:

- Public space and livability. Accessibility of the public pedestrian routes, air quality, acoustic comfort, thermal comfort, spatial perception of urban green.

- Mobility and services. Proximity to transportation networks other than cars, proximity to bicycle parking, proximity to bicycle loan service, parking, loading and unloading.

- Urban complexity. Balance between business activities and residences, local activities, knowledge-dense activities.

- Green spaces and biodiversity. Functionality index of parks and gardens, tree density per roadway, diversity of urban trees.

- Social cohesion. Availability of facilities.

1.5.3 Existing tools that work on walkability

The research performed analyzes the factors and features of other tools that deal with walkability, such as WalkScore, Walkonomics, PERS, MAPS, PEDS, SPACES and IAAPE. In each case we studied their sources, factors and objectives in order to discriminate and choose the most valid, least subjective ones with the greatest influence on walkability and less complex to obtain.

2. Methods

Walkability City Tool was developed in line with the preceding research. It is an analysis methodology based on Geographic Information Systems that allows the walkable network to be customized and measured, including technical, environmental, social, tourist and economic factors, in order to analyze, interpret and plan improvements in them. It can be used to support strategic decisions on the city based on evidence instead of on intuitions and subjective opinions.

2.1 How does the Walkability City Tool analyze walkability?

The factors that most significantly influence walkability have been gathered, culled and studied. The working base of the data-gathering with the WCT is the sidewalk, the place where people walk, and not streets or roads. They are grouped into five thematic areas:

- Modal distribution. Figures on the division of space between the different means of transportation: number of lanes, parking lots, bicycle lanes, pedestrian zones, public transportation, etc.

- Urban grid. Characteristics of the sidewalks: width, pavement condition, protective strip, obstacles, intrusions, slope, etc.

- Urban scene. Figures on the environment around the pedestrian when walking: activities, homes, trees, characteristics of the façades, urban furniture, etc.

- Safety. Factors that influence the perception of safety when walking: street lighting, direction signs, presence of activities, etc.

- Environment. Environmental factors that influence the activity of walking: noise levels, sunlight, pollution, dominant winds, etc.

Crosswalks are analyzed from three perspectives: delay (time it takes to cross them), safety and accessibility.

2.2 Methodology

2.2.1 Data-gathering

2.2.1.1 City and experts

The first information-gathering phase comes from studying the city and the working area with the help of experts in different fields who are familiar with the city, including planning, mobility, education, safety, governance, a range of associations, existing working groups, etc.

2.2.1.2 Citizen participation

A participation strategy is devised to gather information from citizens who live or perform some kind of activity in the area being studied. Depending on the kind of population sample, open information-gathering sessions are organized, some of whose results are later used to prioritize the actions.

2.2.1.3 Field data

The exhaustive gathering of the information needed on the sidewalks, the overall setting and crosswalks takes place on the street. The way the information is gathered is determined based on the scope of the project, although it usually happens by training auditors or in-house staff.

2.2.2 Data analysis

By weighing the data, a score is assigned to each stretch of the sidewalk and each crosswalk indicating their degree of walkability.

The data gathered and the scores are fed into a Geographic Information System. The WCT tool is completed with the Massachusetts Institute of Technology's "Urban Network Analysis" freeware, applying its calculations to flows among nodes.

The data obtained is used to create graphic information that is easily interpretable by managers: "heat" maps assessing the streets, dysfunctions in the network, black spots, repercussions of actions, etc.

3. Results

As part of the Emerging and Sustainable Cities Initiative of the Inter-American Development Bank, Walkability City Tool has been applied in the Financial District of Panama City (Figure 1).

Figure 1. Area of study in Panama City.

A walk through the district reveals that there is much room for improvement on the streets: the sidewalks are invaded by cars and even disappear, and there are obstacles, holes, steps, etc. Efforts are needed to design the pedestrian service, protect against vehicles and improve crosswalks, but it is imperative to be able to see all of these deficiencies in an objective way.

When applying the methodology described above, in the first phase information was gathered from the local authorities and experts: the mayoral team, the urban planning team, the team from the Inter-American Development Bank, neighborhood representatives, wheelchair users, etc.

The second phase involves citizen participation, in which people of different ages and conditions discuss the factors that influence them the most when walking.

Finally, the fieldwork is performed, led by the city's urban planning team. The auditors receive training which enables them to gather the data, specifically 42 items on each sidewalk and 13 items on each crosswalk.

Once all of the data have been fed into the WCT tool, the results enable us to develop an analysis and diagnosis of the walkability of the zone. The average score of the area (Figure 2) gives an idea of its degree of walkability. Furthermore, each stretch of sidewalk and each crosswalk can be analyzed through their overall WCT Score (Figure 3) or thematically.

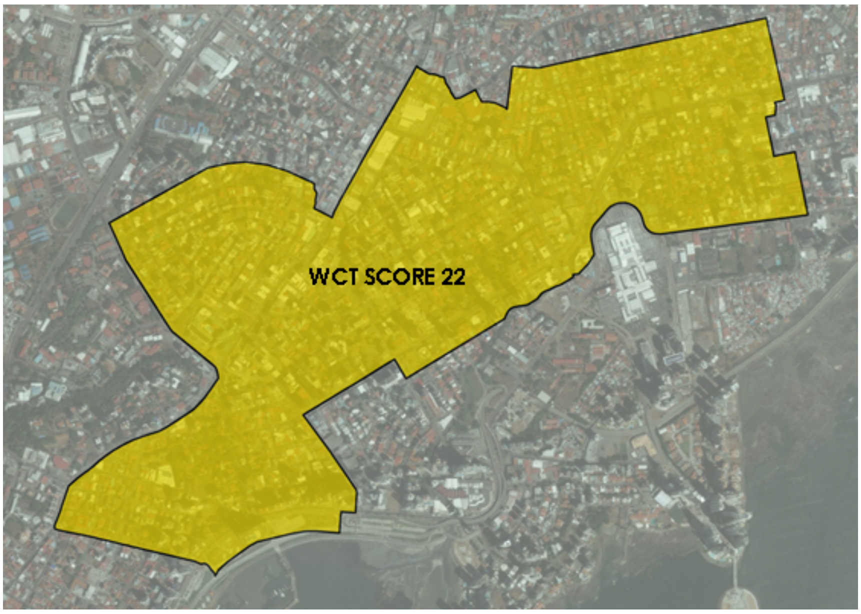


Figure 2. Average WCT Score of the area of study.

Figure 3. WCT Score on stretches of sidewalk.

The average score per zone (Figure 4) allows us to compare the different walkability conditions in each neighborhood.

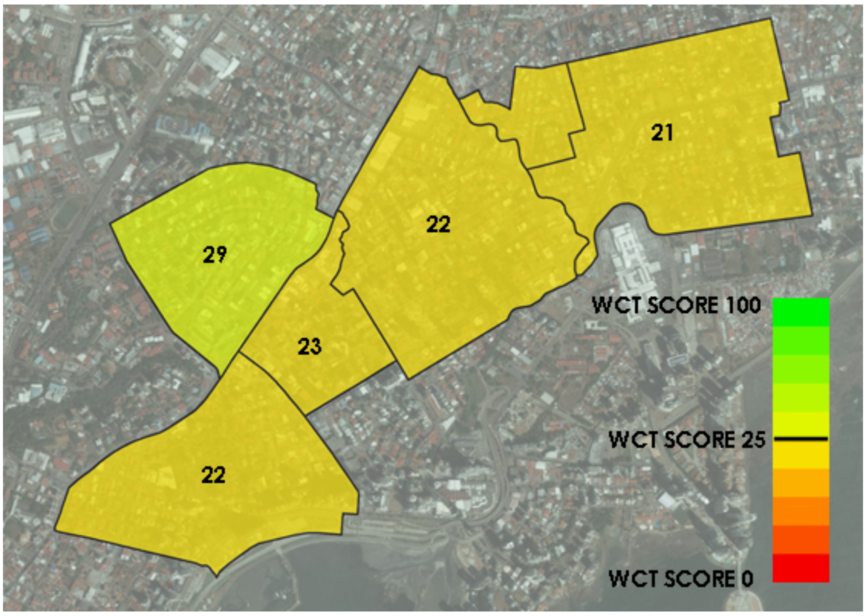


Figure 4. Average WCT Score per neighborhood.

The picture reflects the walkability of the streets projected over the area (Figure 5), revealing the focal points of positive influence, such as parks and the more walkable streets, compared to the zones with the most dire shortcomings.

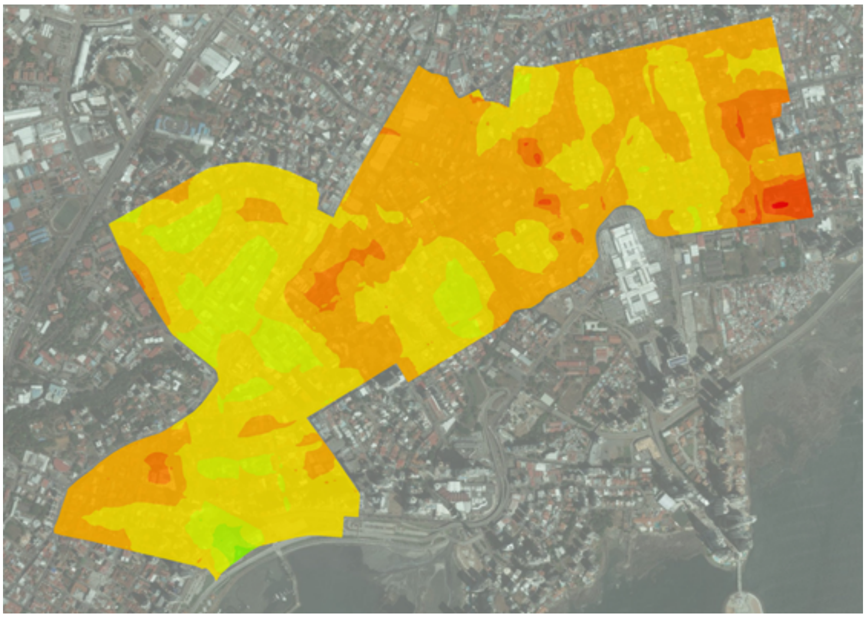


Figure 5. WCT Score in área.

In addition to the analysis from the map with the overall scores of each stretch of sidewalk, studying the different thematic areas separately or even certain particular items by neighborhood (Figure 6) allows us to determine the priority strategies of action.

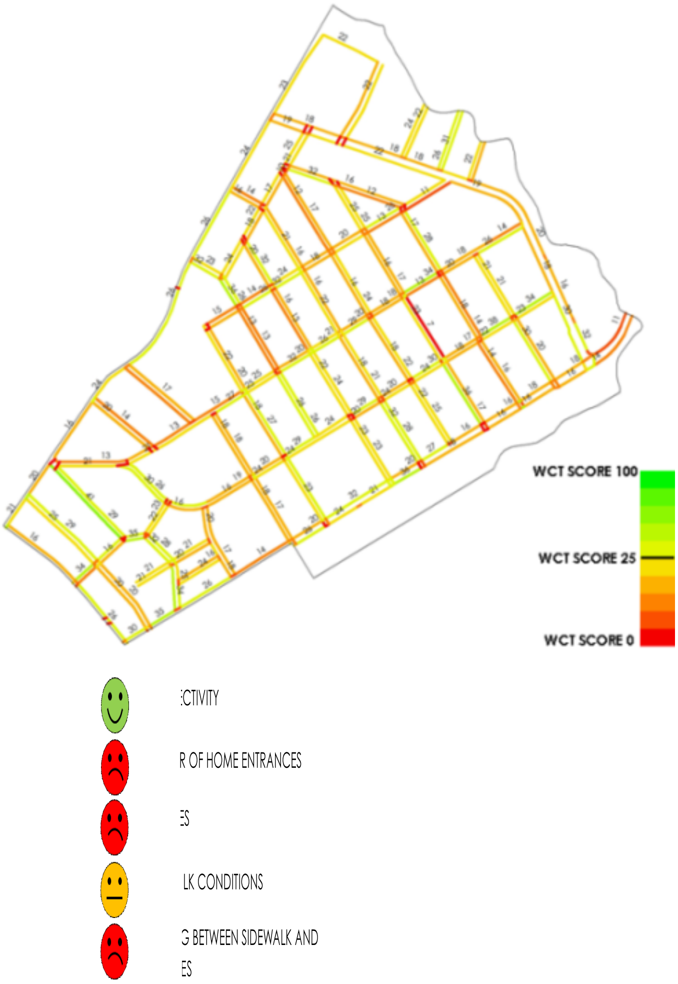


Figure 6. Example of neighborhood analysis.

All the subway stations and their coverage are also analyzed (Figure 7). The roadway network surrounding the subway stations, with their sidewalks and crosswalks, is what provides the pedestrian coverage needed to allow the public transportation network to be used to its fullest. Improvements in the walkable network near the stations will lead to an improvement in their accessibility and a consequent increase in the number of users. Two stations are located within the area of study, situated with a service radius of between 400 and 500 meters (approximately a 5-minute walk). However, this is a theoretical radius which could be transformed into real distances if routes are taken along sidewalks and crosswalks. Thus, these 400 meters considered suitable for the station service are reduced considerably in some areas due to the morphology of the urban fabric, such as large city blocks, few crosswalks, etc. (Figure 8).

Figure 7. Theoretical radial coverage of the stations.

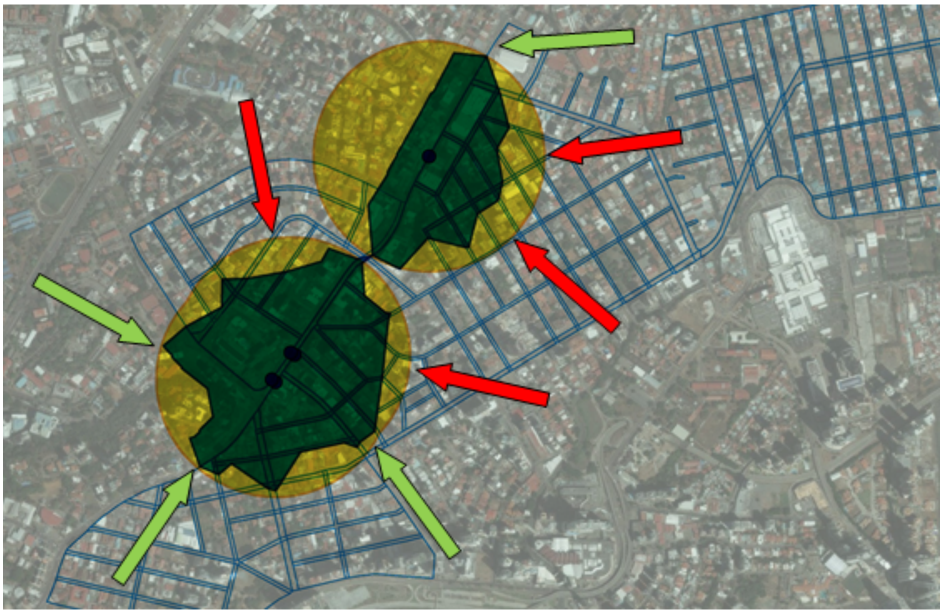


Figure 8. Coverage by sidewalks and crosswalks.

If we further this analysis with the influence of the characteristics of the streets when walking (WCT Score), we can see how the theoretical distance of 400 meters contracts when the scores are low and expands when they are high (Figure 9). This reflects the fact that people are willing to walk more on some streets than others. A superimposition of the study of this coverage with the theoretical initial radius of 400 meters reveals that in some cases the characteristics of the streets are effectively shrinking the area covered by the infrastructure (Figure 10).

Figure 9. Coverage with WCT Score.

Figure 10. Comparison of coverages.

A sound strategy to foster and support the use of the subway network is working on the factors that affect the walkability of the areas around the stations. Some of the factors are quicker and easier to improve than others, and some are the outcome of others and happen naturally over time.

4. Discussion

The WCT tool groups together and weighs the factors that affect walkability by assigning values to the network of sidewalks and crosswalks. Thus, the areas can be analyzed by both the overall value of the streets and the partial scores by areas (Modal Distribution, Urban Grid, Urban Scene, Safety and Environment) and, of course, by viewing the maps of each of the items covered. Just like any database, it has to be consistently updated so that the city managers can have a clear picture of the situation of the streets, establish priorities and intervention strategies and manage the available resources, aimed at investments that seek clear objectives instead of merely generating maintenance costs.

5. Conclusions

In order to ensure that pedestrian mobility is borne in mind at the same level as vehicle mobility in mobility policies and plans, it is essential to have objective data. Walkability City Tool captures 55 main parameters of the pedestrian network (sidewalks and crosswalks) which are weighed to yield a walkability index. Feeding the information into a GIS allows the network as a whole to be analyzed, as well as each element independently, and it also allows routes to be calculated. The tool can be applied in countless ways: making strategic decisions on the city, developing specific indicators to monitor its evolution, laying out specific routes for groups (walks to school, tourism, the disabled), comparing grids, the influence of the walkable network on actions on the urban grid, etc.

Walkability City Tool is therefore a powerful analytical tool for sustainable urban management:

- Environmental sustainability, since intelligently managing mobility based on an analysis of the pedestrian network allows decisions to be made aimed at encouraging less-polluting means of transportation in order to lower emissions, noise, congestion and accidents and improve air quality, acoustic quality and citizen health.
- Economic sustainability, since establishing and monitoring parameters and indicators on urban pedestrian activity allows actions to be planned and prioritized, transforming spending into investment. Furthermore, the tool also provides data to help take strategic decisions on retail and tourism, the economic engines of many of our cities. Indirectly, the environmental and social improvements also translate into economic savings for citizens (for example, less pollution and improvements in healthy living habits lead to lower healthcare spending).
- Social sustainability, since the main goal of intelligently managing the city is to improve its inhabitants' quality of life. The Walkability City Tool allows factors to be identified that can lower social exclusion, foster integration, improve social relations and quality of life in the city and minimize conflictive spots. Furthermore, the improved quality of our public spaces and their transformation to the scale of citizen on the street improves social relations and life in the city.

Analyzing each street and each crosswalk allows us to study urban grids as a whole in the quest for a model that increases complexity, cohesion, compactness, information and knowledge so the compact, diverse city head towards sustainability and the Smart City.

References

Main sources:

Urban Ecology Agency of Barcelona, 2014. Certification of Ecological Urban Development.

Gehl, Jan, 1971a. The Livable Environment: Psychological Aspects of Homes.

Gehl, Jan, 1971b. Life between Buildings.

Lyle, John, 1969. Tivoli gardens.

Gehl, Jan, 1968. Pedestrians.

Kao,Louise, 1968. Seating Preferences on Kongens Nytorv.

Jacobs, Jane, 1961. The Death and Life of Great American Cities.

A new biorefinery concept to valorize maize residues and the organic fraction of municipal solid wastes

Elena Surra[1], Suzanna Lancinha[1], Maria Bernardo[2], Isabel Fonseca[2], Rui Ribeiro [2], José Paulo Mota[2], Nuno Lapa[1], Isabel Esteves[2]

[1]LAQV-REQUIMTE, Departamento de Ciências e Tecnologia da Biomassa, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, 2829-516 Caparica, Portugal

[2]LAQV-REQUIMTE, Departamento de Química, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, 2829-516 Caparica, Portugal

Email contacts: ESurra: e.surra@campus.fct.unl.pt. SLancinha: s.lancinha@campus.fct.unl.pt. MBernardo: mmb11704@fct.unl.pt. IFonseca: blo@fct.unl.pt. RRibeiro: rpp.ribeiro@fct.unl.pt. JPMota: pmota@fct.unl.pt. NLapa: ncsn@fct.unl.pt. IEsteves: iaesteves@fct.unl.pt

Abstract

The management of bio-wastes has become a critical issue in terms of global warming and contamination of natural resources. Anaerobic Digestion (AD) offers the opportunity to produce both biogas and other valuable sub-products derived from the digestate such as Low-Grade Activated Carbon (LGAC). The biogas is suitable for grid injection or for fuel transportation when upgraded to Green Gas (GG) (methane > 97% v/v), and LGAC can be used for biogas upgrading to GG. Two types of wastes that are quite suitable to AD are the Organic Fraction of Municipal Solid Waste (OFMSW) and Maize Residues (MR). OFMSW is produced worldwide in high amounts, while maize, the most produced cereal in the world, generates wastes that often exceed the organic-C quantity needed for soil fertilization, being available as a non-economic waste. Maize residues (MR) can be valorised directly for producing LGAC or can be, after a proper pre-treatment, co-digested with OFMSW for biogas production. This work corresponds to the preliminary phase of a recent European project and comes across the optimization of AD operational conditions and process adjustments for biogas conditioning and upgrading to produce GG through a bio-refinery concept. To run an AD lab-scale unit, it was used a pre-hydrolysed OFMSW obtained from the hydrolysis tank of an industrial AD plant. In order to increase its digestibility, the MR was ground and submitted to different pre-treatments: Microwave Irradiation (MWI) assisted pre-treatments catalysed by sodium hydroxide (Na(OH) 2, 4, 6, 10 and 20 % w/w, an High Boiling Solvent (95 % glycerol + 5 % H_2O, 95 % glycerol + 5 % Na(OH) 1.0 M and 95 % glycerol + 5 % Na(OH) 1.5M) and hydrogen peroxide (H_2O_2) at 0.125, 0.25, 0.5 and 1.0 H_2O_2/biomass ratios). A room temperature chemical pre-treatment with hydrogen peroxide 0.125, 0.25, 0.5 and 1.0 H_2O_2/biomass ratios is carried out. The pre-treated MR with higher lignocellulosic biomass solubilisation, low inhibitors content and higher sugar yield is feed into the digester operated with the OFMSW. The efficiency of (i) the anaerobic digestion of the hydrolysed OFMSW and (ii) the co-digestion of the hydrolysed OFMSW and hydrolysed MR will be assessed through: a) the conversion efficiency of the organic substrate into biogas and b) the biogas quality. The biogas produced, before being introduced into the upgrading system, has to be previously conditioned to reduce hydrogen sulphide (H_2S) and possibly carbon dioxide (CO_2) content. In this project phase, activated carbon columns are installed. In a later stage, Pressure-Swing Adsorption (PSA) technology using the activated carbon produced from the MR and from AD digestate will be applied in the ongoing project, fulfilling the requirements of the bio-refinery concept proposed.

Acknowledgements: the authors would like to thank financial support from ERANET (financed by FP7) and Fundação para a Ciência e a Tecnologia (FCT/MEC) through the projects ELAC2014/BEE0367 and IF/01016/2014.

Keywords: Renewable Energy, Anaerobic Digestion, OFMSW, Maize Residues, Energy Efficiency

Theme 3 posters

A decision with long-term consequences: An empirical study of homeowners' decision-making process for heating system replacements and new installations

Maria Hecher 1, Stefanie Hatzl 1, Christof Knoeri 2, Alfred Posch 1

1 Institute for Systems Sciences, Innovation and Sustainability Research, University of Graz, Austria

2 Group for Sustainability and Technology, Department of Management, Technology, and Economics, ETH Zurich, Switzerland

Abstract

Energy demand from buildings is of particular importance as it accounts for a significant amount of the final energy use, offers massive savings in terms of environmental impacts, and restricts the speed of change through the long lifetime in our build environment. State-of-the-art technologies such as heating systems present a major opportunity to reduce buildings' energy demand and mitigate environmental impacts drastically in the next couple of decades. In this context, an important issue is to get a deeper understanding of homeowners' decision-making process identifying factors which foster or hinder heating system adoption decisions. Although the number of studies which investigate factors influencing such decisions increased in recent years, this study addresses some outstanding issues by (i) conducting real preference research; (ii) operationalizing homeowners' behaviour based on innovation and behavioural models; and (iii) considering heating system adoption decisions as a process. The purpose of this study is to empirically research private homeowners' decision-making process for heating system replacements and new installations identifying their motives to invest, information channels, actors and factors influencing the adoption to specific types of heating systems. In this context, a systematic literature analysis and four guided interviews with experts in the field of heating engineering were conducted (April 2015). These interviews aimed at validating and exploring the decision-making process of private homeowners. The results of the literature analysis and interviews served as a valuable basis to design a quantitative questionnaire. In an empirical survey (September – October 2015) data was collected from private Austrian homeowners of existing or newly build single and double-family houses. A representative sample of 1.000 homeowners was randomly selected by the professional research survey service provider Qualtrics, the world's leading panel survey software company (adopters with N = 560, non-adopters with N = 440). The first results of the empirical survey show, that the decision for specific heating systems is not only depended on building characteristics and economic factors, but is also determined by the (i) motives homeowners have to invest in a new system; (ii) information channels they use and suggestions by contacted actors; and (iii) by ecological factors or factors concerning supply security issues. The results of the study give new insights into the decision-making process of private homeowners and enable to derive policy measures fostering renewable heating systems. Decisions for heating technologies in the private building sector are important as these decisions have long-term effects not only on the future building infrastructure, but also on the future energy demand and our climate.

Keywords: Heating systems; private homeowners, decision-making process

A preliminary assessment on the effects of small hydropower schemes on the aquatic and riparian vegetation. Some Portuguese case studies

Maria Manuela Portela[1], Miguel Mendonça[2], Francisca Aguiar[3]

[1] Instituto Superior Técnico (IST), Civil Engineering Research and Innovation for Sustainability Center (Ceris), University of Lisbon, Lisboa, maria.manuela.portela@tecnico.ulisboa.pt

[2] Instituto Superior Técnico (IST), miguelsrmendonca@gmail.com

[3] Faculty of Sciences, University of Lisbon (FCUL), cE3c - Centre for Ecology, Evolution and Environmental Changes; Instituto Superior de Agronomia, Centro de Estudos Florestais, Universidade de Lisboa, Lisboa, fcaguiar@fc.ul.pt

Abstract

Small hydropower schemes (SHPs) are often defined as schemes with installed capacities up to 10 MW. Due to their small size and exploitation mode they are usually recognized as environmental-friendly technologies. However, they modify the river flow regime, especially along the river reaches between the water intakes and the powerhouse tailraces. Based on twelve SHPs located in Portugal, the study aimed at characterizing the alterations in the river flow regime due to schemes and their effects on the aquatic and riparian vegetation. For each scheme a comparison is done between the flow regime prior and after its construction, by means of indicators of hydrologic alteration (IHA) applied to the natural flows and to the flows resulting from simulation studies. Three river reaches were considered: the one upstream the water intake with natural flow regime; the interfered reach located between the water intake and the powerhouse of the SHP which assumable will denote the most significant alteration; and the modified regime downstream powerhouse and which is most sensitive to the storage capacity of the reservoir of the SHP. Information about the riparian and the aquatic vegetation in river stretches where the schemes are located was collected and summarized in the form of metrics. To identify relationships among the IHA and the river regimes a PCA was performed. It was concluded that there is significant alteration in the flow regime in the river reaches between the water intakes and the turbine tailraces. On the other hand, little or no change was observed between the flow regimes downstream the powerhouse and upstream of the water intakes. Based on the results of the vegetation metrics for the monitoring locations, a small decrease in the ecological quality of the interfered and modified river stretches, when compared with natural ones was observed. Finally, plant traits were assigned to each species and functional, compositional and structural metrics, with expected responses to flow alterations were obtained and compared between monitoring locations and analysed, according to expected responses. The study showed that (i) the river flow alterations are mostly relevant in the interfered river reaches; (ii) a decrease of the ecological quality is observed in reaches with interfered and modified river flow regimes, which might be indicative of the effects of hydrologic disturbance in the vegetation communities and in their lateral and longitudinal structure, making it deserving surveillance; (iii) though responses of metrics were mostly concordant with what was expected under disturbance, the magnitude of changes was small, in comparison with the magnitude of alterations in the flow regime; (iv) despite the similarity between natural and modified regimes, further studies are required in order to analysis the effects of the sub daily flow variations in the structure and composition of vegetation downstream of powerhouses; (v) the methodology applied to these case studies can be replicated for other small hydropower schemes, with the careful prior analysis of other environmental and habitat variables, so that the study of the disturbances due to river flow regime alterations is reliable.

Keywords: Small hydropower schemes; natural, interfered and modified flow regimes; indicators of hydrologic alteration; river flow modelling; aquatic and riparian vegetation

Application of porous materials for purification of flue gas from mercury to avoid atmosphere pollutions

Magdalena Wdowin[1], Rafał Panek[1], Piotr Kunecki[1], Beata Stożek[2],

[1]Lublin University of Technology, Civil Engineering and Architecture Faculty, Nadbystrzycka 40, 20-618 Lublin, Poland

[2] The Mineral and Energy Economy Research Institute of The Polish Academy of Sciences, Wybickiego 7, 31-261 Kraków, Poland

Abstract

Coal combustion is related with emission to the atmosphere of many pollutions occurring in the flue gas stream among others: NO_x, CO_2, SO_2, CO, Hg (gaseous form and solid particles). Considering purification of sulphur or nitrogen pollution there are exist many efficient methods for removal of them from flue gas. In case of carbon dioxide one of the CO_2 reduction option is CCS (Carbon Capture and Storage) technology. the problem is too high cost of carbon dioxide capture stage, where its cover up to 75% of the total cost of CCS. Therefore there is a necessity to search new, cheaper sorbents of CO_2. The second problem constituted a presence of mercury compound in the flue gas during carbon dioxide capture. Mercury compounds, although occur in very small amounts in the exhaust gas stream they reduce of CO_2 sorbents efficiency. Besides during transport of carbon dioxide via pipelines mercury cause their corrosion. Therefore the main aim of the studies was to evaluate possibility of synthesis of micro/mesoporous materials from fly ash in order to evaluate their sorbents properties from point of view mercury removal to avoid air pollution. Tested materials constituted zeolites (Na-X type) and mesoporous materials (MCM-41) obtained from fly ash (coming from hard coal combustion). Derived micro-/mesoporous materials were characterized by mineralogical (XRD, SEM-EDS), chemical (XRF) and textural analysis (BET surface area, PSD - Pore Size Distribution). Carried out examination have shown that Na-X zeolites have micro-/mesoporus nature where MCM-41 is mesoporous. Chemical composition of tested materials revealed a significand amount of silica in both tested materials: Na-X (SiO_2 = 40% wt.) and MCM-41 (SiO_2 = 88%). Besides in X type zeolite it is observed a large amount of aluminum (Al_2O_3 = 28%). In SEM observation Na-X have cubic crystals however MCM-41 have spherical shape grains. Preliminary test of mercury removal carried out on raw zeolite material have shown that this material remove neglect amounts of Hg. Only silver activation of Na-X significant improve mercury sorption (event five times better than commercial active carbon with bromine). Therefore tested porous materials can be promising material for removal of mercury compound but only after activation of them by silver compound or etc.

Keywords: Mercury, CO_2 sequestration, micro-/mesoporous materials, fly ash

This work was financed from National Centre for Research and Development (NCBR) contract number LIDER/384/L-6/14/NCBR/2015

Framework for mitigation simplification and evolutionary citywide energy optimization: Hong Kong Case-study

Luís Coruche[1],

[1]ARSURB (Association for Resilience and Sustainability of the Lisbon Region), Rua da Arrábida no. 64 r/c A, 1250-034 Lisbon, Portugal. luiscoruche@zoho.com

Abstract

From the historical response of the United Nations Framework Convention on Climate Change (UNFCCC) two critical hindrances to effective global mitigation are identified: a) its top-down nature does not fully articulate stakeholders' interests and b) the progressive concentration of these gases outpaces the existent mitigation ability. We argue that solutions to these hindrances are critical for successful mitigation. Hence we present a case-study of the city of Hong Kong (HK), aimed at identifying complementary modes of governance, coupled with a means of acceleration of magnitude in greenhouse gases offsets. We identify the advantages of downscaling the UNFCCC's policy cycle (quantification, evaluation, differentiation and target-setting) and transnational municipal networks as enablers for multi-level stakeholders integration. We identify urban information modeling as an enabler of horizontal stakeholders integration and finally urban 4E (energy, environmental, economical, engineering) analysis as an enabler of progressive mitigation. Based on this, to facilitate the local Climate action plan, we advance a prototype decision support system dubbed Energy Efficiency Information Platform. This platform is consistent with the Intergovernmental Panel on Climate Change and the International Energy Agency methodologies and serves both the evaluation of compliance of HK's voluntary carbon intensity target (-55% by 2020) and to identify progressive mitigation solutions for its achievement. As such, we determined the base carbon intensity (CI) scenario upon which we simulated citywide energy efficiency optimization; thus responding to stakeholders integration and mitigation acceleration in a new world context. This simulation runs on a simplified HK MARKAL-MACRO within which we identify a Priority Set of Systems and simulate its energy optimization. This process therefore represents the potential offset yield of a citywide energy optimization iteration and the corresponding result is tracked in a CI benchmark index of the overall urban system. The results from this offset, in reference to 2015, are: i) the identified Priority Set of Systems belongs to the space conditioning end-use, from leased areas of commercial buildings and comprises only 2% of the total units within its specific demand sub-sector end-use, ii) it achieves -3.3% from the 55% HK's CI target, iii) it offsets 1.7% from the overall HK CO2-equivalent emissions (-905 Kilotonnes CO2-eq) and iii) represents $40,963,000 HK in CO2 emission quotas (Shenzhen exchange, Jun. 2014). Thus we demonstrate that: a) by carbon policy dialectics and bottom-up 4E modeling a citywide optimization algorithm with high offset potential can be identified and b) through integral methodological compatibility it can benefit from the critical properties of iteration, recursion and scalability within global Climate frameworks. Hence we conclude that the Energy Efficiency Information Platform would i) foster integral collaboration, ii) contribute to simplify the global mitigation framework and iii) render a finite nature to mitigation problems. These are invaluable features for: a) Differentiated and refined regulatory frameworks, b) to support integrally compatible carbon finance (financial securitization of energy efficiency, citywide certified emissions reductions, etc...) and c) to identify additional clean urbanization principles. All of which compatible, both at the UNFCCC and transnational municipal networks level.

Keywords: Mitigation,Integral, Simplification, Evolutionary, Optimization

Optimized control of effluent quality for improved energy consumption in wastewater treatment works

Elfrida M. Carstea, Gabriela Pavelescu, Simona Dontu, Dan Savastru

National Institute of Research and Development for Optoelectronics, INOE 2000, Magurele, Atomistilor 409, 077125, Romania; elfrida.carstea@inoe.ro; gpavel@inoe.ro

Abstract

Climate change, population growth, urbanisation and pollution all mean that society faces an urgent need to adapt to reductions in natural resource availability and reductions in energy consumption. Consequently, most countries are implementing national and regional programs to reduce carbon emissions from many industrial sectors. The water industry has a significant role to play in achieving this goal, as wastewater treatment is an energy-intensive operation. The largest energy usage in wastewater treatment is found in the vigorous aeration of settled sewage in the activated sludge process (ASP), which alone contributes to over 55% of the energy costs associated with wastewater treatment. Energy consumption has increased significantly in the last two decades, and further increases of 60% are forecast in the forthcoming 10-15 years. These increases have been brought about primarily in response to tightened legislation and regulation surrounding the discharge of final effluent from WwTWs to watercourses. The quality of wastewater is generally assessed using physical, chemical and microbiological tests. Among these techniques, reliance is often placed on biological oxygen demand (BOD), chemical oxygen demand (COD) and total organic carbon (TOC). However, these global parameters depend on expensive or time-consuming methods, offering only snapshots of moments in time. Consequently, water utilities often over-aerate in order to ensure compliance with final effluent standards. This means that there is a significant opportunity to save energy by optimizing aeration control in the ASP in order to minimize energy consumption whilst maintaining final effluent compliance. It is estimated that 40 % of the energy consumption in wastewater treatment works could be reduced if an effective method is used for effluent quality monitoring. Fluorescence has been shown to be a valuable technique in characterizing dissolved organic matter (DOM) and tracking sources of pollution in surface water. Therefore, this study aims to use fluorescence spectroscopy as an innovative and robust method to monitor and control the chemical and microbiological quality of wastewater in ASPs. The removal efficiency of DOM in five wastewater treatment works, at different processing stages, was investigated. Samples of crude, settled and secondary treated wastewater (activated sludge), and final effluent were collected. Fluorescence was measured for unfiltered and filtered (0.45 and 0.20 μm) samples. The measurements were correlated with BOD, COD and TOC. Moreover, the potential of using portable fluorimeters was explored in comparison to laboratory-based instruments. Good correlations were observed for filtered and unfiltered wastewater samples between fluorescence intensity and BOD ($r = 0.78$), COD ($r = 0.90$) and TOC ($r = 0.79$). BOD displayed a higher correlation at the 0.20 μm filtered samples compared to COD and TOC. Slightly better relation was seen between fluorescence and conventional parameters at the portable fluorimeters compared to laboratory-based instruments. The results indicated that fluorescence spectroscopy could be used for continuous, real-time assessment of DOM removal efficiency in wastewater treatment works. [This work was funded by Core Program, under the support of ANCS, project OPTRONICA IV, PN 16.40]

Keywords: energy, wastewater treatment works, fluorescence spectroscopy, dissolved organic matter

Surface temperature and the environmental assessment of hydroclimatic services provided by the vegetation cover in the semi-arid of Brazil

Felipe Alcântara de Albuquerque[1], Suzana Maria Gico Lima Montenegro[2], Bernardo Barbosa da Silva[3], Helder de Barros Guimarães[4]

[1] Federal Institute of Pernambuco - IFPE, felipe.alcantara@afogados.ifpe.edu.br

[2] Federal University of Pernambuco - UFPE, suzanam@ufpe.br

[3] Federal University of Campina Grande - UFCG, bbdasilva.ufpe@gmail.com

[4] Ministry of Defense – Brazilian Army, helderprof@gmail.com

Abstract

The assessment of the environmental services provided by ecosystems can be considered one of the new tools about the prospects for land surface with human occupation. The expectation that such services may provide regulatory process and the provision of goods, meet the new demands for sustainable development. This paper seeks to establish some mechanisms of evaluation for some of the hydro environmental services in areas under pressure by human occupation, in order to use, these services, for regional development. Remote sensing technology tools and digital geo physical data were used to analyze the diagnoses semi arid local ecosystem. Vegetation index, albedo and the relief of watersheds were used in the assessment of the behavior of the surface temperature, and consequently give support to the potential assessment of climatic and hydric comfort. The vegetation associated with the physical characteristics of the relief formed a set of very important variables in explaining surface temperature. Just the vegetation, limited or no by their physiological characteristics, already could be a very important interference factor for that region. Knowing the importance of environmental services and the difficulties of managing natural resources in theses semi-arid areas, the conservation of natural vegetation areas could potentially provide much of the climatic and environmental water services on a regional scale. Thus, local authorities should be interested in the results of this assessment, because the mapping of environmental services areas, associated with surfaces under anthropic pressure for resources consumption, can be considered for regional development and creation of new public policies.

Keywords: Geoprocessamento; Sensoriamento remoto; Hidrologia; Semiárido.

1. Introduction

The concept of Environmental Services (ES) came up with the need to demonstrate that natural areas are responsible for complying essential functions in the maintenance processes of life, in opposition to the false idea that preserved or intact ecosystems are considered “unproductive” or “obstacles to the economic development”. This means that the entire ecosystem is a natural system that produces a number of benefits of which man appropriates (such as water, wood and food) or consumes (such as landscape, climate regulation and air purification) (CAMPANILI and SCHAFFER, 2010).

The characterization of environmental services is not simple and the evaluation of their qualities even less, this is because the ecosystems are rich in specifics, and questions about the balance, stress and potential about provision of the service may suffer considerable variations. This complexity makes it relatively expensive a systematic experimental analysis for an ecosystem of large or medium scale, being necessary to the development of new strategies such as the use of applied technology.

With the development of the remote instrumentation, that is an increment of hardware and software applied to obtain physical data without direct contact, mainly from the 70s, became possible the increasing use of mechanics, thermophysical and computational technology directed to the environmental studies, so appears the field of scientific studies based on remote sensing.

Through the images and data obtained by remote sensing is viable to analyze terrestrial targets based on photodynamic spectral characteristics. This technology is emerging as an alternative of experimental realization of dynamic environmental research for large scales, from the stimulus and geoprocessing appropriate to the directed interpretation.

Orbital images obtained by diverse types of satellite can also be useful tools for evaluation of the space distribution and the status of environmental components. In turn, hydric elements present potential for practical applications of orbital remote sensing, because it has easiness in interacting with the electromagnetic energy and presents a great strategical importance. (ZWART & BAASTIANSSEN, 2007).

So, the objective of this research was to use the orbital images of the satellite Landsat 5 (sensor TM), generated from the remote sensing of the Brazilian semi-arid region's surface, as a technical subsidy to develop strategies of evaluation of the regional hydroclimatic environmental services, estimating its cause and local integrity based on visual interpretation and statistical analysis.

The region selected for the propose of this assessment is important for the development of the state of Pernambuco – Brazil, because, according to the Water Agency (ANA) in your Atlas (2005) and the local strategic planning for water, Pernambuco (2008), the region concentrates a mix of conditions naturally adverse to human installation and the production of goods, with a very limited water supply (intermittent rivers) and political conflicts. At the same time has a rate of irradiance perfect for irrigated production and production of photovoltaic electricity, beyond the strategic positioning for the development of semi-arid region of Northeast Brazil.

2. Materials and Methods

2.1 Description of the study area

The Pajeú's River watershed fits into the context of experimental and representative basins of the SUDENE (CIRILO et al., 2007), which is located between the geographical coordinates of 07°16’20” and 08°56’01” south latitude and 36º59’00” and 38°57’45” west longitude of Greenwich. It is inserted in the physiographic region of the Pernambuco’s backwoods, in the microregions of the Pajeú, of the Sertão do Moxotó, of the Salgueiro and of the Itaparica (CIRILO, 2008).

The Pajeú's watershed is limited to the north by the states of Ceará and of Paraíba, to the south by the third group of basins of small interior rivers GI3 (UP22) and the Moxotó’s watershed, to the east by the Moxotó’s watershed and the state of Paraíba, and to the west by the watershed of the Terra Nova river (UP10) and the fourth group of basins of small interior rivers GI4 (UP23).

It is one of the Pernambuco's basin that belong to the strand of the São Francisco River and also is the most extensive among the river basins of the state, with an area of 16685.65 kmª, which corresponds to 17.02% of the state surface (SRHE-PE, 2006). The area has a annual rainfall averages less than 800 mm, concentrated in the months February, March and April, period in which the precipitation represents up to 70% of annual total (SECTMA-PE, 2006) and where are located the sources of the river system's first makers.

In the Pajeú’s basin, and throughout the Pernambuco’s backwoods mesoregion, rainfed agriculture and livestock are the main economic base of the region, and the extreme exploration of livestock, is a determinant for the fragility of the economy. Irrigation is present with little influence due to water potential generated within the region.

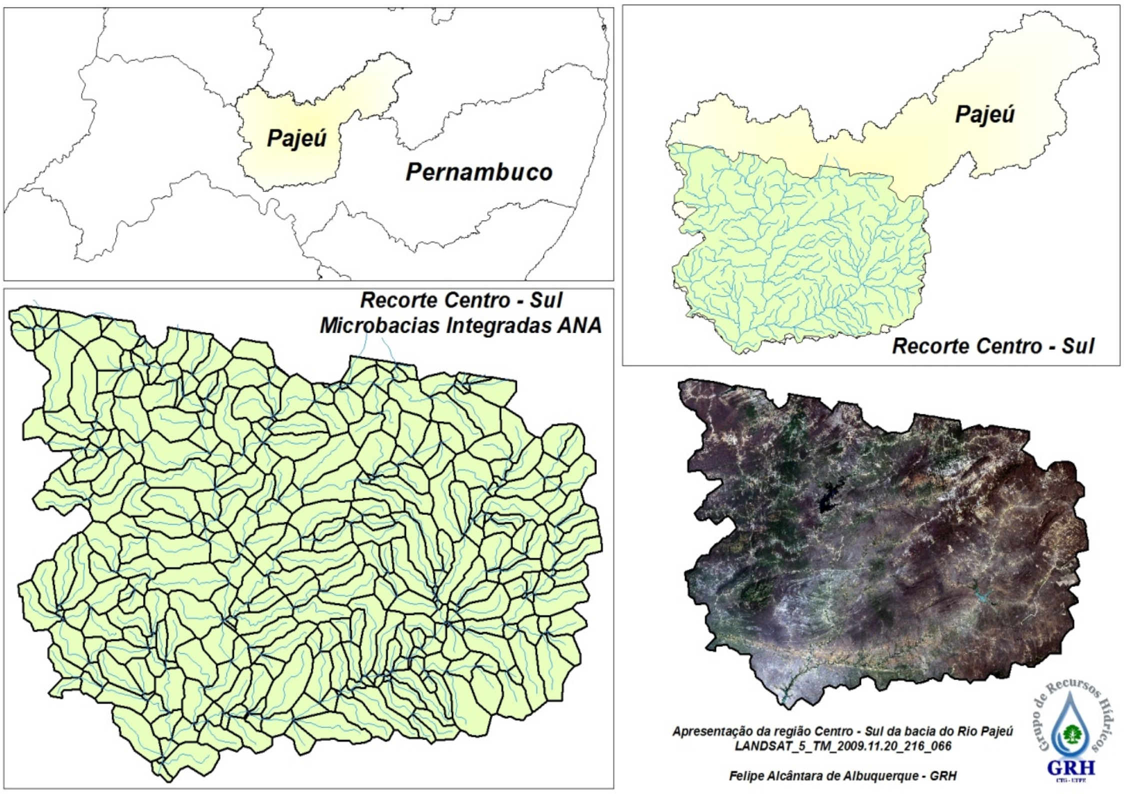


Figure 1: Determination of the crop area, in this case, the south-central portion of the Pajeú's watershed.

2.2 Methods

The choice of the area's limits to perform the modeling obeyed to the mosaic's cut of the integrated Brazilian watersheds referring to the Ottobacias project of the National Water Agency – ANA, thus forming a landscaped fractional fragment from the central region of Pernambuco, corresponding to a big part of the watershed of Pajeú.

From the image TM of the Landsat 5 satellite, precisely of the orbits 216 point 66, on 20/11/2009 the procedures for application of the model were performed. The images were geometrically corrected and then it was possible to safely perform the step of deleting the gray areas, which mean, areas with cloud cover.

The initial step in modeling was the computation of the spectral radiance of each band ($L_{\lambda i}$), obtained by transforming the digital number (*DN*) of each pixel in monochrome spectral radiance, process which is also known as radiometric calibration.

The radiance represents the reflected solar energy for each pixel, per unit of area, time, solid angle and wave length, measure to the level of the Landsat satellite 5 TM. For the spectral bands, it represents the energy emitted by each pixel, which can be obtained according to the equation of Markham & Baker (1987):

$$L\lambda i=ai+bi-ai254DN-1 \qquad (1)$$

Where: "a" and "b" are the minimum and maximum spectral radiance ($Wm^{-2}\ sr^{-1}\mu m^{-1}$) reported by Chander and Markham (2007), DN is the pixel intensity (integer between 0 and 255) and "i" is each band of Landsat 5 TM.

In the second stage it was gotten the computation of monochromatic reflectance of each band $(\rho_{\lambda i})$, which is defined as the ratio between the flux reflected radiation and the flux incident of radiation. From the data about the maps of spectral radiance of each band, information about the cosine of the solar zenith angle and spectral irradiance at the top of the atmosphere according to Chander and Markham (2007), was estimated the global spectral reflectance in each band by equation Allen et al. (2002), based on the first approach described in Bastiaanssen, (1995):

$$\rho\lambda i=\pi\cdot L\lambda ik\lambda i\cdot \cos Z\cdot dr \qquad (2)$$

$L_{\lambda i}$ is the spectral radiance of each band, $k_{\lambda i}$ is the spectral irradiance of each band at the top of the atmosphere , Table 2), Z is the solar zenith angle and d_r is the square of the ratio Earth-Sun's distance average (r_o) and the Earth-Sun distance (r) at a given Julian day of the year (JD) according to Iqbal (1983).

To make the model more sensitive to surface variations, the proposed calculation for the solar zenith angle for each pixel was used. In areas with steep slopes the angle of incidence of solar radiation depends on the surface slope and its aspect, that is, the azimuth of the normal to the surface, requiring in this case, the Digital Elevation Model Land – DEM and which was obtained by the equation proposed by Duffie e Beckman (1991):

$$\begin{aligned}\cos\theta rel = {} & \sin\delta\sin\phi\cos s-\sin\delta\cos\phi\sin s\cos\gamma \qquad (3)\\ & +\cos\delta\cos\phi\cos s\cos\omega\\ & +\cos\delta\sin\phi\sin s\cos\gamma\cos\omega\\ & +\cos\delta\sin\gamma\sin s\sin\omega\end{aligned}$$

In what δ is the sun declination (positive in the summer of the northern hemisphere); φ is the latitude of the pixel (positive for northern hemisphere and negative for the southern hemisphere); s is the surface slope, s=0 for horizontal and s=π/2 rad for a decreasing inclination in the vertical line (s is always positive and represents the decrease of the inclination in some direction); ϒ is the angle of the surface's aspect, and ϒ=0 for inclinations guided for south, ϒ=-π/2 rad for inclinations guided for east, ϒ=+π/2 rad for inclinations guided for west and e ϒ=±π radianos for inclinations guided for north. The parameter ω is the hourly angle, in what ω=0 to the half day, ω is negative during the morning and positive in the afternoon. All trigonometric functions are in radians. In the case of a flat surface, in which the aspect and the inclination are ignored, Equation 3 is reduced to the following equation:

$$\cos\theta hor=\sin\delta\cos\phi+\cos\delta\cos\phi\cos\omega \qquad (4)$$

Getting the elevation angle of the sun (E), the solar zenith angle for a plain and horizontal surface can be calculated as the difference between the solar culmination angle and the angle of the rise, to a flat surface, as can be seen below:

$$\mathrm{Cos}\theta=\cos(90°-E) \qquad (5)$$

Another important characteristic is that through the correction of **cosZ** for the **cosθ_{hor}** it is possible to reorganize the albedo not adjusted to the atmospheric transmissivity that now will use the value of the **$\cos\theta_{hor}$** for each pixel.

The next step is the computation of planetary albedo (α_{toa}), which is the albedo uncorrected to the atmospheric effects, obtained by linear combination of the monochromatic reflectance:

$$\alpha toa=0,293\rho 1+0,274\rho 2+0,233\rho 3+0,157\rho 4+0,033\rho 5+0,011\rho 7 \quad (6)$$

e ρ_7 are the planetary reflectance of the bands 1, 2, 3, 4, 5 and 7.

The surface albedo or also known as albedo corrected to atmospheric variations could be calculated based on the expression (Bastiaanssen et al., 1998):

$$\alpha=\alpha toa-\alpha p\tau sw2 \quad (7)$$

Where $\boldsymbol{\alpha_{toa}}$ is the planetary albedo, $\boldsymbol{\alpha_p}$ is the albedo of the atmosphere itself, that range between 0.025 and 0.04 and $\boldsymbol{\tau_{sw}}$ is the atmospheric transmissivity, gotten for clear sky conditions by equation proposed by ASCE-EWRI (2005).

$$\tau sw=0.35+0.627\exp[-0.00146PKt\cos\theta hor-0.075\ W\cos\theta hor\ 0.4] \quad (8)$$

$$P=101.3293-0.0065z2935.26\ldots(9)$$

$$W = 0.14eaPair+ 2.1 \quad (10)$$

Where P is the atmospheric pressure (kPa) - Eq. (7); W is the precipitable water (mm) - Eq (8); θ_{hor} is the solar zenith angle with the horizontal surface - Equation (4); K_t is the coefficient of turbidity of the atmosphere - K_t=1 for clear sky and K_t=0,5 for extreme turbidity, with many particles or polluted air (ALLEN 1996; ALLEN et al., 1998).

In sequence is the calculation of vegetation indices. First, the Normalized Difference Vegetation Index (NDVI), which is obtained by the differences in the reflectivity of near infrared (ρ_{IV}) and of the red (ρ_V), through the sum of the both:

$$NVDI=\rho IV-\rho V\rho IV+\rho V \quad (11)$$

ρ_{IV} and ρ_{IV} represent the planetary reflectance of the bands 4 and 3 of the TM - Landsat 5.

To calculate the Soil Adjusted Vegetation Index – SAVI, which is an index that aims to soften the effects of the soil background, was used the expression of Huete (1988):

$$SAVI=1+L\rho IV-\rho VL+\rho IV+\rho V \quad (12)$$

In what "L" is a function of the soil type. In several studies it was observed that L may vary from 0.1 to 0.5, and this last value is the most frequent value. For this study it was used L = 0.1 (Huete &Warrick, 1990; Accioly et al., 2002; Boegh et al., 2002).

The Leaf Area Index (LAI) was defined as the ratio between the leaf area of all vegetation per unit of area used by this vegetation. The LAI is an indicator of the biomass of each pixel, and it was computed by the following empirical equation obtained by Allen et al. (2002):

$$LAI=-\ln 0{,}69-SAVI0{,}590{,}91 \quad (13)$$

To obtain the surface temperature, was used the Planck equation inverted, valid to a black body. Since not each pixel emits electromagnetic radiation with a black body, it is necessary to introduce the emissivity of each pixel in the spectral domain of the thermal band $\varepsilon_{NB,}$ which is: 10.4 - 12.5 µm. In turn, in relation to the compute of longwave radiation emitted by each pixel, it is to be considered emissivity in the entire domain of longwave radiation - ε_0 (5 – 100 µm). According to Allen et al. (2002), the emissivities ε_{NB} and ε_0 can be gotten, to NDVI > 0 and LAI < 3, based on:

$$\varepsilon NB=0{,}97+0{,}0033.LAI \quad (14)$$

$$\varepsilon 0=0{,}95+0{,}01.LAI \quad (15)$$

For pixels with LAI ≥ 3, the $\varepsilon_{NB} = \varepsilon_0$ was considered equal to 0.98, and for the water bodies (NDVI < 0), $\varepsilon_{NB} =$ 0.99 and $\varepsilon_0 =$ 0.985, according to recommendations of Allen et al. (2002).

Finally, to calculate land surface temperature (LST), were used the spectral radiance of the thermal band ($L_{\lambda,6}$) and the emissivity obtained in the last step. This way it was computed the LST (K) for the study area, by the following expression:

$$TST=K2\ln\varepsilon NBK1L\lambda,6+1 \quad (16)$$

Where, K_1 = 607.76 W/m² sr^{-1} μm^{-1} and K_2 = 1260.56 K, are constants of the thermal band of Landsat 5 TM (Allen et al., 2002; Silva et al., 2005).

To perform a statistical geoprocessing, was elaborated a sampling grid, type *fish net,* from where were collected the physical data from the pixel's centroid. The points have an equidistant disposal to 3 km of ray of any another amostral point. In total, 1055 points were scattered on the image semi-arid surface, as can be seen in the Figure 2.

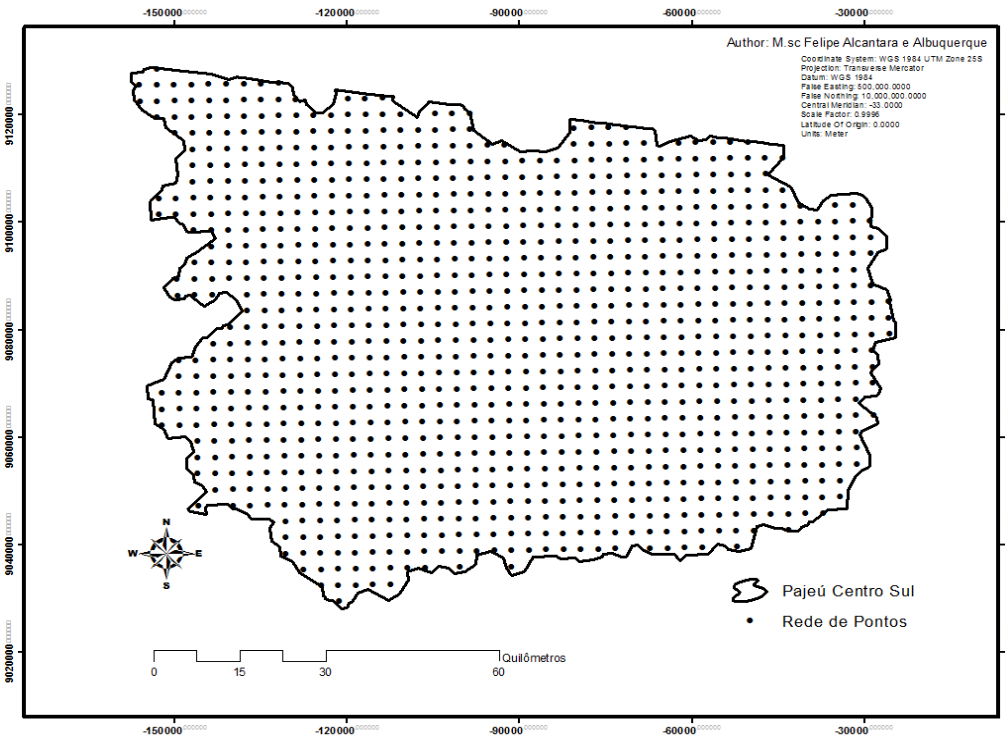


Figure 2. Methodological structure for environmental data sampling from the geoprocessing products and remote sensing products of the watershed in question.

3. Results and Discussion

3.1 Surface Temperature

The land surface temperature (LST) is spatialized from the detection of longwave radiation emitted in the thermal infrared range detected by satellite sensors. The LST is a variable that refers to the heat flux given in terms of the balance of radiation that reaches and leaves a body, and has a spatial variation influenced by the received insolation, the surface nature, the distance from the hydric body, the relief, the nature of prevailing and temporal winds, conditioned mainly by seasonal variations in the volume of the received radiation, which varies with the latitude and the degree of continentality.

The air temperature, which depends of a number of external factors (incidence of radiation, daily and annual cycle, latitude, topography, altitude) and internal factors (moisture, chemical composition of the elements of the soil, and others), usually answer quickly to changes in land cover, since the presence of vegetation cover assists in thermal regulation of the surface by means of the evaporation process. The LST is very important for understanding the interactions between the surface and the atmosphere and for the modeling of air temperature in the lower layers of the urban atmosphere, been used in many studies, as example, for the development of climatic models. In addition to studies of climate issue, the LST, that is quite sensitive to vegetation and soil moisture, is used to detect changes in land cover (MALLICK et al., 2008; AMIRI et al., 2009; IFATIMENHIN and ADEYEMI, 2008).

In this study it was possible to observe that the surface temperature was lower in areas with apparent vegetation cover with concentration of moisture and indirectly to the presence of water. The minimum values for the used image were 19.6°C, observed in water reservoirs. In turn, the maximum values were 45.3 ° C, observed in areas of rocky outcrop, possibly of gypsum formations in the region, and values close to these were also observed in areas of intense urbanization.

The average value of the surface temperature for the south-central region of the Pajeú to this imaging was 35.8°C at the time of image capture.

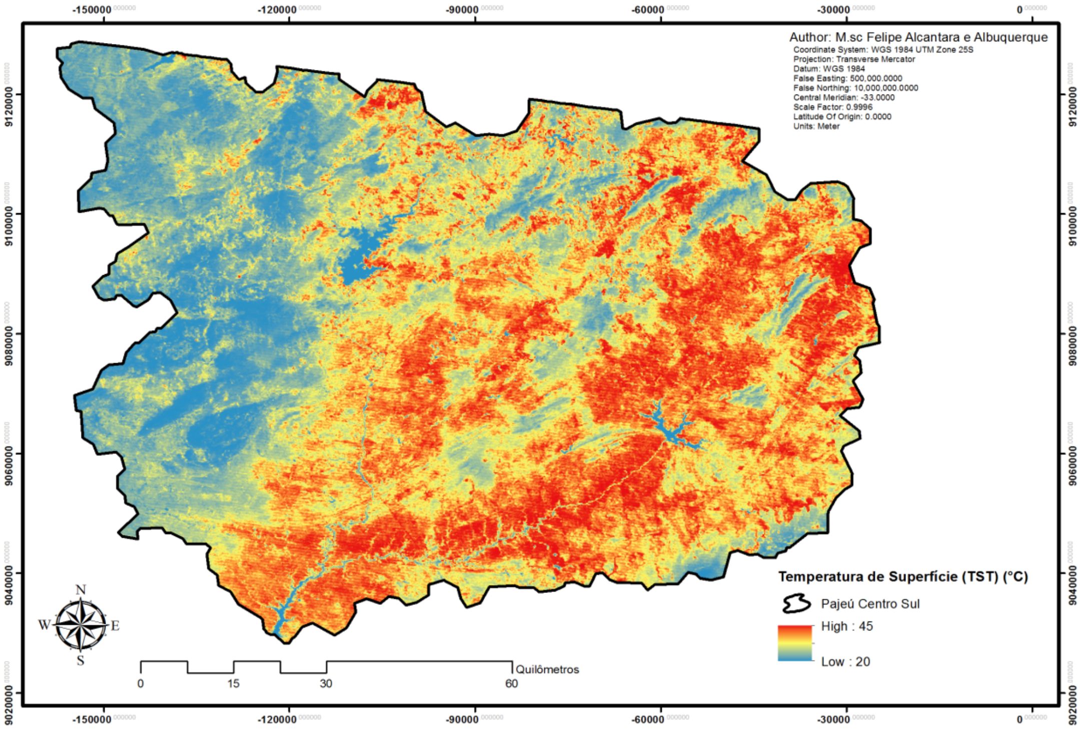


Figure 3. Map of the surface temperature (LST) in the south-central region of the Pajeú's watershed.

3.2 Surface Temperature x NDVI

The value of F (regression) referring to the analysis of the temperature dependence in relation to the NDVI is very significant ($p < 0,0001$), rejecting the nullity hypothesis and accepting the alternative that the surface temperature varies with the positive and negative variations of the NDVI. It is evidenced, in this example, from the adjusted coefficient of determination (R^2), that 48.68% of the dependent variable is explained by the predictive variable, should other factors act as additional predictors on the temperature variation.

As can be seen below in Figure 4, the data distribution from the pixel extraction grid shows a visibly predictive trend.

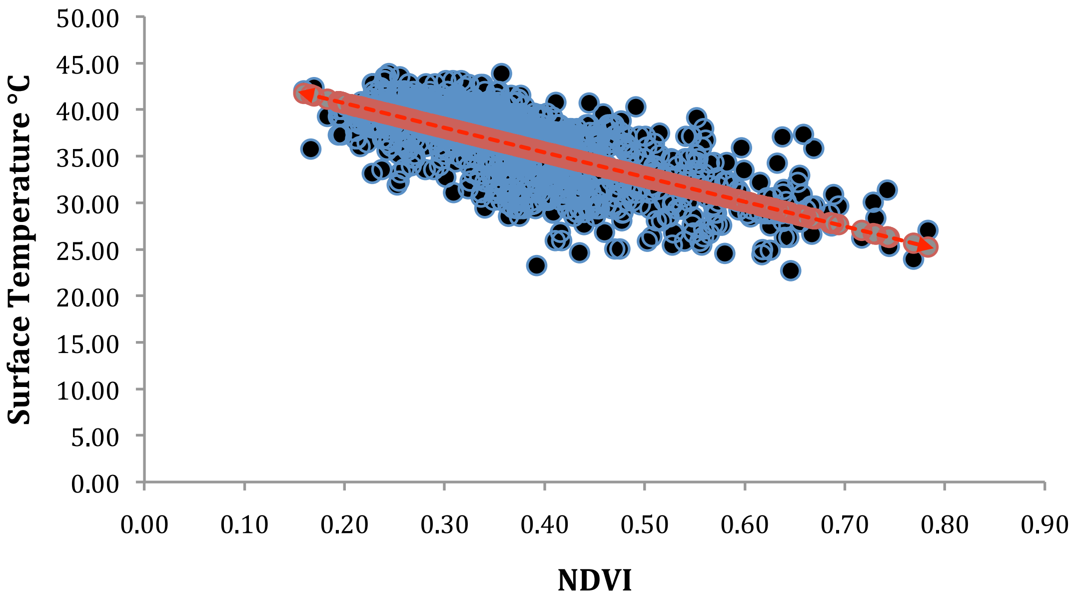
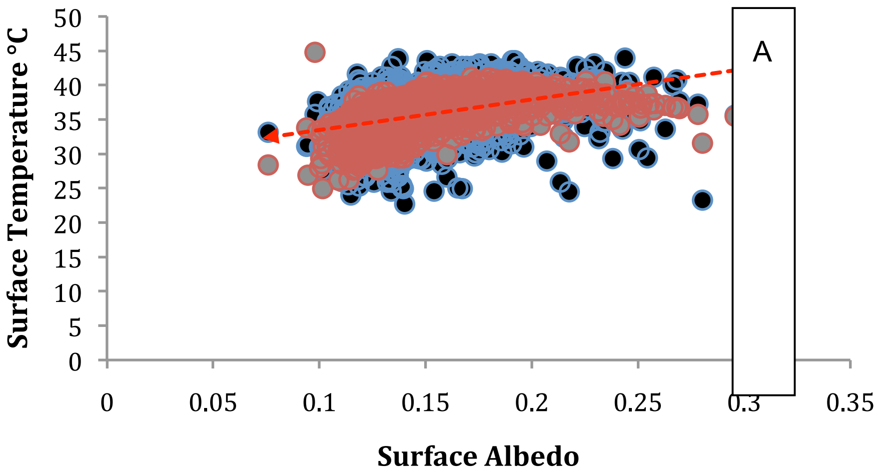
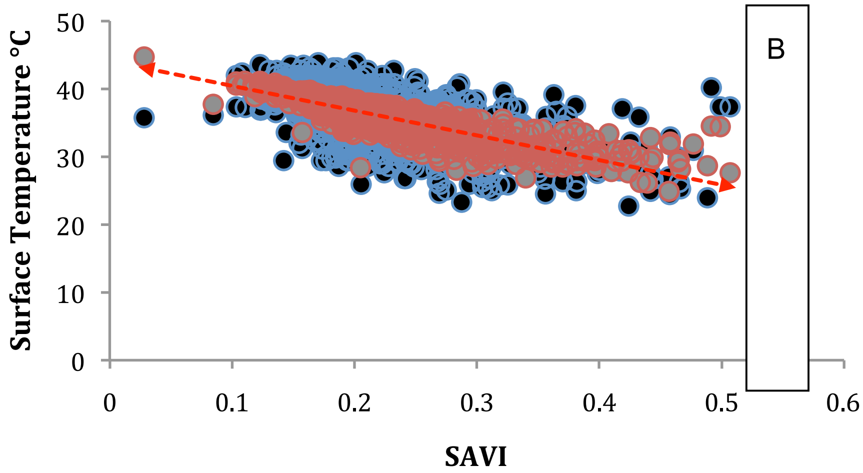


Figure 1. Study of the dependence of LST variable in relation to NDVI.

3.3 Multivariate analysis: LST x ALBEDO x NVDI x SAVI x LAI

The result of this analysis could incorporate other environmental factors as contributors to explain the variation of LST. With an adjusted R^2 in 51% of explicability, a $p<0.0001$ and a multiple correlation coefficient of 72%, it is considered that the judged variables are highly explicable for the dependent variable. Even so, it was possible to observe that the multivariate regression test rescued an explicability just a little bigger than the previous linear analysis, where was confronted just the NDVI's participation. In the Figure 5 below, it can be observed the performance of the linear trends for each prediction.





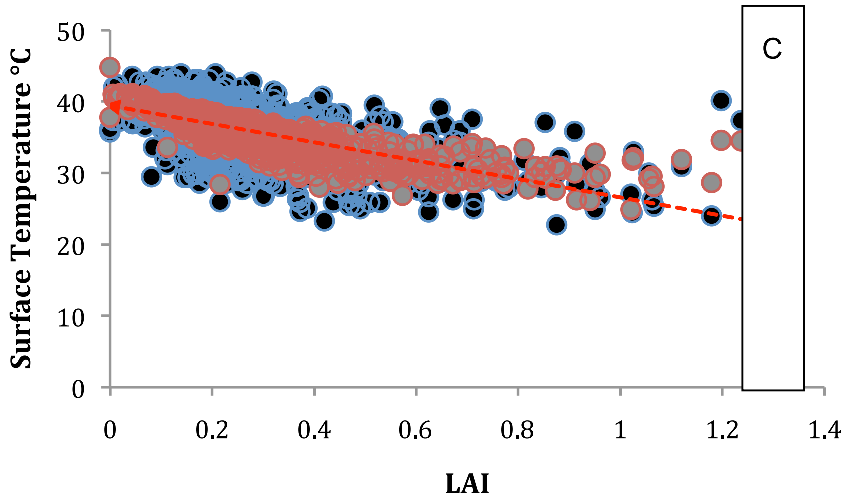


Figure 2. Regression test between the addressed variables in the construction of the surface temperature map. The component A refers to the surface albedo, B to the SAVI and C to the LAI component.

Each observed variable as a sub-product for construction of the surface temperature map (LST) has an implication in the explicability of the temperature's superficial variation in the south-central region of Pajeú. It was possible to be observed in Figure 7, but, the applicability of the set of associated variables to the surface characteristics were not sufficient to relate totally or almost entirely the temperature variation. This way, it is necessary to do others dependency studies, relating physical factors to the surface temperature, like the altitude.

3.4 LST and Altitude

The temperature is influenced by several factors, including the amount of insolation received, the surface nature, the distance from watercourses, the relief, the predominant winds, beyond the ocean currents (AYOADE, 2010).

The altitude and the temperature follow complementary paths and *Fritzons et al. (2008)* describe that in tropical and subtropical regions, an altitude diference of a few hundred meters causes significant changes in the climate, soil, vegetation and consequently in the adaptation of animals and plants and in the land use.

This dependence study between the surface temperature and the altitude of the south central region of Pajeú obtained a value of F (regression) very significant, ($p<0{,}0001$), rejecting the nullity hypothesis and accepting the alternative that the surface temperature really varies with oscillations in the terrain altitude. The explicability according to the adjusted R^2 was 17% and the correlation coefficient 41%. Considering that many environmental factors are admittedly interferentes to the explicability model, the altitude starts to be one of its more important constituent, increasing the 51% previously observed, for a value close to 70% of prediction.

In Figure 8, of visual expression 3d, can be clearly observed that the highest areas have lower temperatures,as well as areas of hydric reservoirs and accumulation bodies. Such relations of temperature variation in relation to the altitude and its particularitities to the environment are studied with frequency, as Barry (2008), Bonan (2008) e Pape (2009), but not in order to characterize the provision of environmental services and their consequent variations.

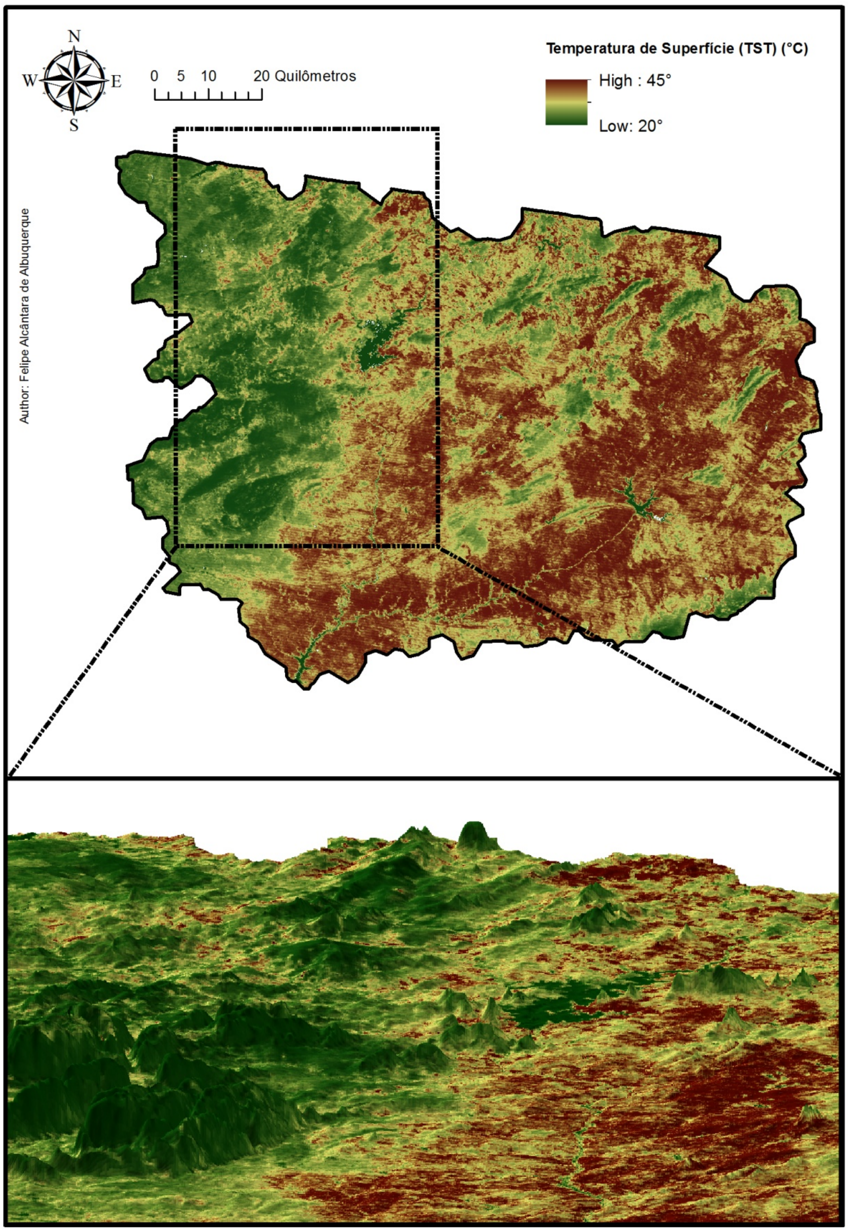


Figure 3. 3d Model cut of the study area showing the surface temperature tendency to be milder in areas of higher altitudes or in wetter areas.

3.5 Evaluation of Environmental Hydroclimatic Services

When the landscaped natural limits are used for determination or evaluation of ecosystem functions and of environmental services, and further, when these limits are watersheds, these phenomena can be named as hydroclimatic by these services are particularly related to the transport phenomena of water between the atmosphere and land surface.

When compared, the micro watersheds of the database of Agência Nacional de Águas (ANA), it was possible to observe a definite standard of average temperature for the vocational groups. The basins with 70% or more of surface area characterized for being soil exposed areas had presented an average temperature of 40.81ºC, with a maximum of 45°C and a minimum of 27.5°C. Meanwhile, the micro watersheds that preserved at least the corresponding to the percentage of legal reserve defined by law (20%), or more, had presented an average temperature of 30.75°C, with a maximum of 45 ° C and minimum of 19.8ºC.

Through comparative analysis between NDVI and surface temperature is observed that the vegetation index NDVI presents lowest values where there is a greater amount of surface temperature and vice versa. This mechanism contributes to the decrease of the surface temperature and of the air through the direct effect of shading and evapotranspiration (SILVA et al., 2013). The amount of solar radiation arrives to the surface below the pantry is reduced in areas with dense vegetation, since a part of incident solar radiation is absorbed by the leaves and used for photosynthesis, and another fraction is reflected back into the atmosphere (SANTOS, 2011).

Many other important environmental factors can also be influencing in the explicability of the surface temperature, and this is just one of the strategic components for understanding the radiation flux and energy, being able to be used for understanding more complex environmental services. More specifically, the information about balance of energy flows of the earth's surface is indispensable necessary to determine the vegetal hydric stress (KUSTAS & NORMAN, 1999). The requirement or not of water for agricultural production is a data that can be used to know the efficiency of conversion of resources for the grains production. Such concepts can be investigated from other models, and with this explain other issues associated to the environmental regulation services, this can be especially useful in arid regions or in semi-arid climates with strong limitations of water and temperature. Generally, water productivity (ZWART et al., 2010) or radioactive efficiency are issues addressed to integrate environmental impacts to the forecast of liquid biomass productivity, thus, it is had limitation's forecast and potential of biomass production in relation to the hydric offer, whether natural or artificial (BASTIAANSSEN and ALI, 2003).

Through the remote sensing and its products linked to the use of thermal bands, it is possible to perceive in regional scale the limit key condition in the transport of groundwater to vegetation and the atmosphere (KUSTAS et al 2007; KUSTAS and ANDERSON 2009). Thus, the remote sensing of land surface temperature serves as an important metric to the detection of the state of surface moisture and vegetation, which, in turn, will influence the evapotranspiration, carbon assimilation (ANDERSON et al., 2007a; 2007b) and income of the culture or vegetable production in general. Therefore, the forecast of income of the cultures by means of water or of photosynthetic productivity would be of great advantage to the understanding of hydric balance and potential of biomass production in function of the scarce hydric resources in the semi-arid regions.

4 Conclusion

Measure the surface temperature, extract its complex interaction with environmental variables and know the situations of hydric balance in the provision of regulatory environmental services in the semi-arid, still represents a challenge to be conquered and dominated, even that might have an idea of how these processes may be important in water management and crop.

Above of being a strategic question for the local hydric management, the products in this study were also influenced by the General Assembly of the United Nations, which happened in April 2000, when, the general secretary of the United Nations (UN) at the time, Kofi Annan, pointed the *Millennium Ecosystem Assessment – MA* as the necessary effort to assess the situation of the main ecosystems of the planet.

Involving governments, private sector, non-governmental organizations and hundreds of scientists from several countries around the world, the MA studies were realized between 2001 and 2005 to assess the consequences of ecosystem change on human well-being, and to establish the scientific basis of the actions needed to improve the conservation and the sustainable use of ecosystems and to satisfy human needs.

Although this is a way to go, the necessary information for its complex execution need to be constructed and updated constantly from the development of new tools for analysis and action. It is in this direction that the development of new tools of ambient analysis proves being useful to the measure that multidisciplinary incorporates the mission of integrated and continuous diagnostics.

Therefore, by this document it was possible to conclude an initial proposal of directed environmental studies, knowing that this tends to be developed and expanded with the use of other more complex tools. The efficient management of natural resources, on the various ecosystems of the world, depends on the evolution of new tools of analysis and interpretation, mainly with the use of remote sensing and geoprocessing. Thus, will be possible the simple understanding of the several interactions of the terrestrial ambient physical, chemical and biological, on large scales, and consequently, we will be able to develop a reaction to its complex management.

5. Acknowledgment

We are grateful to the National Council for Scientific Development and Technology of Brazil – CNPq for the financial support on the project MCTI/CNPQ/Universal 14/2014, process: 448236/2014-1. Thanks to the Federal Institute of Education, Science and Technology of Pernambuco = IFPE and to the Federal University of Pernambuco - UFPE.

6 References

Allen, R.G., Pruitt, W.O., Businger, J.A., Fritschen, L.J., Jensen, M.E. & Quinn, F.H..In: Wootton et al. (ed.), Evaporation and Transpiration. Chapter 4, (pp. 125–252), ASCEHandbook of Hydrology. New York, NY, 1996.

Allen, R. G.; Pereira, L. S.; Raes, D.; Smith, M. Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56. Rome, Italy, 1998.

Amiri, R.; Weng, Q.; Alimohammadi, A.; Alavipanah, S. K. Spatial-temporal dynamics of land surface temperature in relation to fractional vegetation cover and land use/cover in Tabriz urban area, Iran. Remote Sensing of Environment, v. 113, p. 2606-2617, 2009.

ANA-Agência Nacional de Águas. Conjuntura dos Recursos Hídricos do Brasil. Brasília, 2012. Disponível em <http://conjuntura.ana.gov.br/>, acesso em outubro de 2014.

ANA, Agência Nacional de Águas. 2005. Atlas Nordeste: abastecimento urbano de água. Brasília, DF.

Anderson, M.C., Norman, J., Mecikalski, J., Otkin, J., Kustas, W., A climatological study of evapotranspiration and moisture stress across the continental United States based on thermal remote sensing: 1. Model formulation. J. Geophys. Res. 112, D10117, doi: 10110.11029/12006JD007506, 2007a.

Anderson, M.C., Norman, J., Mecikalski, J., Otkin, J., Kustas, W., A climatological study of evapotranspiration and moisture stress across the continental US based on thermal remote sensing. 2. Surface moisture climatology. J. Geophys. Res. Atmos. 112, doi: 011110.011029/ 012006JD007507, 2007b.

Asce–ewri. The ASCE standardized reference evapotranspiration equation. ASCE–EWRI Standardization of Reference Evapotranspiration Task Committe Rep., ASCE Reston, Va, 2005.

Ayoade, J. O. Introdução a Climatologia para os trópicos. 13ªed. Rio de Janeiro: Bertrand, 332p, 2010.

Barry, R,. Mountain Weather and Climate. Third Edition. New York, New York: Cambridge University Press, 2008.

Bastiaanssen, W.G.M. Regionalization of Surface Flux Densities and Moisture Indicators in Composite Terrain. A Remote Sensing Approach Under Clear Skies in Mediterranean Climates. Tese, Wageningen Agricultural University, The Netherlands,1995, 273p. 1995.

Bastiaanssen, W.G.M. and Ali, S. A new crop yield forecasting model based on satellite measurements applied across the Indus Basin, Pakistan, Agriculture, Ecology and Environment 94 (3): 321-340, 2003.

Bonan, G. Ecological Climatology: Concepts and Applications. Second Edition. New York, New York: Cambridge University Press, 2008.

Campanili, M. & Schaffer, W.B. 2010. Mata Atlântica: patrimônio nacional dos brasileiros. MMA, Brasília.

Chander, G.; Markham, B. L.; Barsi, J. A. Revised Landsat-5 thematic mapper radiometric calibration. IEEE Geoscience and Remote Sensing Letters, v.4, n.3, p.490-494, july, 2007.

Cirilo, J. A. et al. (org.) o uso sustentável dos recursos hídricos em regiões semiáridas. Recife: ABRH – Editora Universitária: UFPE, 2007.

Cirilo, J. A.. Políticas Públicas de Recursos Hídricos para o Semi-Árido Brasileiro. Estudos Avançados (USP.Impresso), v. 63, p. 61-82, 2008.

Duffie, J. A.; Beckman, W. A. Solar engineering of thermal process, 2nd Ed., Wiley, N.Y. 1991.

Fritzsons, E.; Mantovani, L.E.; Aguiar, A.V. Relação entre altitude e temperatura: Uma contribuição ao zoneamento climático no estado do Paraná. Revista de Estudos Ambientais, v. 10, n. 01, p. 49-64, 2008.

Huete, A.R. A Soil-Adjusted Vegetation Index. Remote Sensing of Environment.v. 25, p.295-309, 1988.

Iqbal, M. An Introduction to Solar Radiation, Toronto, Academic Press Canada, 390p., 1983.

Kustas, W .P., Anderson, M.C., Norman, J.M., Li, F., Utility of radiometric–aerodynamic temperature relations for heat flux estimation. Boundary-Layer Meteorol. 122, 167–187.

Kustas, W. P. and Anderson, M. C.: Advances in thermal infrared remote sensing for land surface modeling, Agric. For. Meteorol.,149, 2071–2081, 2009.

Pape, R. et al.(2009). Modelling near-surface temperature conditions in high mountain environments: an appraisal. Climate Research, Vol. 39, 99 – 109, 2007.

Ifatimenhin, O. O.; Adeyemi, S. A Satellite Remote Sensing Based Land Surface Temperature Retrieval from Landsat TM Data. Ehtiopian Journal of Environmental Studies and Management, v. 1, n. 3, p. 63-70, 2008.

Mallick, J.; Kant, Y.; Bharath, B.D. Estimation of land surface temperature over Delhi using Landsat – 7 ETM+. Journal of Indian Geophysical Union, v. 12, n. 3, p. 131-140, 2008.

Markham, B. L.; Barker, J. L. Landsat MSS and TM post calibration dynamic ranges, exoatmospheric reflectances and at satellite temperatures. EOSAT Landsat Technical Notes 1:3-8, Earth Observation Satellite Company, Lanham, Md. 1986.

Pernambuco. 2008. Secretaria de Recursos Hídricos, Plano Estratégico de Recursos Hídricos e Saneamento. Secretaria de Recursos Hídricos. Recife. 112 p.

Santos, C.A.C.; Silva, B.B.da; Rao, T.V.R.; Satyamurti, P.; Manzi, A.O. Downward longwave radiation estimates for clear-sky conditions over Northeast Brazil. Revista Brasileira de Meteorologia, v.26, n.3, p.443-450, 2011.

Silva, Bernardo Barbosa da; Machado, C.C.C.; Galvíncio, J. D.; Montenegro, S. M. G. L.;Oliveira, Leidjane Maria Maciel. Determinação por sensoriamento remoto da produtividade primária bruta do Perímetro Irrigado São Gonçalo - PB. Revista Brasileira de Meteorologia (Impresso), v. 28, p. 57-64, 2013.

Zwart, S.J., Bastiaanssen, W.G.M., 2007. SEBAL for detecting spatial variation of water productivity and scope for improvement in eight irrigated wheat systems. Agric. Water Manage. 89 (3), 287–296

The renewable energies in the carbon market in Latin America

Lira Luz Benites-Lazaro[1], Alice Falleiro[2], André Luiz Miranda Silva Zopelari[3] Neli Aparecida de Mello-Théry[4], Celio Andrade [5]

1,4 University of São Paulo, lbenites@usp.br, namello@usp.br, 2 Universidade Federal Santa Maria, alice.falleiro@gmail.com.3 Universidade Federal do Rio de Janeiro, andre.zopelari@uol.com.br,5 Universidade Federal da Bahia, jcelio.andrade@gmail.com

Abstract

The past decade was the best in economic terms of the modern history of Latin America. An overwhelming majority of countries showed growth rates, allowing the improvement of their social situation and the rise of millions of people in poverty towards the new middle class. Consequently, Latin America has reproduced certain growth patterns that affect heavily on environmental and social issues: the higher levels of demand for energy. However, the climate change and the need to manage diminishing fossil fuel reserves are, nowadays, one of the challenges facing the humankind. It is widely accepted that we must act now to reduce energy consumption and substantially cut greenhouse gases. World leaders have resolved to tackle global warming by signing the UN Climate Convention, the Kyoto Protocol and the Paris Agreement to reduce the greenhouse gases emissions. The Latin America participation in these climate negotiations has been highlighted, especially to promote the Clean Development Mechanism (CDM) projects. Thus, the paper aims to describe the main features of the countries' positions in the CDM renewable energy projects in Brazil, Mexico, Chile and Peru. The first effort was to evaluate the CDM portfolio concentrating on renewable energy projects. Moreover, a special analysis was in the public policy in order to identify how political-institutional and economic aspects have influenced the development of CDM projects. The paper shows that these four countries have very different policies regarding stimulate CDM projects in the renewable energy sector. However, they have similar discourse in the complex relationship with both sustainable economic development and environment in the public policy.Each one of the four countries needs to face important obstacles in order to advance in the environment topic and contribute to climate change mitigation.

Keyword: Renewable Energy, CDM, Economic Growth, Public Policy, Sustainable Development, Latin America.

To Import Coal or Invest in Renewables? A Real Options Approach to Energy Investment in the Philippines

Casper Agaton

Ruhr University of Bochum, cbagaton@iuj.ac.jp

Abstract

The Philippines, being a developing country, has been struggling to become energy independent. Considering the current share of imported fossil fuel for electricity generation is relatively high, the country's security of energy supply has been vulnerable to sudden changes in prices of fossil fuels. Renewable energy is seen as a promising alternative to suffice the energy needs. However, investments on these projects are challenged by the perception as an expensive, intermittent, and not competitive source of energy. It is therefore important to make a study that analyzes the attractiveness of renewable energy investments to address the country's concern on energy sufficiency and sustainability. This paper adopts the Real Options Approach to analyze investment decisions for energy projects in the Philippines. The main purpose is to evaluate the comparative attractiveness of either investing on renewable energy or continue importing coal for electricity generation considering the uncertainty of coal prices. This delves deeper into identifying which renewable energy source from wind, solar, hydroelectric, and geothermal is the most attractive for project investors. Dynamic optimization is used to maximize the value of each investment and to analyze the dynamics of the trigger coal price for shifting technologies from coal to renewable energy. The results find that renewable energy is a better option than continue importing coal for electricity generation. Among the renewable energy sources, geothermal is the most attractive, followed by wind, hydroelectric, and solar. The results identify that earlier shifting to renewable energy decreases the possible welfare losses from waiting to invest. This suggests that the Philippine government should boost its programs to reduce coal imports and invest on renewable energies earlier, especially with the current trend of rising coal prices.

Keywords: real options analysis, renewable energy, stochastic fuel price, dynamic optimization, investment timing

The conditions for development of clean technologies of electricity production in Poland

Lidia Gawlik[1], Monika Pepłowska[2], Dominik Kryzia[3]

[1] Mineral and Energy Economy Research Institute, Polish Academy of Sciences, lidia.gawlik@meeri.pl

[2] Mineral and Energy Economy Research Institute, Polish Academy of Sciences, monika@meeri.pl

[3] Mineral and Energy Economy Research Institute, Polish Academy of Sciences, kryzia@meeri.pl

Abstract

Currently, hard coal is the main source for power generation in Poland. In 2014, 136 TWh of electricity were generated from hard coal and lignite, representing 85.46% of the total national electricity production, while only 4.5 TWh, i.e. 2.85% were produced from the so-called “clean fuels" (natural gas). Production of electricity based on coal is considered as one of the most harmful to the natural environment, emitting a number of pollutants. Recently, a progressive change in the manufacturing structure of Polish power sector becomes clearly visible, which contributes to a change in the domestic fuel mix. The factors determining this process are: European Union requirements imposed on Poland, mainly aimed at reducing the emissions of carbon dioxide, obsolete and depreciated boilers in Polish power plants and CHP plants, crisis of the domestic hard coal mining, commissioning of the LNG terminal in Świnoujście. The development of low-emission coal technologies, expansion of renewable energy sources, natural gas-fired electricity generation, and the opportunity to invest in nuclear power will affect the future costs of the sector and the level of pollutants emitted into the environment. There are many forecasts of development of the domestic electricity sector, unanimously assuming an increased share of clean energy technologies. The main aim of this article is to present the possibilities for the development of clean energy technologies in Poland in the context of current and future economic, legislative, and social conditions. A lignite-fired steam unit with supercritical parameters with the gross efficiency of 47% emits 0.868 kg of carbon dioxide per kWh of electricity generated, hard coal-fired steam unit with supercritical parameters with the gross efficiency of 48% emits 0.685 kg of CO_2/kWh, while natural gas-fired steam unit with supercritical parameters with the gross efficiency of 60% emits 0.329 kg of carbon dioxide per kWh of electricity. This places natural gas in the first place among the fossil fuels with the lowest emissions of pollutants into the atmosphere. Comparing various scenarios for the development of Polish structure of Polish power sector, the authors have estimated the reduction of CO_2 emissions.

Keywords: clean coal technologies, electricity in Poland, natural gas, hard coal, fuel mix, electrical power engineering, electricity generation, fuels for power industry

1. Introduction

Coal is the main source for power generation in Poland. For many years, it has been the basis of the Polish industry, particularly electricity generation, guaranteeing the energy security of the country. The documented balance resources of hard coal in Poland as of 31.12.2014 amount to 51 960 million Mg and are more than two times larger than lignite resources amounting to 23 511 million Mg (Bilans, 2015). The majority of generating capacity of the domestic power industry is basing on hard coal and lignite. What is more, new coal-fired units at the Kozienice, Jaworzno, and Opole power plants will be commissioned later this year. The combustion process of lignite and hard coal is responsible for significant emissions of carbon dioxide (CO_2) into the atmosphere, hence the pressure on phasing out of these fuels from the energy sector.

The European Union (Poland is the European Union Member State since 1st May 2004) has undertaken a number of actions to counter the global warming by reducing greenhouse gas emissions and supporting the shift towards a low-carbon economy, which will be based on improved energy efficiency. Decarbonization of the European Union and – first and foremost – the introduction of the European Union climate and energy package extended to 2030 and 2050 imposes a number of environmental obligations on Poland. The implementation of the guidelines contained in EU directives into national legislation is a very big challenge, especially for a country, where coal is the primary energy source. The European Union climate and energy package, the so-called 3x20%, obliges Member States to a 20% reduction of greenhouse gas emissions, a 20% increase in the share of renewable energy sources (RES) in energy production and a 20% increase of the energy efficiency. When it comes to the specific objectives for Poland, the target of a 15% share of energy from renewable sources by 2020 has been determined. The next stage of implementing the climate package was agreed in 2014 and will apply in the period 2021–2030; the objectives include a 40% reduction of greenhouse gas emissions and increasing the share of renewable energy sources to 27% (Wojtkowska-Łodej, 2014). Despite the fact that specific objectives for individual countries have not yet been determined, it can be stated that the EU policy directly affects the development of the market for raw materials and energy mix of the Member States.

2. The Polish power generation sector

The share of hard coal in electricity generation structure decreases each year, mainly in favor of renewable energy sources, natural gas, and (in recent years) lignite. Still, the share of solid fuels in the energy mix of the Polish power industry exceeds 89% (Fig. 1).

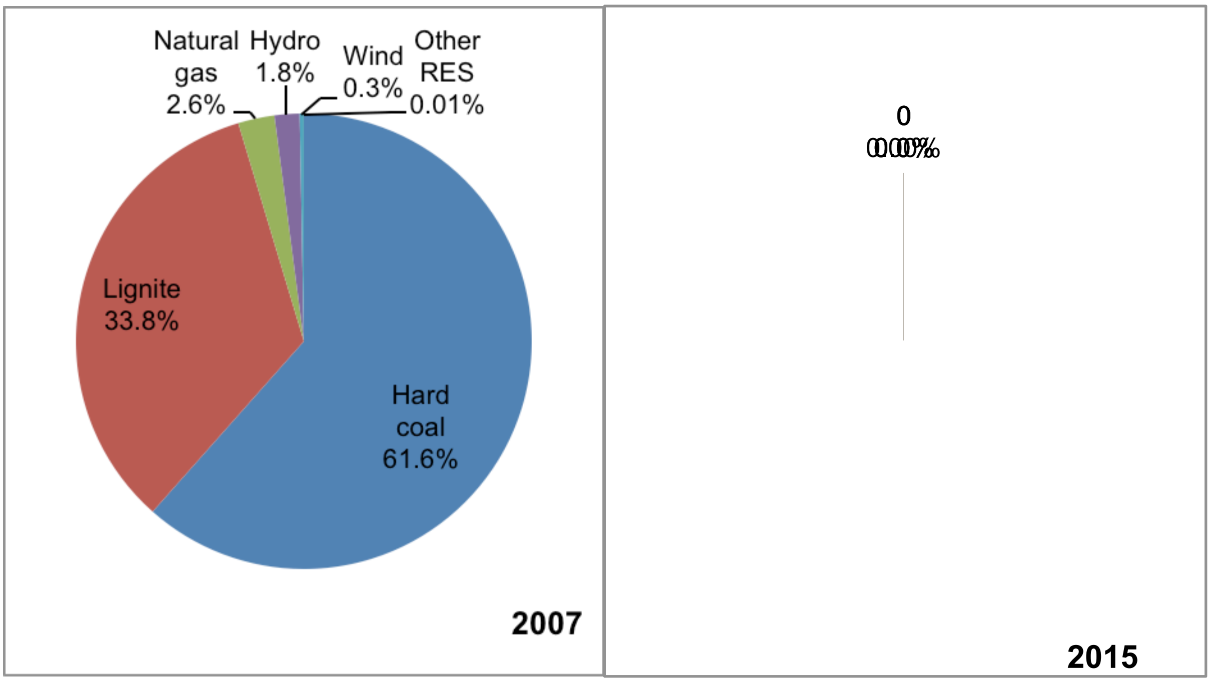


Figure 1. The comparison of fuel structure of electricity generation in the Polish power sector in 2007 and 2015, percentage values

Source: (PSE, 2016)

The majority of Polish coal-fired boilers are depreciated; over 60% of generation capacity is more than 30 years old. In addition, domestic coal-fired power plants usually have low efficiency, not exceeding 40%. Generally, hard coal-fired power plants are characterized by higher efficiency compared to lignite-fired power plants using lower-quality lignite. The aforementioned low efficiency is one of the reasons for high carbon dioxide emissions. At the same time it is worth noting that the draft of Polish Energy Policy until 2050, already submitted to consultations, assumes that coal will maintain its high share in the domestic energy sector despite the fact that Poland is currently facing the hard coal mining crisis. There are ongoing efforts to find alternatives to hard coal used in power plants and to develop clean coal technologies (Hausner and Białecka, 2014; PEP, 2015).

3. Legal regulations related to the energy-climate package

The key regulation of the European Commission (EC) concerning the reduction of greenhouse gas emissions is the introduction of new guidelines for the CO_2 emission trading system (EU ETS). The current target is a 21% reduction of emissions covered under the EU ETS compared to 2005 levels.

Increasing energy efficiency is implemented in accordance with the Directive of the European Parliament and of the Council 2012/27/EU of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. The provisions of the directive have changed the energy efficiency target from 20% to 17%.

In Poland, the implementation of the objectives set in the aforementioned documents is carried out largely by carrying out thermal modernization of buildings (Dyrektywa, 2012). In addition, cogeneration technologies are also being promoted – Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC (Dyrektywa, 2004).

The directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (the so-called IED Directive) is another regulation concerning the package. This document imposes emission limits for generation units with a capacity of over 50 MW; Member States shall apply the laws, regulations and administrative provisions adopted in accordance with this Directive from 1 January 2016 (Dyrektywa, 2010).

Directive on the geological storage of carbon dioxide – CCS affects the energy sector (Dyrektywa, 2009b).

Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC is crucial for renewable energy sources (Dyrektywa, 2009a).

Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe is also of great importance (Dyrektywa, 2008).

Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment (Dyrektywa, 2011).

Additional regulations of the Committee on the implementation of the Directive have also been adopted.

Accepting the regulations prepared by the European Commission significantly affected the changes in the internal regulations of the country.

4. The development of low carbon technologies

Currently in Poland, a large emphasis is placed on the development of low carbon technologies. These include both investments in the development of renewable energy sources and low-emission coal technologies. A project to build a nuclear power plant is also being considered. According to the Polish program of nuclear energy, this technology will become an important element of the energy sector after the year 2025 (Uchwała, 2014).

The development of clean coal technologies is important for the Polish coal industry. Currently, the term "clean coal technology" (CCT) describes technologies designed to improve the efficiency of extraction, processing, and utilization of coal and to increase the acceptability of these processes from the environmental point of view (Kubica et al., 2007). The development of clean coal technologies includes primarily the following processes: the enrichment and processing of coal surface and underground gasification, co-firing of biomass with coal, capture and storage of carbon dioxide, processing of coal in the production of liquid fuels and hydrogen to power fuel cells. The most important problem of Clean Coal Technologies is a very high cost of CO_2 capture at power plants (Hausner and Białecka, 2014).

The abovementioned changes will significantly affect the total operating costs of the sector and the level of pollutants emitted into the environment. However, the use of natural gas is related to a high volatility of prices due to the fact that this fuel is imported from a single source, namely the Russian Federation. Moreover, the prices of gas remain at a relatively high level (Olkuski et al., 2015; Szurlej et al., 2014).

In Poland, gas fuels are also increasingly used in the form of Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG), mainly in urban transport vehicles (Orzechowska and Kryzia, 2014).

The extraction of gas from shale formations gives hope for both lower prices of this fuel and the energy independence. It is estimated that Poland has an average of 378 billion m^3 of exploitable gas resources in shale deposits (Table 1). It is reported that Polish shale belt covers about 37 thousand km2, i.e. 12% of the country (Weigensperg, 2013).

Table 1. Estimated exploitable reserves of shale gas in the EU

Ordinal number	Country	Reserves [billion m^3]		
		minimum	average	maximum
1	Austria	116	147	241
2	Bulgaria	183	395	1000
3	Denmark	178	710	1360
4	Estonia	2	9	17
5	France	705	2819	5822
6	Germany	339	636	2266
7	Hungary	270	473	1000
8	Ireland	35	62	109
9	Latvia	4	14	25
10	Lithuania	0	0	113
11	Netherlands	41	165	1105
12	Poland	234	378	4193
13	Romania	172	687	1445
14	Spain	140	1224	2966
15	Sweden	57	227	425
16	The United Kingdom	18	71	737
Total UE		2494	8017	22824

Source: (ICF, 2014)

Wind power is the most dynamically growing among renewable energy sources. The year 2010 marked the rapid development of wind power, which doubled when compared to the previous year and amounted to 1180 MW, accounting for over 46% of the total installed capacity in renewable sources. In the following years this share continued to increase; in the years 2013 and 2014, the capacity of wind power plants accounted for 61% and 62% of the domestic balance of renewable energy sources, respectively (Mirowski et al., 2015). The installation of new capacities based on renewable sources saw the involvement of domestic prosumers, since the owners of smaller installations have priority access to the network and guaranteed preferential fixed-price tariffs thanks to the implemented regulations. In this case, energy systems based on photovoltaic cells are of significant interest (Mirowski and Sornek, 2015).

The development of renewable technologies causes a decrease in the demand for hard coal for electricity generation, replaced by biomass fuel combusted in dedicated blocks or co-fired with coal in conventional blocks (Malec et al., 2016). Currently, co-firing of biomass with coal is the preferred technology. It is important that co-firing can be done in already existing power plants. The combustion process can be carried out in three ways, namely (Niedziółka and Szpryngiel, 2014):

- direct biomass firing that is entering streams of coal and biomass into the combustion chamber. In this case, it is possible to mix the biomass and coal before the feeding system and entering the mixture to the combustion chamber using the carburizing system;
- indirect biomass firing process taking place in two stages. The first stage involves burning biomass or biogas in the so-called Dutch oven and the second involves the gasification of biomass in the gasifier and the combustion of resulting gas using gas burners;
- parallel firing (including hybrid systems); conventional and renewable fuels are burned in separate combustion chambers while maintaining the process requirements for each of the fuels.

This technology appears to be reasonable in the case of a country with great potential for coal and biomass production.

5. Scenarios of development of the domestic manufacturing structure

An analysis of the impact of the rate of development of CCS technology on the level of consumption of coal in the domestic energy sector has shown the possibility of using coal in the domestic energy sector. The three possible scenarios of demand for coal for power industry, developed with the use of methods of mathematical modeling and specialized models for analysis of fuel and energy systems, implemented on computing platforms, are presented below (Gawlik et al., 2013; Gawlik and Mokrzycki, 2014; Gawlik and Lorenz, 2014).

The aforementioned scenarios assumed a certain level of demand for electricity in the perspective of 2050; the EU policy, as set out in the Energy Roadmap 2050 set out in the Road Map 2050, has been implemented (Roadmap, 2011). This has been done by determining the growth path of prices of CO_2 emission allowances and the required minimum share of electricity production from renewable energy sources, estimating fuel prices and the development of individual energy technologies, taking into account changes in investment and operating costs. The aim was to choose the optimal – from the point of view of system costs – investments in order to ensure meeting the long-term demand for electricity.

Owing to the uncertainty regarding the development of CCS technology, the three scenarios regarding the pace of development of this technology have been established:

- Scenario 1 – it was assumed that the technology will develop quickly and will be ready for commercialization in 2025,
- Scenario 2 – it was assumed that the CCS technology will be ready for implementation in 2030,
- Scenario 3 – it was assumed that the CCS technology will not be available for commercial use in the analyzed period – that is, until 2050.

Fig. 2 shows the optimal choices regarding installation of new production capacities necessary to cover the demand for electricity in light of decommissioning old, depreciated generation units and the growing demand for electricity broken down by technologies and fuel types. All scenarios point to the need for installation of an additional 3.6 GW of power based on hard coal in the coming years in order to ensure the continuity of electricity supply. The development of energy sector based on renewable energy sources is very similar in all scenarios, which in turn results from the assumption regarding the required shares of these sources. The structure of other sources depends on the assumed rate of development of CCS technology.

The availability of CCS technologies in 2025 (Scenario 1) stimulates the use of low-carbon technologies: the construction of hard coal-fired units with carbon capture and storage system and the total capacity of 11.4 GW, together with additional 1.5 GW of nuclear power, 6.4 GW of power based on lignite (also with CCS) and 3.2 GW gas power is the optimal solution. If CCS technology will be available later – in 2030 (scenario 2) – the total capacity of hard coal-fired units with carbon capture and storage system will amount to 9.8 GW, while a greater use of nuclear power (3 GW) and natural gas (3.4 GW) will be the optimal solution.

However, if CCS technology will be unavailable (scenario 3), further investments using solid fuels, other than the construction of hard coal-fired units with the total capacity of 3.6 GW before 2020, are not expected. The optimal development of the energy sector requires the construction of 3 GW of nuclear power and 19.4 GW of gas power.

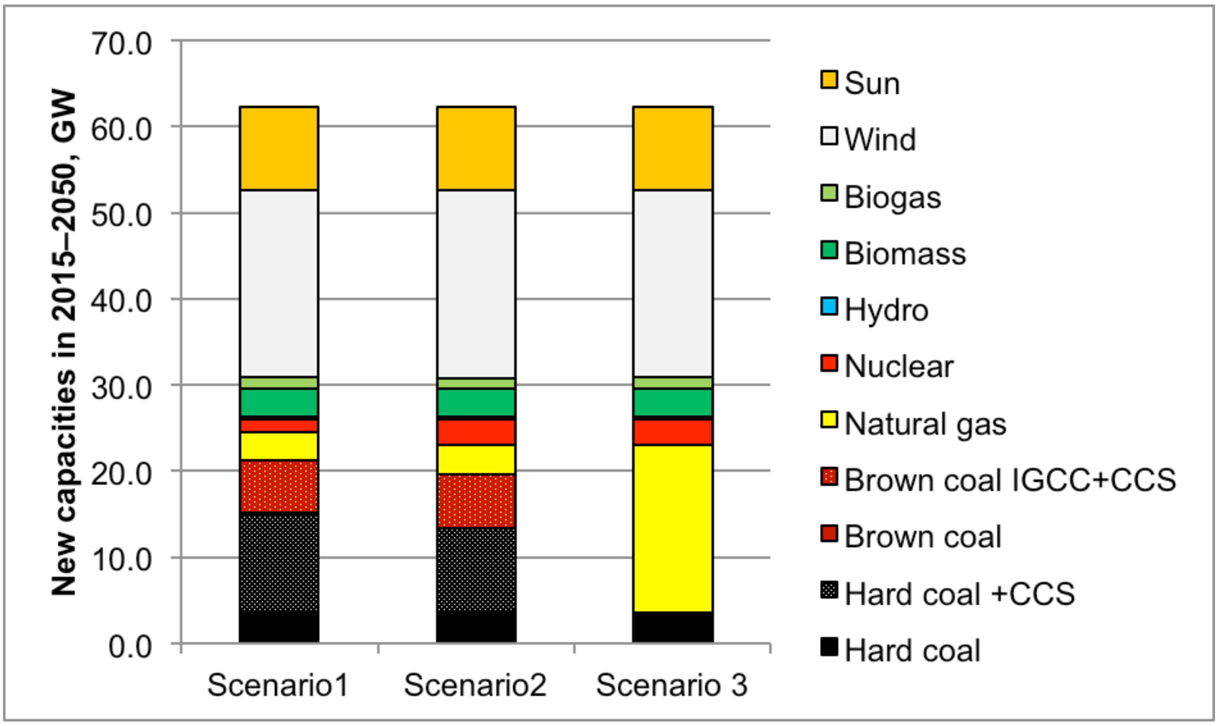


Figure 2. Installation of new capacities in power generation, required to meet the demand for electricity, in the years 2015–2050, GW

Source: own work based on (Gawlik et al., 2013)

The use of hard coal in power generation depends on whether the clean coal technologies will have a chance to develop.

Fig. 3 shows the use of coal in the individual scenarios of development of CCS technology.

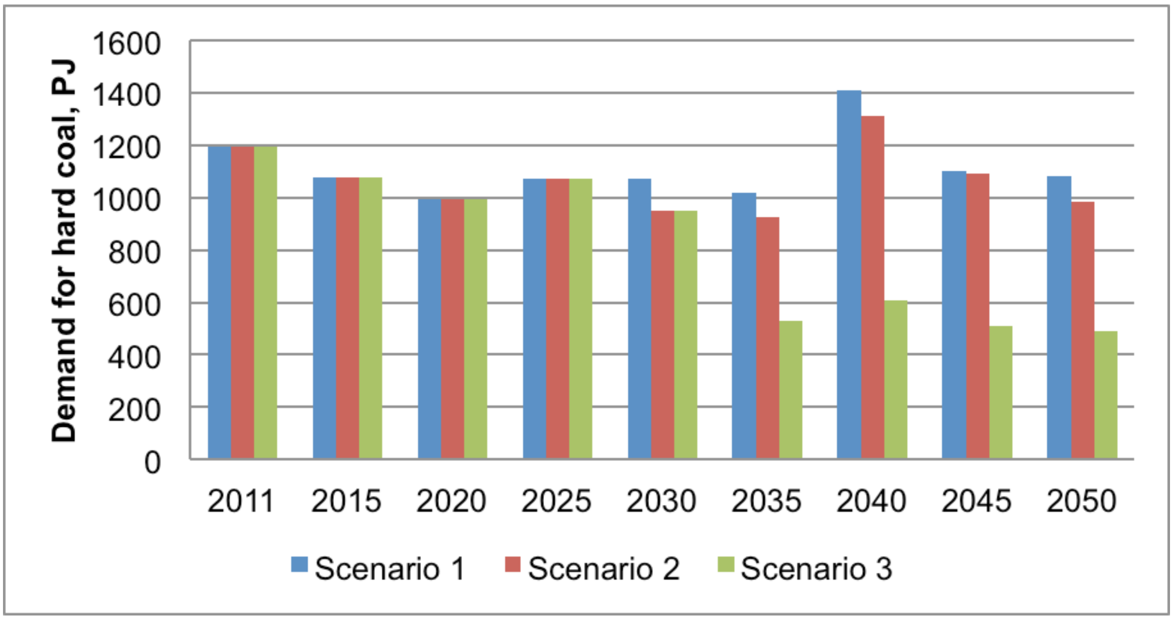


Figure 3. The demand for hard coal for power generation in different scenarios of technological development of CCS technology, PJ

Source: own work based on (Gawlik et al., 2013)

The impact of the availability of CCS technology on the demand for coal for electricity production after 2025 is clearly visible. The rapid development and possibility of early commercial use of this technology will help to maintain a high level of consumption of coal in power generation; after the year 2040, it will be at a higher level than it is today. In case of the unavailability of carbon capture and storage (scenario 3), hard coal will be gradually withdrawn from use as a fuel for power generation.

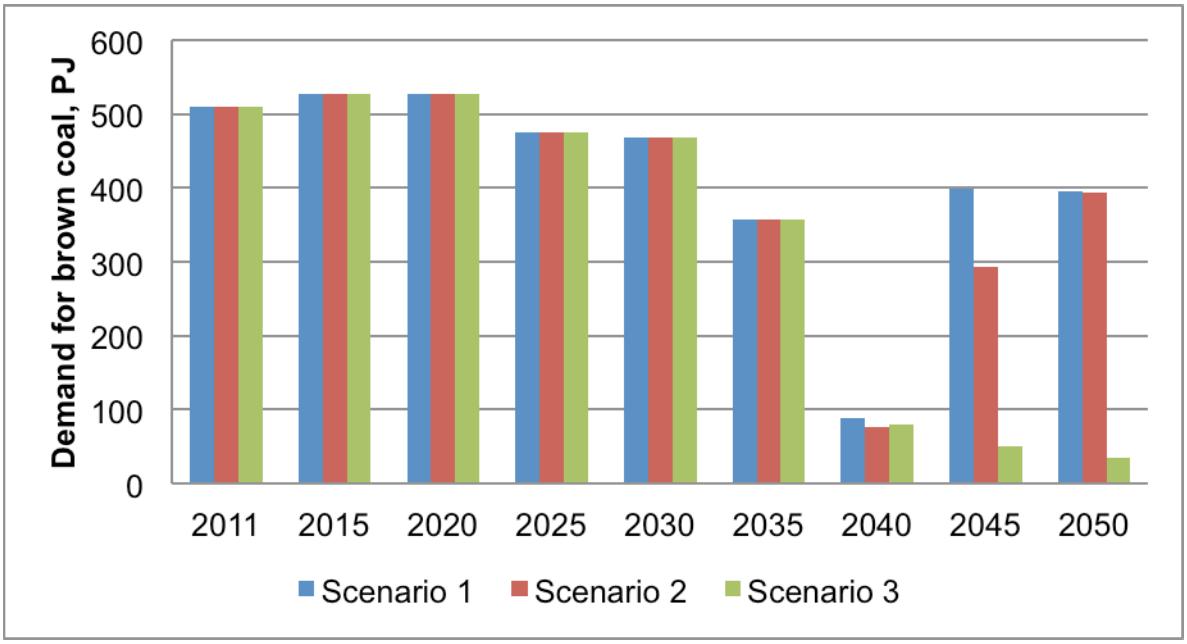


Figure 4. The demand for lignite for power generation in different scenarios of technological development of CCS technology, PJ

Source: own work based on (Gawlik et al., 2013)

The demand for lignite (Fig. 4) is heavily dependent on the availability of the CCS technology. Without this technology, the construction of new lignite-fired power plants is not the optimal solution. The currently existing lignite mines will supply old power plants until depletion of resources or decommissioning of a power plant. The CCS technology creates the opportunity to open new lignite mines after the year 2040.

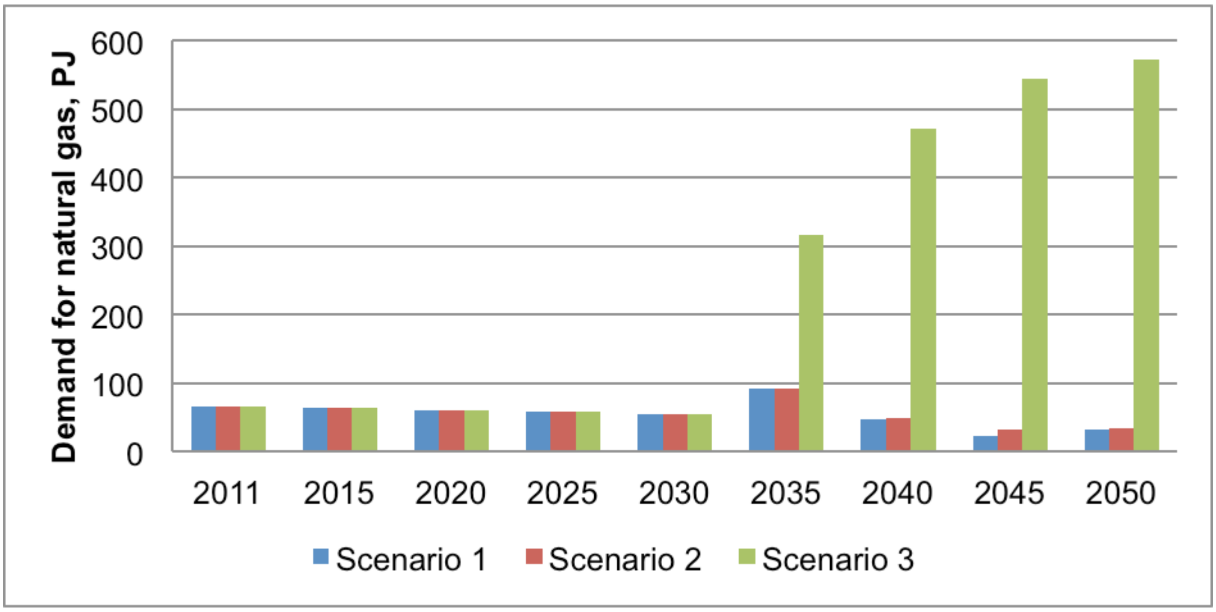


Figure 5. The demand for natural gas for power generation in different scenarios of technological development of CCS technology, PJ

Source: own work based on (Gawlik et al., 2013)

Given the current and projected prices of natural gas, the energy sector based on this fuel is not profitable in Poland (Fig. 5). The demand for natural gas by 2030 is lower than the current for all scenarios. Natural gas, as a low-emission fuel, is an alternative to solid fuels in the case when the CCS technology is not available for implementation (Scenario 3).

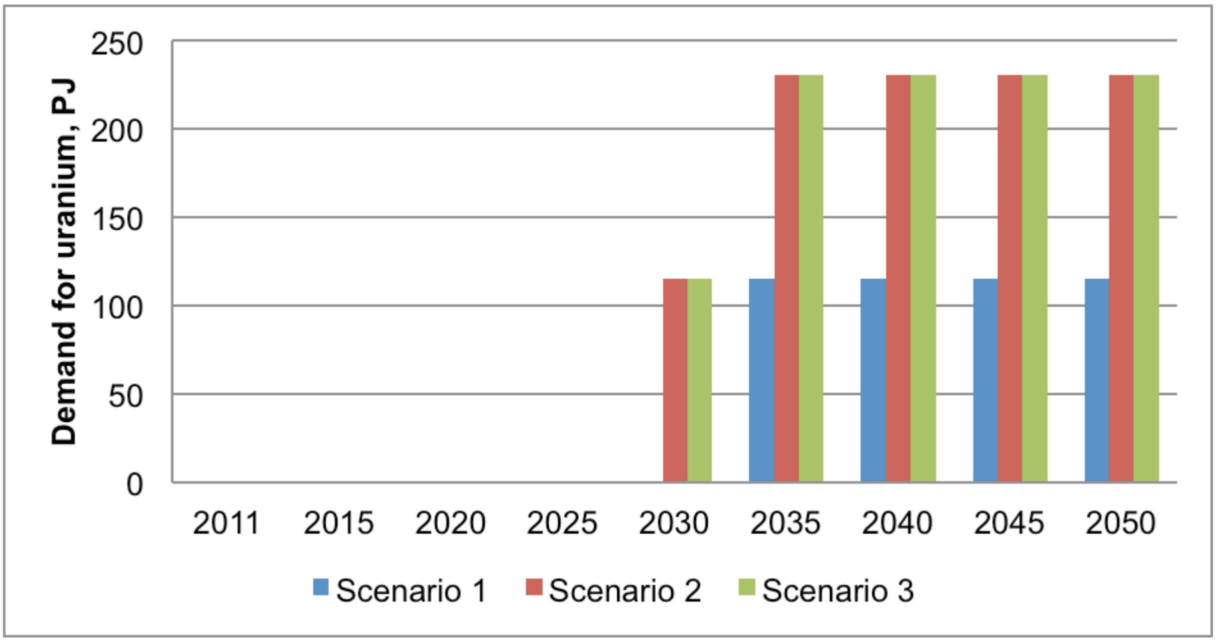


Figure 6. The demand for nuclear fuel for power generation in different scenarios of technological development of CCS technology, PJ

Source: own work based on (Gawlik et al., 2013)

The implementation of the ambitious objectives of the EU in terms of reducing CO_2 emissions raises the need to include nuclear energy into the structure of electricity generation in Poland. The demand for nuclear fuel (Fig. 6) depends on the analyzed scenarios. In the case of scenario of rapid development and implementation of CCS already in 2025, the construction of a power generation unit with a capacity of 1.5 GW, which should be commissioned in 2035, is required. In this case, the demand for nuclear fuel in the next few years will remain at a level of about 115 PJ by 2050. However, if the CCS technology will not reach technological maturity before 2025, its use will require the construction of two nuclear power units and commissioning them in 2025 and 2030.

The possibility of use of CCS technology makes coal technologies in the energy sector more environmentally friendly. Fig. 7 shows the total carbon dioxide emissions for each scenario. The effect of reducing carbon dioxide emissions from the current level of about 167 million Mg to just under 50 million Mg is visible when coal-fired power units are equipped with CCS technology. When CCS technology is not available, the reduction of CO_2 emissions in the sector is lower, reaching a level of about 86 million Mg of carbon dioxide in 2050.

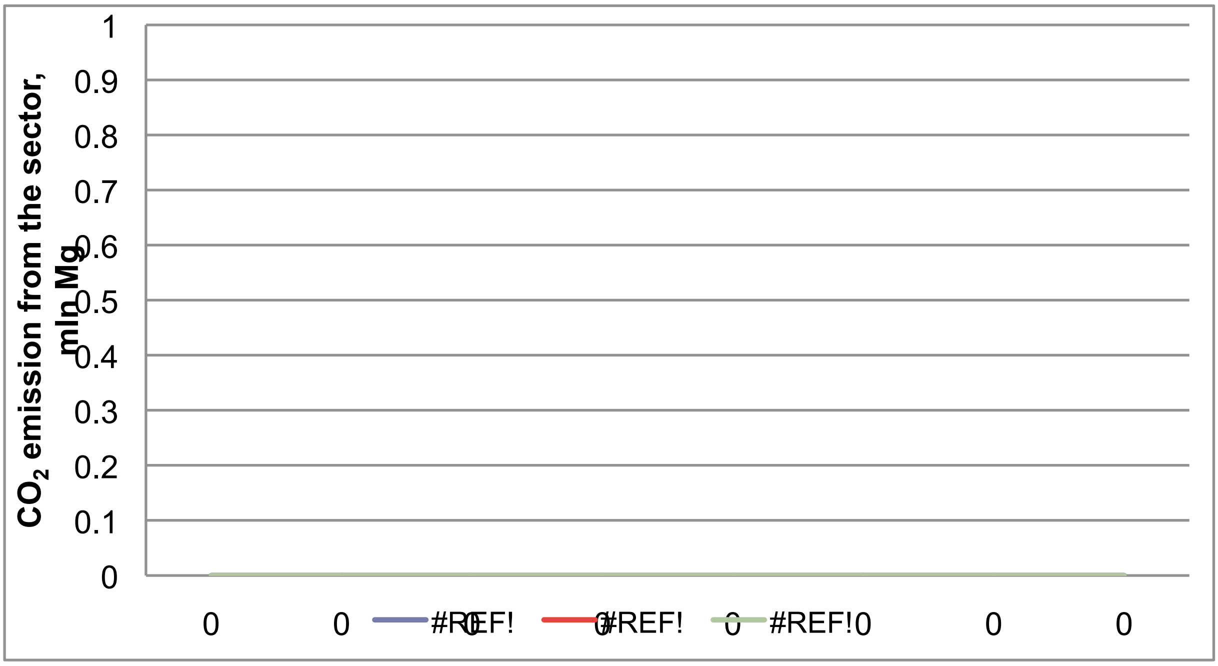


Figure 6. The emissions of carbon dioxide from the electricity generation sector for different scenarios of technological development of CCS technology, million Mg

Source: own work based on (Gawlik et al., 2013)

What is more, coal technologies (including CCS) are relatively cheaper: the cost of electricity production in 2050 are the lowest in scenario 1 and amount to PLN 299.1 / MWh, while in scenario 3 they amount to PLN 310.5 / MWh.

6. Conclusions

Historical conditions, resulting from the available resources, are the reason why the Polish energy sector is based on coal. The energy generated from coal is relatively cheap, while the use of own resources contributes to greater energy security of the country. Further economic development will require modernization of the existing and installation of new production capacities in the energy sector. The development of the power sector must take into account the fact that the solid fuels burned in power plants are the reason for significant emissions of CO_2 into the atmosphere. The future energy mix should be diversified, primarily due to its impact on the environment. The directions of development will depend on the adopted energy policy of Poland, which will be created in response to the targets set by the EU climate policy. When it comes to the manufacturing structure of the energy sector, the depreciated coal-fired units will have to be replaced with modern energy sources, which will be accompanied by the expansion of renewable energy sources (mainly wind power).

The results presented in this article indicate that it is possible to change the structure of the energy sector in order to achieve a significant reduction in emissions of pollutants into the environment. The share of coal, gas and nuclear power in the structure of power generation will depend on the investment decisions.

The development of carbon capture and storage will be of key importance for the possible wide use of coal in the future. The development of clean coal technologies is particularly important for Poland, the only country in the European Union with substantial gas resources. The use of this technology, assuming the implementation of the basic elements of sustainable development including: the high energy security resulting from the use of own resources and the availability of energy for the economy and population at (relatively) low prices and in an environmentally acceptable way, allows meeting the electricity demand in 2050.

Acknowledgments

The work was done within the framework of statutory research of the Mineral and Energy Economy Research Institute of the Polish Academy of Sciences

References

Bilans, 2015. Bilans zasobów złóż kopalin w Polsce. Stan na 31.12.2014 r., PIG, Warszawa.

Roadmap, 2011. Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions. Energy Roadmap 2050, COM (2011) 885/2 final. European Commission (EC).

Dyrektywa, 2004. Dyrektywa Parlamentu Europejskiego i Rady 2004/8/WE z dnia 11 lutego 2004 r. w sprawie wspierania kogeneracji w oparciu o zapotrzebowanie na ciepło użytkowe na rynku wewnętrznym energii oraz zmieniająca dyrektywę 92/42/EWG (Dz. U. WE L 52, str. 50; Dz. U. UE Polskie wydanie specjalne, rozdz. 12 t. 3 str. 3).

Dyrektywa, 2008. Dyrektywa Parlamentu Europejskiego i Rady 2008/50/WE z dnia 21 maja 2008 r. w sprawie jakości powietrza i czystszego powietrza dla Europy (Dz. Urz. UE L. 152 z 11.06.2008, str. 1).

Dyrektywa, (2009a). Dyrektywę Parlamentu Europejskiego i Rady 2009/28/WE z dnia 23 kwietnia 2009 r. w sprawie promowania stosowania energii ze źródeł odnawialnych zmieniającą i w następstwie uchylającą dyrektywy 2001/77/WE oraz 2003/30/WE (Dz. Urz. UE L 140 z 05.06.2009 r., str. 16).

Dyrektywa, (2009b). Dyrektywa Parlamentu Europejskiego i Rady 2009/31/WE z dnia 23 kwietnia 2009 r. w sprawie geologicznego składowania dwutlenku węgla oraz zmieniająca dyrektywę Rady 85/337/EWG, Euratom, dyrektywy Parlamentu Europejskiego i Rady 2000/60/WE, 2001/80/WE, 2004/35/WE, 2006/12/WE, 2008/1/WE i rozporządzenie (WE) nr 1013/2006 (Dz. U. L 140 z 5.6.2009).

Dyrektywa, 2010. Dyrektywa Parlamentu Europejskiego i Rady 2010/75/UE z dnia 24 listopada 2010 r. w sprawie emisji przemysłowych (zintegrowane zapobieganie zanieczyszczeniom i ich kontrola) (Dz.U. L 334 z 17.12.2010, s. 17).

Dyrektywa, 2011. Dyrektywa Parlamentu Europejskiego i Rady 2011/92/UE z dnia 13 grudnia 2011 r. w sprawie oceny skutków wywieranych przez niektóre przedsięwzięcia publiczne i prywatne na środowisko (Dz. U. UE L 26. z 28.1.2012, s. 1).

Dyrektywa, 2012. Dyrektywa Parlamentu Europejskiego i Rady 2012/27/UE z dnia 25 października 2012 r. w sprawie efektywności energetycznej, zmiany dyrektyw 2009/125/WE i 2010/30/UE oraz uchylenia dyrektyw 2004/8/WE i 2006/32/WE. (Dz. U. UE. L. z 14.11.2012 r. L 315/1-56).

Gawlik, L. (Eds.), Grudziński, Z., Kamiński, J., Kaszyński, P., Kryzia, D., Lorenz, U., Mirowski, T., Mokrzycki, E., Olkuski, T., Ozga-Blaschke, U., Pluta, M., Sikora, A., Stala-Szlugaj, K., Suwała, W., Szurlej, A., Wyrwa, A., Zyśk, A., 2013. Węgiel dla polskiej energetyki w perspektywie 2050 roku – analizy scenariuszowe, Górnicza Izba Przemysłowo-Handlowa, Wyd. IGSMiE PAN, Katowice. [Online] www.giph.com.pl/attachements/article/278/Wegiel_dla_polskiej_energetyki_2050_GIPH_MINPAN.pdf (accessed: 11.04.2016)

Gawlik, L., Lorenz, U., 2014. Ile węgla kamiennego dla energetyki. Polityka Energetyczna – Energy Policy Journal, t. 17, z.3, s. 19–32.

Gawlik, L., Mokrzycki, E., 2014. Scenariusze wykorzystania węgla w polskiej energetyce w świetle polityki klimatycznej Unii Europejskiej. Przegląd Górniczy, nr 5(1098), s. 1–8.

Hausner, J., Białecka, B., 2012. Analiza procesu wdrażania czystych technologii węglowych w Polsce. Research Reports Mining and Environment, nr 2, s. 33–47.

ICF, 2014. Mitigation of climate impacts of possible future shale gas extraction in the EU: available technologies, best practices and options for policy makers. ICF International, Prepared for EC – DG Climate Action, January.

Kubica, K., Szlęk, A., Wilk, R., 2007. Czyste technologie węglowe – badania, rozwój i upowszechnianie wyników, Monografia Instytut Techniki Cieplnej, Gliwice.

Malec, M., Kamiński, J., Kaszyński, P., 2016. Regulacje środowiskowe w energetyce a zapotrzebowanie na węgiel kamienny. Polityka energetyczna – Energy Policy Journal, t. 19, z. 1, s. 21–34.

Mirowski, T., Mokrzycki, E., Ney, R., 2015. Energetyka Wiatrowa – stan obecny i szanse rozwoju, Wydawnictwo Instytutu Gospodarki Surowcami Mineralnymi i Energią PAN, Kraków.

Mirowski, T., Sornek, K., 2015. Potencjał energetyki prosumenckiej w Polsce na przykładzie mikroinstalacji fotowoltaicznych w budownictwie indywidualnym. Polityka Energetyczna – Energy Policy Journal, t. 18, z. 2, s. 73–84.

Niedziółka, I., Szpryngiel, M., 2014. Możliwości wykorzystania biomasy na cele energetyczne. Inżynieria Rolnicza, nr 1, s. 155–164

Olkuski, T., Szurlej, A,, Janusz, P., 2015. Realizacja polityki energetycznej w obszarze gazu ziemnego. Polityka Energetyczna – Energy Policy Journal t. 18, z. 2, s. 5–18.

Orzechowska, M., Kryzia, D., 2014. Analiza SWOT wykorzystania gazu ziemnego w transporcie drogowym w Polsce. Polityka Energetyczna – Energy Policy Journal, t. 17, z. 3, s. 321–332.

PEP, 2015. Projekt Polityki energetycznej Polski do 2050 roku, Ministerstwo Gospodarki, Warszawa.

PSE, 2016. Polskie Sieci Elektroenergetyczne SA. Struktura produkcji energii elektrycznej w elektrowniach krajowych, wielkości wymiany energii elektrycznej z zagranicą i krajowe zużycie energii – wielkości miesięczne oraz od początku roku – wielkości brutto. [Online] www.pse.pl/index.php?modul=8&y=2015&m=12&id_rap=212 (accessed: 11.05.2016).

Szurlej, A., Kamiński, J., Janusz, P., Iwicki, K., Mirowski, T., 2014. Rozwój energetyki gazowej w Polsce a bezpieczeństwo energetyczne. Rynek Energii, nr 6, s. 33.

Uchwała, 2014. Uchwała nr 15/2014 Rady Ministrów z dnia 28 stycznia 2014 r. w sprawie programu wieloletniego pod nazwą „Program polskiej energetyki jądrowej".

Weigensperg, T., 2013. Gaz ziemny z łupków w Polsce. Nowoczesne Budownictwo Inżynieryjne nr 3, s. 71−72.

Wojtkowska-Łodej, G., 2014. Wyzwania klimatyczne i energetyczne a polityka Unii Europejskiej. Polityka Energetyczna – Energy Policy Journal, t. 17, z. 2, s. 39–52.

Authors' Index

The index is organized by surname, first name, and respective track(s) where the paper was presented.

Names and tracks in bold refer to the 1st author

C

D

E

F

G

H

I

J

N

O

S

T

U

V

W

X

Y

Z

Sponsors and supporters

Caixa Geral de Depositos

SONAE SIERRA

ÁGUAS DE PORTUGAL

ESPORÃO

xerox

NOVA School of Business & Economics — Shaping powerful minds

NOVA IMS Information Management School

UNIVERSIDADE ABERTA www.uab.pt

European Environment Agency

CP COMBOIOS DE PORTUGAL — VÁ DE COMBOIO — ISDRS CONFERENCE 2016 — Intercidades | Regional InterRegional

sumol+compal — É da nossa natureza

Casa do Pão de Ló de Alfeizerão

Cantinho das Aromáticas

Central Cervejas e Bebidas

Routledge Taylor & Francis Group

ALMADA CÂMARA MUNICIPAL

DELTA CAFÉS

Sesimbra câmara municipal

REPÚBLICA PORTUGUESA — CULTURA — DRC ALENTEJO

PARQUE NATURAL DA ARRÁBIDA

RE-FOOD

ArtesanalPesca

ICNF Instituto da Conservação da Natureza e das Florestas

moinho recycled cotton paper

Official Carrier:

TAP PORTUGAL — de braços abertos *with arms wide open* — A STAR ALLIANCE MEMBER

Media Partners:

ambiente online

água & ambiente

GREENMATCH

E-mail ISDRS2016@campus.fct.unl.pt
Website http://www.isdrsconference.org

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA
SCHOOL OF SCIENCE AND TECHNOLOGY

Faculdade de Ciências e Tecnologia
Universidade Nova de Lisboa
2829-516 Caparica
Portugal
Telefone: +351 212 948 300
http://www.fct.unl.pt/

CENSE
center for environmental and sustainability research

Departamento de Ciências e Engenharia do Ambiente
Faculdade de Ciências e Tecnologia
2829-516 Caparica
Portugal
Telefone: +351 212 948 397
http://cense.fct.unl.pt/

ISDR Society

International Sustainable Development Research Society
http://isdrs.org