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Decision making for ecosystem-based adaptation: *Methodological developments and field studies*

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Lili Ilieva
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SUMMARY

In the quest for adaptation to climate change, ecosystems in good structural and functional status are widely recognized as fundamental asset for the enhancement of resilience of the broader system called socio-ecosystem (SES), by delivering benefits to communities via their services. In parallel, society is able to strengthen SES's adaptive capacity; through for example ad hoc climate change adaptation plans (CCAP).

Ecosystem-based Adaptation (EbA) is being distinguished for its integrated approach to reduce vulnerability of social-ecological systems to global changes and strengthen adaptive capacity by generating direct services as food and building material in addition to indirect services as coastal protection and water purification. Despite the notable progress in exploring ecosystem functions and their role in human livelihoods, it is in the last two decades when the concept of ecosystem services has firmly stepped on the ground. With the remarkable scientific works of MA (2005) and TEEB (2010) on estimating and valuing the benefits ecosystem services provide for human well-being, a new line of research was established. In the attempts to identify ecosystem services, quantify and estimate their value, researchers paved the road to incorporate this concept into the economic and policy agenda. Yet, few obstacles still prevent the ecosystem services approach to be better embedded in decision-making and planning for climate adaptation.

With this in mind, this research seeks to explore this perspective through the lens of adaptive and dynamic social-ecological systems and formulate it to support decision-making processes. This research has an overall goal to demonstrate that acknowledging ecosystem services in decision making for adaptation would result in the design and implementation of effective and sustainable responses. To do so, the research is built upon an integrated methodological decision-support approach (NetSyMoD Network Analysis – Creative System Modelling – Decision Support) and proposes a methodological enrichment to incorporate the concept of ecosystem services in the decision cycle. The research takes as a case the potential of Payments for Ecosystem Services (PES) to be considered as EbA measure and proposes design mechanisms for two case studies – Dojran Lake, Macedonia and West Demerara, Guyana.

Founded on an assessment of scientific dialogues and evidence from case studies, the present dissertation undertakes a methodological journey to identify challenges and opportunities in integrating an ecosystem services approach to decision making for adaptation. Therefore, it enriches the knowledge and methodology on possible paths to transform ecosystem services research into rigorous decisions through methodological developments and field studies.

Table of Contents

List of Figures

List of Tables

ABBREVIATIONS

CBD	Convention for Biological Diversity
CCAP	Climate Change Adaptation Pans
DRR	Disaster Risk Reduction
EbA	Ecosystem-based adaptation
ES	Ecosystem services
FAO	Food and Agriculture Organization of the United Nations
IPCC	International Panel for
MEA	Millenium Ecosystem Assessment
NetSyMoD	Network Analysis – Creative System Modelling – Decision Support
PES	Payments for Ecosystem Services
REDD	Reduced Emission from Deforestation and Degradation
SES	Social-Ecological System
TEV	Total Economic Value TNC The Nature Conservancy
TEEB	The Economics of Ecosystems and Biodiversity
UN	United Nations

1. Introduction

1.1 Introduction to the problem context and relevance of the research

Ecosystems are of “most varied kinds and sizes”, identified by the common feature of being a system (Tansley, 1935). Such systems are defined by the Convention for Biological Diversity (CBD) as “a dynamic complex of plant, animal and micro-organism communities and their nonliving environment interacting as a functional unit” where humans make an integral part (UN, 1992). Ecosystems can be categorized by a set of biological (e.g. species composition; surface cover), climatic (e.g. climatic zones), social (e.g. land use; resource management) factors. Defining boundaries of an ecosystem is often guided by the principle in that there is a strong interaction among these factors.

Humans have reshaped most of the ecosystems on Earth to create landscapes better adapted in favour of social needs. Many of these landscapes are an evidence of the co-evolving character of the relationship between people and nature over centuries to create cultural landscapes. Such landscapes are characterised by a dynamic interaction between nature and people to influence physical attributes and associate values (Phillips, 2005). Yet, such reshaping of ecosystems may have led in positive outcomes as food production, or on the contrary it has greatly affect biodiversity and ecological processes (Raudsepp-Hearne et al. 2010). Understanding such complex interaction of social and ecological elements implies a holistic view of the system. Analysing coupled human and natural systems presents a stimulating theme of interest to a number of scientific fields to elaborate the concept of social-ecological systems (SES) (Redman et al. 2004; Folke et al. 2010).

As interlinked components in the SES, human well-being and ecosystems are tightly connected. Ecosystem processes and functions and their interaction with the social system underpin the generation of ecosystem services (ES) widely acknowledged to benefit human livelihoods (Reyers et al. 2013). The Millenium Ecosystem Assessment Report (MAE, 2005), outlines the interconnectedness and strong linkage between the two components through four categories: i) provisioning services (e.g. food, fuel and fibre), ii) regulating services (e.g. pollination, hydrological regulation), iii) cultural services (e.g. sense of place and tourism), and iv) supporting services (e.g. soil formation and nutrient cycling). Agriculture makes a source of living for 1.3 billion stallholder farmers worldwide, most of which are highly vulnerable to climatic changes, in particular the tropical regions (WB, 2008; Salinger et al., 2005). Recognising that smallholder farming in many low -income countries accounts for the vast majority of all farms worldwide. Farms of less than 1 hectare make up to 72 percent of world’s farms, which often contribute to the majority of food production in these countries (FAO, 2013). However, smallholder-farming systems are described as “complex, diverse and risk-prone” (Chambers et al. 1989). The intrinsic vulnerability of these systems derives from their interlocked complexity and stressors (e.g. agricultural policies, market failures, environmental degradation), which contribute to limited adaptive capacity (Adger et al., 2003; Morton J.F. 2007). Additionally, these systems are often located in areas of high variability of rainfalls and exposed marginal environments with high risk of natural hazards such as drought or flood. The high dependence of smallholder agriculture farming on fragile ecosystems with high vulnerability to climatic changes requires urgent and appropriate responses. Yet, along with their vulnerability, smallholder farmers possess resilience characteristics as livelihood diversity and indigenous knowledge, which allows them to cope with crises (Ellise, F. 2000).

Agro-ecology has emerged as a discipline, which embraces ecological principles in the management of agricultural systems to provide sustainable production in an environmentally, culturally and socially just manner (Altieri, 1995). Agro-ecological systems have shown resilience to natural hazard events based on their high level on-farm biological diversity and traditional management practices (Altieri, 2002; Holt-Gimenez, E., 2001). Yet, exploring these systems goes beyond one-dimensional understanding of the functionality of the system but embraces a multi-dimensional structure. In such a structure, ecological and social elements co-evolve through the complex dynamic feedback processes and thresholds at different time and scale (Vandermeer, 1995; Redman et al. 2004).

Agricultural systems are a good example of ecosystem management to demonstrate how the provision of ES can enhance or degrade dependent on the drivers and interactions (Kumar 2010; Power 2010). The ecological dimension of these SES can be observed in the interaction and dependence of the system with neighboring natural ecosystems and their biodiversity that provide benefits such as pollination, reduced soil erosion and pest control. Scientific enquiry in this realm implies that agro-ecosystems generate social benefits beyond the provision of food and fiber (Pascual & Perrings, 2007). In the presence of conservation or traditional practices, such as agroforestry or intercropping it is suggested that more ecosystem services are delivered compared to conventional farms (Altieri, 1999).

As part of SES, social and economic factors affect the processes determining ecosystem management interventions such as land use change or crop diversification. Such factors can drive change in one or more ecosystem services leading to trade-offs (diminishing one service while enhancing the other) or alternatively synergies (enhancing both services) (Bennett E. and Garry D., 2009). The components of such system interact with one another and the physical environment to supply and/or enhance critical ecosystem services to the farming process, such as soil building, nitrogen fixation, nutrient cycling, water infiltration, pest or disease suppression, and pollination, thus promoting sustainable agriculture (Pearson, 2007). The co-evolution of landscapes with human activities develops the foundation of socio-ecological system. It is where, the ecological dimension depends on the continuation of maintaining practices to support biodiversity and other services, which in turn deliver benefits to humans. Another aspect of the human dimension is the role of traditional knowledge, culture, social institutions and knowledge networks that play a role in the resilience of the SES. Such social values and connections often occur beyond on-farm interactions. The integration of such factors has proven to be difficult and especially when the boundaries of the system need to be determined.

It is widely asserted that environmental and climatic changes pose most tangible effects on communities highly dependent on natural ecosystems to support their livelihoods (Adger *et al*. 2005). Environmental and human-induced disruption of ecosystem functions (e.g. operation of hydrological cycle contributing to flood control and drinking water supply) makes socio-ecological system more vulnerable to external threats (MEA 2005). Hence the maintenance of an integrated and functional natural capital to deliver environmental goods and services is a precondition for development of a resilient socio-economic system (Daily 1997). Adapting to climatic changes can be perceived as a systematic response formed via the interconnection between ecosystem services (e.g. provisioning, supporting, regulating and cultural) and social services (e.g. maintenance, conservation and sustainable management of natural resources) for the design of a holistic approach to address the complexity of climate impacts.

The role of ecosystems in protecting coastal shorelines, mitigating floods and contributing to food security is evident, yet the emergence of ecosystem-based adaptation (EbA) is a rather recently introduced concept (Barbier, 2006 and Munang *et al.,* 2013). By combining practices for biodiversity conservation and maintenance of ecosystem services into a broader adaptation framework, the ecosystem approach is embedded into the concept of socio-ecological system resilience (Berkes *et al.,* 2003).

The ecosystem-based adaptation (EbA) calls not only for the consideration of natural (i.e. environment, resources, biodiversity) elements but provides a foundation for an integrated view in which human (i.e. socio-economic, cultural, religious) elements of the social-ecological system and their interactions are as well explored. The opportunity thus emerges to develop innovative assessment and management approaches which go beyond the rather consolidated approach based upon the analysis of ecosystem services. An avenue for innovative and more effective approaches can come from the development of consolidated ES analysis towards a novel notion. An opportunity emerges to develop innovative assessment and management approaches which go beyond the rather consolidated approach based upon the analysis of ecosystem services and, in case, on the establishment of PES mechanisms (Payment for Ecosystem Services) as a policy solution for nature valorisation and poverty alleviation.

Despite the notable progress in exploring ecosystem functions and their role in human livelihoods, it is in the last two decades when the concept of ecosystem services has firmly stepped on the ground. With the remarkable scientific works of MA (2005) and TEEB (2010) on estimating and valuing the benefits ecosystem services provide for human well-being, a new line of research was established. In the attempts to identify ecosystem services, quantify and estimate their value, researchers paved the road to incorporate this concept into the economic and policy agenda. Yet, few obstacles still prevent the ecosystem services approach to be better embedded in decision-making and planning for climate adaptation.

With this in mind, this research seeks to explore this perspective through the lens of adaptive and dynamic social-ecological systems and formulate it to support decision-making processes. To unfold this objective the following research questions were considered:

Q1: How ecosystem approach contributes to better understand vulnerability of social-ecological systems?
Q2: How do ecosystem services contribute to reducing vulnerability of social-ecological systems to global changes?
Q3: Do Payments for Ecosystem Services contribute to identified adaptation objective?
Q4: How to integrate ecosystem services in designing responses to address vulnerability of social-ecological systems?

1.2 Structure of the thesis

The dissertation is divided into seven chapters, which are framed by the conceptual background and proposed methodological framework. Figure 1-1 presents how the research questions are addressed by the chapters and the links between them.

Chapter 1 is an introduction to the concept of ecosystem services and their role in ecosystem-based adaptation to global changes as the motivating element for this research. The chapter underlines the challenges that this research pursues to address and shapes the aim and objective guiding the following chapters.

Chapter 2 provides a description of the conceptual background, linking key concepts, upon which this research is developed and in parallel introduces the methodological steps. The methodology determines the approaches undertaken throughout the decision support exercises in the research.

Chapter 3 gives a description of the selected case studies: 1) Demerara region in Guyana and 2) Lake Dojran in Macedonia. This chapter provides a background for the two study sites and the rationale behind their selection.

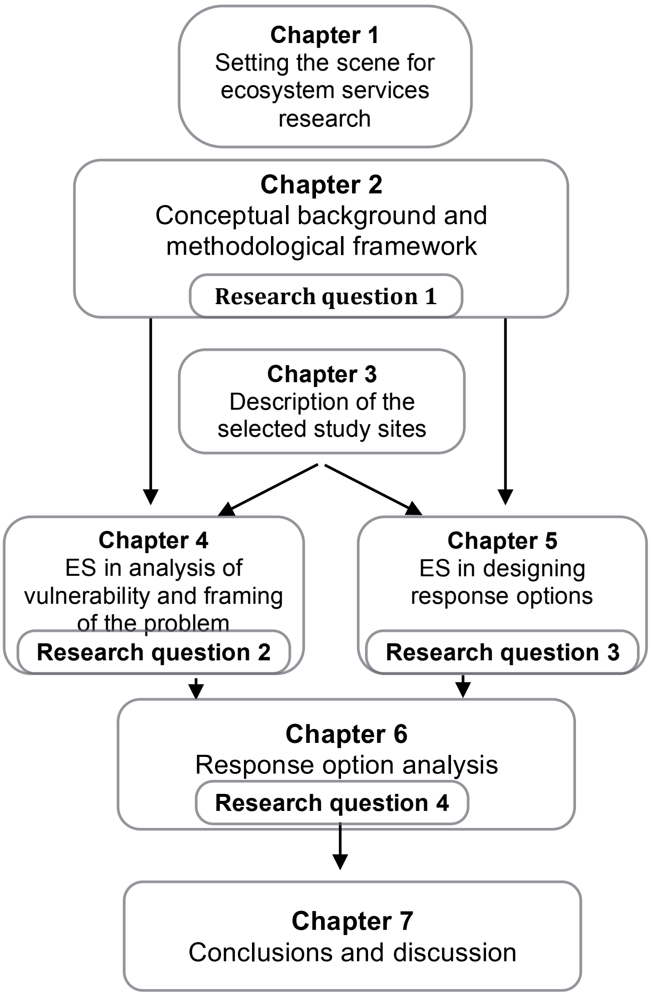
Chapter 4 aims to demonstrate the application of the initial steps of the methodological framework in the study sites. This chapter explores the role of ecosystem services in analysing vulnerability of social-ecological systems and in problem framing and analysis in the context of Demerara region in Guyana and Dojran Lake in Macedonia. This chapter is conducted by applying qualitative and participatory approaches for data collection to elicit multi-stakeholder perceptions on vulnerability to global changes.

Chapter 5 aims to explore how the concept of ecosystem services can be incorporated in local planning for adaptation. The development of scenarios and response options are founded upon outcomes from Chapter 4. The analysis explores the link between ecosystem-based adaptation measures and Payments for Ecosystem Services (PES) as alternative adaptive options in both study sites applying the methodological steps for decision-making support.

Chapter 6 explores the proposed PES designs for the case studies and applies a SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) as a methodological step to decision support for ecosystem-based decision making.

In conclusion **Chapter 7** is a synthesis of the research and seeks to unite the results for both studies and develop a deeper understanding the gaps between research and decision-making and how they manifest looked through the lenses of ecosystem services. The research outcomes from Chapter 4, 5 and 6 will facilitate the interpretation of how the concept of ecosystem services is considered in planning and decision-making processes.

Fig. 1-1: Diagram representing the structure of the dissertation and depicts the logical sequence of the research.



2. Ecosystem services in the context of adaptation to global change: Conceptual and Methodological framework

This chapter describes the foundation of the conceptual and methodological approaches undertaken by this study. It outlines major concepts of vulnerability and ecosystem services to provide a better understanding where these two concepts meet and how their components interact. Both the conceptual and methodological approaches are interlinked at every stage of the research and indicated as a reference element for all other chapters. Chapter 2 has the objective to respond the Research Question 1 - How do ecosystem services contribute to reducing vulnerability of social-ecological systems to global changes?

2.1 Ecosystem-based adaptation: Theory and practice

2.1.1 Emergence of ecosystem services approach

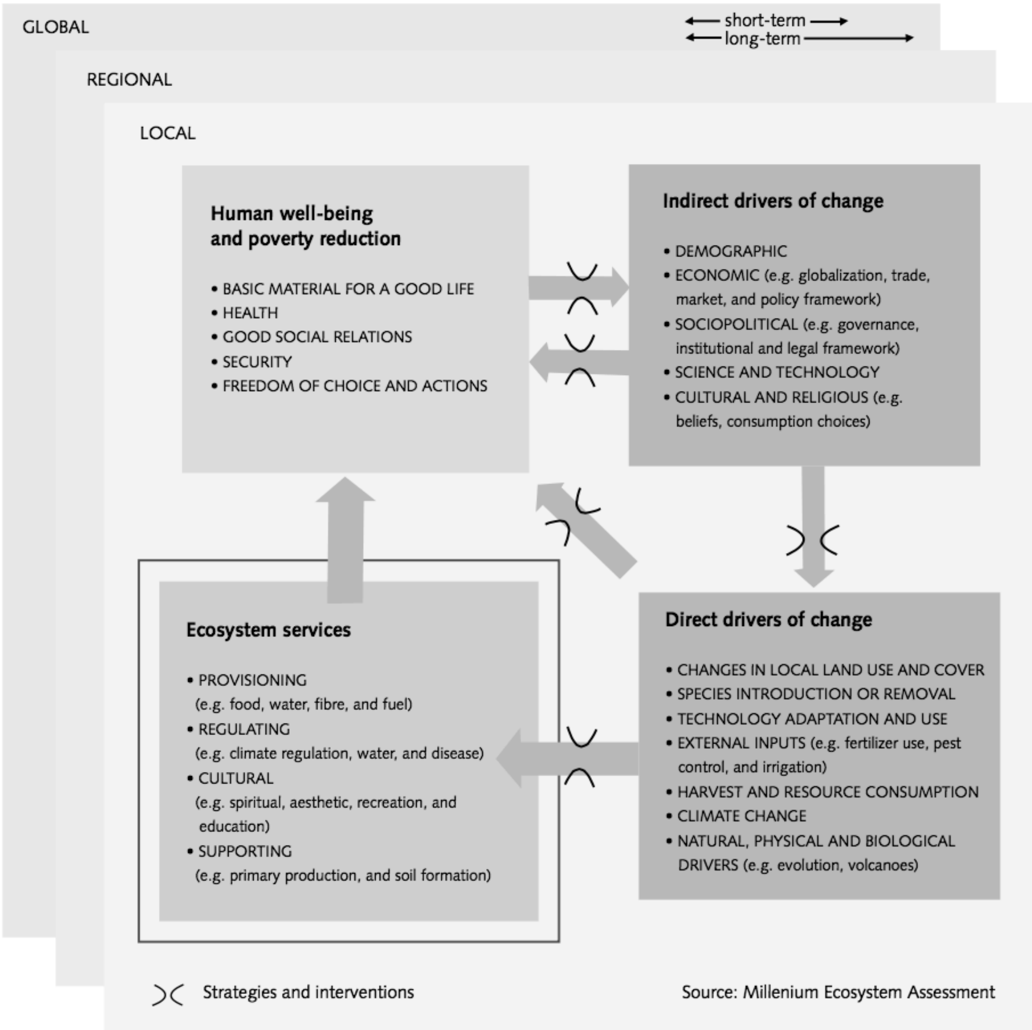
Despite the notable progress in exploring ecosystem functions and their role in human livelihoods, it is in the last two decades when the concept of ecosystem services has firmly stepped on the ground. With the remarkable scientific works of MA (2005) and TEEB (2010) on estimating and valuing the benefits ecosystem services provide for human well-being, a new line of research was established. In the attempts to identify ecosystem services, quantify and estimate their value, researchers paved the road to incorporate this concept into the economic and policy agenda. Yet, few obstacles still prevent the ecosystem services approach to be better embedded in decision-making and planning for climate adaptation. Hydrological ecosystem services also known as watershed services (Smith et al., 2006), make one part of the bundle of essential ecosystem services. Figure 2-1 lists the key watershed ecosystem services. Ecosystem services provided by watersheds are diverse and generate multiple direct and tangible benefits to people (MA 2005).

Fig. 2-1: Overview of watershed ecosystem services (Smith et al., 2006)

Provisioning services Services focused on directly supplying food and non-food products from water flows • Freshwater supply • Crop and fruit production • Livestock production • Fish production • Timber and building materials supply • Medicines • Hydroelectric power	**Regulating services** Services related to regulating flows or reducing hazards related to water flows • Regulation of hydrological flows (buffer runoff, soil water infiltration, groundwater recharge, maintenance of base flows) • Natural hazard mitigation (e.g. flood prevention, peak flow reduction, landslide reduction) • Soil protection and control of erosion and sedimentation
Supporting services Services provided to support habitats and ecosystem functioning • Wildlife habitat • Flow regime required to maintain downstream habitat and uses	**Cultural services** Services related to recreation and human inspiration • Aquatic recreation • Landscape aesthetics • Cultural heritage and identity • Artistic and spiritual inspiration

Economic growth, increased population and unsustainable land use practices are only few of the drivers of such changes. Examples have shown that some sustainable land-use practices can actually positively affect the provision of watershed ecosystem services. Yet, due to the characteristics of public goods there are few incentives for landholders, for instance upstream, to consider changing their land-use practices to contribute to a better water quality and quantity to downstream communities.

Fig 2-2: Conceptual ecosystem services framework of the Millennium Ecosystem Assessment (MA, 2005)



As interlinked components in the SES, human well-being and ecosystems are tightly connected. Ecosystem processes and functions and their interaction with the social system underpin the generation of ecosystem services (ES) widely acknowledged to benefit human livelihoods (Reyers et al. 2013). The MA (2005), outlines the interconnectedness and strong linkage between the two components through four categories: (i) provisioning services (e.g. food, fuel and fibre), (ii) regulating services (e.g. pollination, hydrological regulation), (iii) cultural services (e.g. sense of place and tourism), and (iv) supporting services (e.g. soil formation and nutrient cycling). Figure 2-2 illustrates the linkages between the four categories of ecosystem services with components of human well-being.

2.1.2 Ecosystem services from agro-ecological farming systems

Traditionally, management practices in agricultural systems have been focused, above all, for the optimal production of food, yet agricultural landscapes are an explicit example of social –ecological system that generates a range of ecosystem services that support human well-being (Daily, 1997; Kremen, 2005). With this in mind, agro-ecosystems are further analyzed in this study through the lens of SES and the services they generate. Questions however remain on the dynamics of the links between land management practices and provision of ecosystem services. A divergent line of studies highlights the importance of certain agricultural management practices for maintaining habitat vital for biodiversity (Amend *et al.,* 2008; Altieri, 1999) and enhancing ecosystem services to buffer natural hazards (Rosset *et al.* 2011; Holt-Giménez, 2002). The ecosystems services flow may differ in special distribution where their benefits are at farm scale (on-farm) for farmers and other beneficiaries on-site, while other services have benefits at a larger scale (off-farm). Table 2-1 lists an example of services generated by agro-ecosystems defining on-farm and off-farm benefits.

Tab. 2-1: Ecosystem services from agro-ecological systems and their benefits on – and off-farm (Adapted from Garbach K. *et al.* 2014*)*

Ecosystem services	Description	On-farm benefits	Off-farm benefits
Provisioning services			
Provision of food, fuel, fiber	Harvestable goods from agro-ecosystems	Food and other goods for on- farm consumption or sale	Goods for agricultural markets
Regulating services			
Water flow regulation	Buffering and moderation of the hydrologic cycle, including water infiltration into soils and aquifers, moderation of runoff, and plants transpiration	Water in soils, aquifers, and surface bodies available to support plant growth	Stabilize stream base flow and mitigate flooding to downstream areas; recharge into aquifers and bodies of water
Water purification	Filtration and absorption of particles and contaminants by soil and living organisms in the water and soil	Clean water available for human consumption, irrigation, and other on-farm uses	Clean water available to downstream users

One of the hydrologic services (Tab. 2-1) is water flow regulation to control the amount of water flowing through a landscape. In particular, this service refers to the ability of watersheds to capture and store water from heavy rainfall thus reducing runoff and flood peaks (MA 2005, TEEB 2010, Daily 1997; Brauman et al. 2007). Ecosystems affect the water balance through two processes: interception and infiltration (Nedkov and Burkhard 2012). The factors affecting flow regulation are directly linked to infiltration processes shaped by soil properties and fauna, land cover and productivity. Such characteristics of the system determine surface water runoff, which in turn is considered a main element for flood formation (Zhang et al. 2001).

Conservation agricultural practices as tillage and riparian buffers on the other hand, perform well in enhancing the capacity of water retention in the system (Pert et al. 2010). Recent studies have demonstrated evidence that agro-ecological systems show greater level of resilience to environmental disturbances than conventional agriculture (Kremen et al. 2012). Case studies show that captured water in organic plots was nearly double the amount in conventional plot, hence performing higher rates of percolation, lower volumes of surface run-off and also reduced erosion rates (Lotter et al. 2003, Pimentel et al. 2005).

Regulation services such as flood regulation services, are generated at a certain ecological scale e.g. ecosystem or landscape, thus benefits may reach stakeholders at different institutional scale (Hein, L. et al 2006). The flow connecting service provisioning areas with benefiting areas and the benefits transferred between them is characterised by the hydrological system. Beneficiaries flood regulation services can be at community level to national and international level.

In the specific case of agro-ecological farming systems, water flow regulation is described as the buffering capacity and moderation of the hydrologic cycle. The ecosystem functions of water filtration in soils and aquifers and control of runoff, provides benefits both on-farm and off-farm stakeholders. Direct benefit from this service on-farm is retention of water in soils and aquifers thus supporting plant growth. The major benefit for off-farm stakeholders is mitigation of flooding by stabilizing stream flow and recharging of aquifers thus reducing rainfall runoff. Therefore, the preservation and enhancement of hydrological services from agro-ecosystems through conservation practices is acknowledged to be of significant value for a range of different stakeholders.

2.1.3 Ecosystem-based adaptation

Ecosystem-based adaptation (EbA) is defined as "use of biodiversity and ecosystem services as part of an overall adaptation strategy" (CBD, 2009) and is acknowledged as a holistic approach to address adverse effects of climate vulnerability and hazards. EbA implies sustainable management, conservation and restoration of ecosystem to enhance the generation of ecosystem services with high adaptation value to people's livelihoods in a context of global changes. Ecosystem Based Adaptation (EbA) is already established approach, which will be further explored by integrating the human dimension, trough capabilities for integrated system dynamic. The aim of the research reported in this work is to go beyond the usual approach in exploring factors contributing to vulnerability and pathways to strengthen resilience of communities, by means of a dynamic integration of nature and the human dimension. With the proposed approach both humans and ecosystems are recognized as being the entities of the same process to respond to threats and exploit opportunities that may derive from global change and, in particular from climate variability and extreme events. Capturing the essence of this approach in the context of adaptation and effectively communicating it to policy makers requires effective interfaces between the various actors involved.

Some management approaches to be incorporated in designing EbA measures to maximise benefits include (TCN, 2009):

- Sustain interconnected ecosystems to enable their adjustment to changing environmental conditions and enhance the generation of ecosystem services;
- Restore degraded ecosystems and re-generate environmental processes of critical importance;
- Adapt natural resource management strategies and programs to incorporate the notion of climate-induced impacts.

Apart from direct benefits that contribute to adaptation of people EbA provides multiple social, economic and cultural co-benefits while being shaped to a local context (Roberts *et al.,* 2011). EbA approaches are considered as cost-effective manner to tackle climate change challenges, thus providing a background to review the predominant paradigm in the disaster risk reduction and adaptation agenda where technical options and grey infrastructure have too long been considered as solutions (Jones et al., 2012). Therefore, the systematic integration of EbA approaches in local decision-making and planning for adaptation has the ultimate potential to address pressing issues of community vulnerability and disaster risk mitigation in the search to foster socio-ecological sustainability transformations (Andersson, 2006; Roberts et al., 2011; Wilkinson et al., 2013; Wu, 2014).

2.2. Where ecosystem services and vulnerability of social-ecological systems meet?

It is widely asserted that environmental and climatic changes pose most tangible impacts on communities highly dependent on natural ecosystems to support their livelihoods (Adger *et al*. 2005). Environmental and human-induced disruption of ecosystem functions (e.g. operation of hydrological cycle contributing to flood control and drinking water supply) escalates vulnerability of socio-ecological systems to external shocks (MEA 2005).

Vulnerability theory emerged as the effort to better understand the risk of such external shocks, providing a basis to assess impacts and plan adaptation measures (IPCC 2007). The two research realms on disaster risk reduction (DRR) and climate change adaptation (CCA) examine vulnerability through different lenses. DRR studies focus mainly on the risk analysis to determine hazard, while CCA research pays attention to understand the adaptive capacity and sensitivity of the system at risk. In the attempts for integration of the two research paths, the IPCC-SREX (2012) proposes an adapted version, which explores the notion of vulnerability, as an integral component in risk assessment, weakening the causal link between natural hazards and exposure with vulnerability. This conceptualization is further elaborated in the IPCC AR5 (2014) to portray vulnerability as "the predisposition to be adversely affected".

Among the diverse spectrum of asserted theoretical and applied frameworks, a dynamic and system-oriented approach of vulnerability analysis is illustrated in a framework defined by Turner et al. (2003). The framework intends to go beyond the simple conceptualization of risk but rather analyse the vulnerability of coupled social-ecological components addressing the perceptions of exposure, sensitivity and resilience tangled in their causal relationships (Turner et al. 2003). It further considers wide range of conditions and factors, incorporating the notion of human and natural capital in the context of climate impacts and resilience research. The author argues that the state of the coupled socio-ecological system determines its sensitivity, exposure and influences its coping mechanisms. These mechanisms produce feedback, which affects each of the elements, in other words a response in the social sub-system would influence the ecological sub-system to either better cope or not with the stress (Turner et al. 2003). It is an illustration of the profound understanding that vulnerability is dynamic property of coupled social-ecological systems, which draws attention to the range of factors and linkages determining the state of the systems at specific spatial scale.

The framework is applied to case studies in Mexico, Kenya and Tanzania to assess vulnerability of agricultural systems and demonstrate its limitations and space for innovations (Luers et al. 2003; Eriksen et al. 2005; Eakin, 2005). The work of Luers and colleagues (2003) suggest a metric to measure vulnerability of key variables in the causal chain. In parallel Eriksen et al. (2005) and Eakin (2005) argue that the interaction of multi-level social dynamics in socio-ecological system as livelihoods, social structure and governance, provide better insight to determine vulnerability of the system. In the search for an appropriate vulnerability measure, Adger (2006) highlights that it often considers incorporating more broadly defined well-being variables to reflect important social aspects of the system.

As a property of social-ecological systems, vulnerability incorporates both the social and ecological dimensions. In this context the ecological dimension of vulnerability is expressed through the capacity of ecosystems to support human needs. The influence of the social dimension on the state of the ecosystems and their capacity to provide goods and services has direct feedback reflecting on the vulnerability of communities to external or internal stress (MEA 2005). Recognizing the importance of ecosystem services in other dimensions as sustainable livelihoods and poverty alleviation, few attempts have been made to conceptualize and frame such relations (Fisher et al. 2014; Reed et al. 2013; many more). Integrating the MEA framework for ecosystem services in the international development context has led to the emergence of the Ecosystem Services and Poverty Alleviation (ESPA) conceptual framework, which "unpacks the services/wellbeing nexus" to elaborate a methodological understanding of the complex system. Acknowledging that wellbeing is highly contextual, the ESPA framework serves as a guideline for prioritization of ES in particular situation in the context of poverty alleviation. Both MEA and ESPA frameworks are consistent identifying that material wellbeing and health are primarily dependent on provisioning services followed by supporting and regulating services. Cultural services are seen as substantial for social wellbeing and identity, while regulating services are important for reducing physical explore and ecological sensitivity (MEA 2005; ESPA source). Thus, ecosystem services and specially regulating services can foster social-ecological resilience to curb impacts from extreme events as those services are mainly associated with the coping capacity of systems to adapt to various kinds of disturbances (Carpenter et al. 2006). Hence the maintenance of an integrated and functional natural capital to deliver environmental goods and services is a precondition for development of a resilient socio-ecological system (Daily 1997).

Unifying the frameworks for both vulnerability and ecosystem services in the context of SES would provide an insight into the role of ecosystems in strengthening the elements underpinning sensitivity and adaptive capacity of systems. Human wellbeing is a dimension interlinked in both concepts acting as an intermediary and is described through several components. The four major wellbeing components identified in the literature are: basic material for good life; health; security and good social relations (Narayan et al. 2000; MEA 2005). Examples of social vulnerability criteria used in quantitative research refer to income; health; social capital and access to natural resources among others, which often strongly relate to the provision of ecosystem services (Cutter et al. 2003; MEA 2005). Vulnerability may result from limited access to provisioning services or degraded regulating services (flood prevention, etc.)

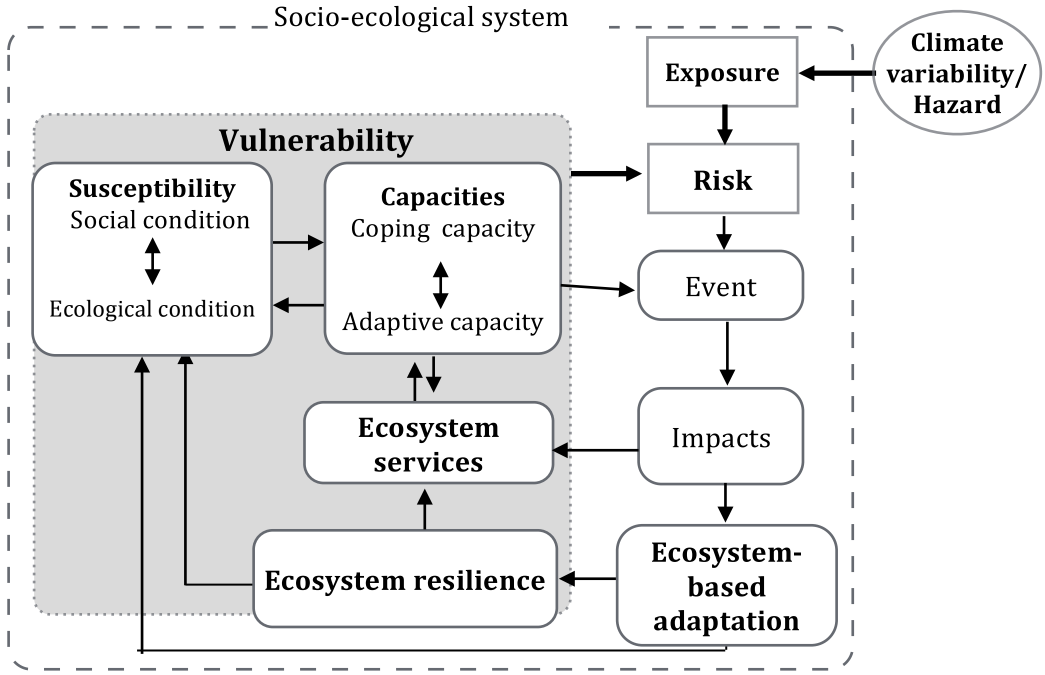
Vulnerability research from around the world focus on diverse elements underpinning the sensitivity and adaptive capacity of the system, such as resource access and policy reform, ethnicity, poverty, dependence of livelihoods on natural resources sensitive to climate variability. These examples, demonstrate the complex relationship among indicators describing wealth, diversity and equity, underlining the critical role of natural and social capital, policy and institutional change in interpreting vulnerability. In the attempt to explore in parallel the scientific fields of vulnerability and ecosystem services, there are notably few cross-linkages. The human well-being components previously defined are described through a list of proxies collected from well-grounded assessments and are found to be highly relevant to sensitivity and copying capacity of the system underpinning its vulnerability level. Based on MEA framework, a wide range of "provisioning" and "regulating" ecosystem services were identified to be directly or indirectly influencing the proxies and thus the vulnerability components.

2.3. Designing a conceptual framework

Based on the provided theoretical concepts influencing the research on vulnerability, the presented conceptual framework considers SES as the subject of analysis. It aims to explore the role of SES in provisioning of ecosystem services with high importance for adapting to global changes. The presented conceptual framework in Figure 2-3 below attempts to combine principles from the vulnerability frameworks introduces by Turner (2003), Ostrom (2009) and Adger et al. (2005) linking selected elements with the ecosystem service's concept presented in MEA (2005). The proposed framework takes a system approach to describe place-based vulnerability of social-ecological system. It is composed of elements describing vulnerability while integrating the concept of ecosystem services and their role for enhancing coping and adaptive capacities.

Vulnerability of the system is composed of three main elements: susceptibility, coping and adaptive capacities of the social and ecological dimensions. Susceptibility of the socio-ecological systems describes the current state of the ecological components as specific sensitivity of the ecosystem (i.e. endangered species, endemic habitats) and livelihood components (i.e. per cent of income from agricultural activities). In this framework, capacities consist of coping and adaptive capacity of both social and ecological components to cope with stress and adapt to changing conditions (Smit and Wandel, 2006).

Fig. 2-3: Vulnerability framework for social-ecological system analysis. *Modified from Turner et al. (2003), MEA (2005) and Ostrom (2011).*



This conceptual framework represents the role of ecosystem services provision for strengthening the coping and adaptive capacities to address global changes. Ecosystem resilience is defined by the ability of the ecological system to absorb and resist disturbance. The ecosystem dimension of adaptive and coping capacities is defined by the ability of the ecological system to absorb and resist disturbance and refer to the concept of ecosystem robustness as defined by Gunderson and Holling (2002). The genetic and biological diversity in heterogenic landscapes are some of the major elements underpinning ecosystem resilience termed as "ecosystem robustness" by Carpenter and Gunderson (2001). There is an explicit feedback between ecosystem services and the capacities of the system in order to highlight the interdependence of both components. The framework incorporates the concept of ES as introduced by MA (2005) with the identified four categories. Yet, the application of the framework focuses only on regulating, provisioning and cultural services. The forth category which consists of supporting services is not included in the research analysis, however it is recognized that these services produce the conditions for generation of the rest of the categories.

Vulnerability of SES has a dynamic dimension responding to the changing character of internal perturbation in the systems itself as well as external ones which provoke disturbance. Such behaviour is illustrated by feedback loops and interlinkages among the component of the systems. The framework presents vulnerability in a causal structure, where on the right side are the drivers of change and the left side shows the consequences. The external driver in this research is considered as climate variability or natural hazard which poses stress on the system and interacts with its exposure. Exposure of people, livelihoods, environmental services and resources, economic and social assets to natural disaster is another element, which characterizes the social-ecological system. Combining the exposure and vulnerability determine the level of risk at which the system may experience adverse impacts due to slow or fast onset events.

The adjustment to actual or expected climate variability and associated impacts are explored through adaptation strategies. Ecosystem-based adaptation responses are integrated as focus for this conceptual framework. Through ecosystem restoration measures and conservation initiatives is perceived to result in enhanced ecosystem resilience thus supporting the flow of ecosystem services with high adaptation value.

The conceptual framework shows a simplified reflection of system dynamics in reality, yet it is complex in its operational structure to provide "a useful point of departure for examining vulnerability" (Turner et al. 2003).

2.4 Methodological framework

Although conceptually established, the integration of ecosystem services approach to socio-ecological problem analysis and decision-making faces certain methodological challenges. The integration process requires a comprehensive framework to complement the efforts in providing a suitable approach to accommodate ecosystem service variables in the context of dynamic socio-ecological systems.

Despite the extensive research on ecosystem services approach in recent years, many obstacles have been identified on how to apply the findings in decision-making for ecosystem management and even less for adaptation responses to global changes. One of the questions asked by de Groot et al. (2010) is: "How can analytical and participatory methods be combined to enable effective participatory policy and decision making dialogues?".

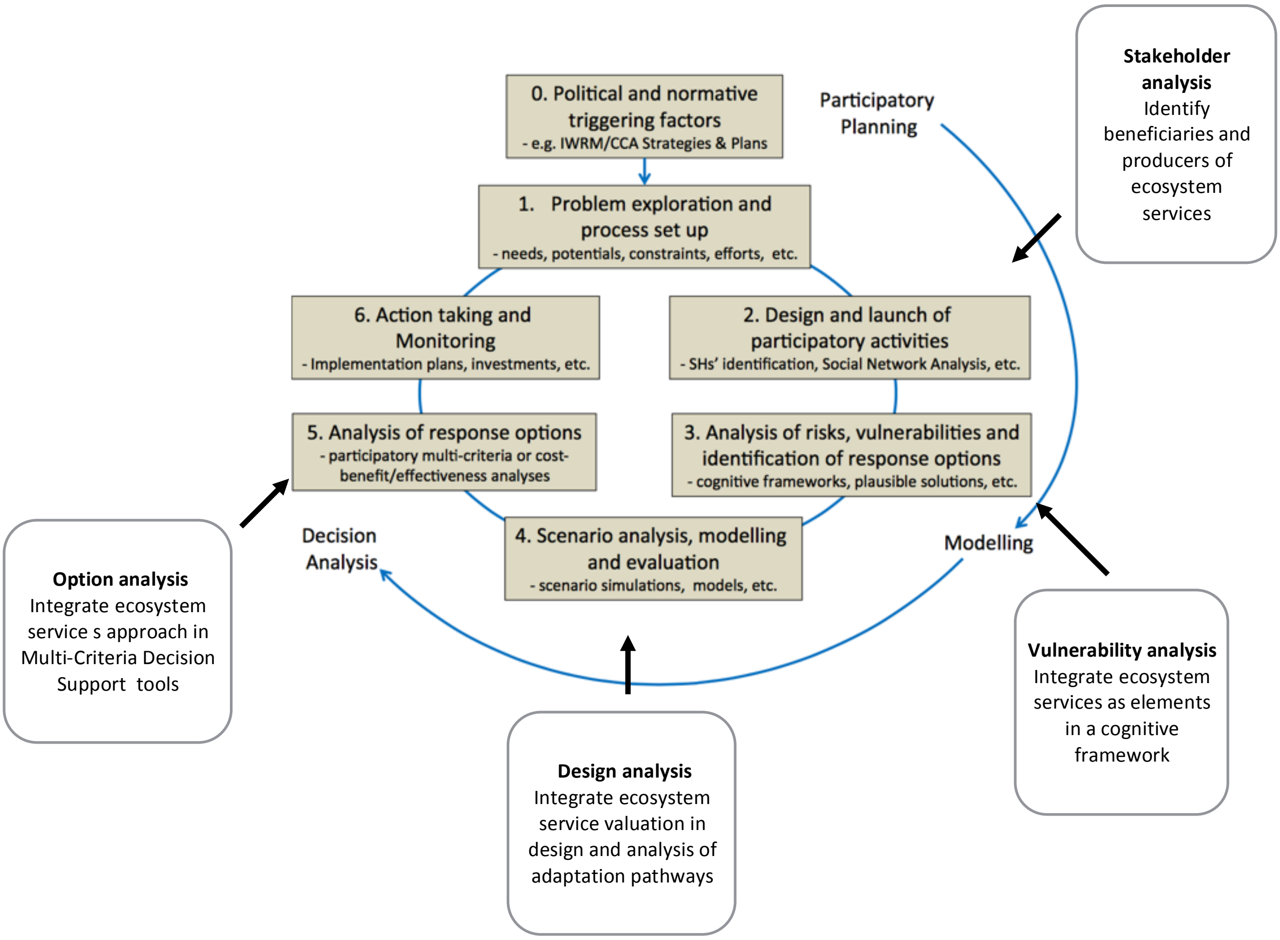
This research is found upon a scientifically established and tested methodological approach allowing for the incorporation of a range of components required for informed decision making within the context of climate change research. The methodology called NetSyMoD (Network Analysis – Creative System Modelling – Decision Support) provides a space for synergies between simulation modeling (SM), public participation (PP) and decision analysis (DA) in order to capture the essential elements allowing for a rigorous decision cycle (Giupponi 2014). NetSyMoD is designed as a generic structured approach, which uses a suite of methods and support tools to facilitate a participatory involvement of stakeholders or experts in decision-making processes.

The NeTSyMod methodology is flexible but comprehensive, which makes it possible to explore how to incorporate the concept of ecosystem services in the cycle of decision making for adaptation. The NetSyMoD approach has been adapted to different contexts with focus on climate change and specific application for integrated water resource management and coastal management. This experience demonstrates the suitability of the methodology approach to the presented case studies for this research. Figure 2-4 illustrates the sequence of methodological steps of NeTSyMoD approach and where the elements of ecosystem services can be incorporated to highlight their role in adaptation planning.

The NetSyMoD methodology is formalized as a sequence of six steps that describe the process of participatory decision-making. Each step implements a different method for data collection and analysis. This research proposes an informed integration of ecosystem services approach to decision-making for adaptation. For this purpose the presented NetSyMoD methodology is described in three main phases in which the analytical elements from the ecosystem services approach are being incorporated. The three main phases are:

(1) Exploring the problem and actors involved;
(2) Problem analysis;
(3) Analysis of alternative response options
(4) Analysis of response options

Fig. 2-4: Integrating ecosystem services concept in the methodological steps of NetSyMoD framework (Adapted from Giupponi, C., 2014).



1. Problem exploring and process set up - The initial step of the proposed approach defines the elements and steps to be taken in the problem exploration process. At this stage the case specific policy developments in the context of climate change adaptation are discussed and stakeholder involvement is defined.

2. Participatory activities - In order to take an ecosystem services approach to identify stakeholders, it should be taken into consideration the spatial and temporal scale. The scale may determine the interest of different stakeholders and reveal the value of ecosystem services for them. Scales for ecosystem services may vary from site-level (e.g. recreation) to global level (e.g. carbon sequestration) (Turner et al. 2000). The identified scales guide the research to identify the appropriate institutional scale for decision-making (Hein et al. 2006). Dependent on this scale of ecosystem services provision, it can be determined the stakeholder benefiting from it: individuals, households, municipal, state or provincial, national, and international level (Vermeulen and Koziell, 2002). While households and local stakeholders directly depend on ecosystem services, national stakeholders are involved in ecosystem management and access to ecosystem services. Therefore, stakeholder analysis is based on (i) scales of ecosystem services provision; (ii) scales of socio-economic systems and (iii) scales and stakeholders in relation to ecosystem services (Hein et al. 2006). Yet, it should be taken into consideration that ecological and institutional boundaries rarely coincide therefore ecosystem services and stakeholders cut across scales.

The combination of methodological steps aims at developing a good understanding of the system, the problem to be addressed and identifies the actors who are involved. Social Network Analysis (SNA) facilitates the representation of relationships between and roles of stakeholders in the analyzed SES.

3. Analysis of risks, vulnerabilities and identification of response options - This step of the methodological framework includes an in-depth analysis of problematic issues related to the social-ecological system complemented by participatory approach. Results are represented through mental models that provide qualitative descriptions of causal links between the components of the social-ecological system and defined variables. Such mental models may include cognitive maps following a DPSIR framework (driving forces, pressures, state, impacts, and responses) as a comprehensive framework to formalize complex human-environment relationships (EEA, 1999).

The concept of ecosystem services has a fundamental link to DPSIR framework, associated with the production and delivery of benefits for society and the ability of the DPSIR approach to represent it. Processes of generating such benefits are *Drivers,* which can create *State Changes* and *Impacts* and need *Response* to ensure the long-term delivery of the benefits*.* One important aspect in the development of the DPSIR framework as part of this research is the integration of principles of vulnerability analysis and the role of ecosystem services as described in the conceptual framework presented earlier in this chapter.

4. ***Scenario analysis and evaluation -*** The analysis of alternative response options consist of decision support system design and analysis of options that are developed upon the conceptual basis and indicators defined by the previous steps. The objective of these steps is to involve local actors and experts to design and evaluate a set of alternative responses to address previously analyzed problems. Through integrating scientific knowledge and preferences of local actors, the analysis of options is elaborated in the process of participatory activities supported by an ad-hoc decision-support-system tool (mDSS) (Giupponi, 2014).

To recognize the role and value of ecosystem services in alternative adaptation options, the Economics of Ecosystems and Biodiversity (TEEB) suggests analysing and valuing benefits dependent on ecological processes (Balmford et al. 2008). Different disciplines and cultural views assign a different "value" and understand differently the importance of ecosystems services, which turns decision-making into a challenging task (Goulder and Kennedy 1997). Valuation of ecosystem services may undertake two paths, either following a utilitarian approach to valuation or non-utilitarian approach. The utilitarian approach attaches use and non-use values to ecosystem services applying numerous methodologies to quantify the benefits provided. The non-utilitarian values reflect on the ethical, cultural, religious and philosophical importance of ecosystem services referred to as intrinsic values (TEEB, 2010). Choosing the valuation method is determined by the availability of data and specifications of the case study.

5. ***Analysis of response options -*** This methodological step comprises of the comparison of the alternative options as the final phase of the decision making process under NetSyMoD. At this phase the use of Multi-Criteria Analysis (MCA) evaluation techniques, all options are judged against a certain criteria to solve the identified problem, through the elaboration of the criterion values. The main aim of MCA is to reduce the "multidimensionality" of decision problems – and incorporate option performances - into a single measure thus facilitating an effective ranking of options defined by stakeholders. An enrichment element of this methodological step is the combined application of two decision-support tools - SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) and APH (Analytical Priority Hierarchy) to demonstrate the relevance of the proposed EbA measures.

3. Problem exploration and process set up: Description of social-ecological systems in study sites

This chapter aims to describe the socio-ecological systems at both study sites – West Demerara in Guyana and Dojran Lake in Macedonia. Understanding the core elements defining a specific context is a foundation to start a rigorous problem exploration process. Therefore, this first step of the NeTSyMoD approach has the prime objective to bring together the key context-specific factors on geographical characteristics, socio-ecological system specifics and legal context at the case studies, in order to grasp the needs, potentials and constraints for the developing an adaptation strategy.

3.1. West Demerara region, Guyana

The case study of Guyana was selected as a 9-month fellowship was awarded under the Conservation Leadership Program (CLP) and conducted at the country office of Conservation International in Guyana in collaboration with the National Office of Climate Change.

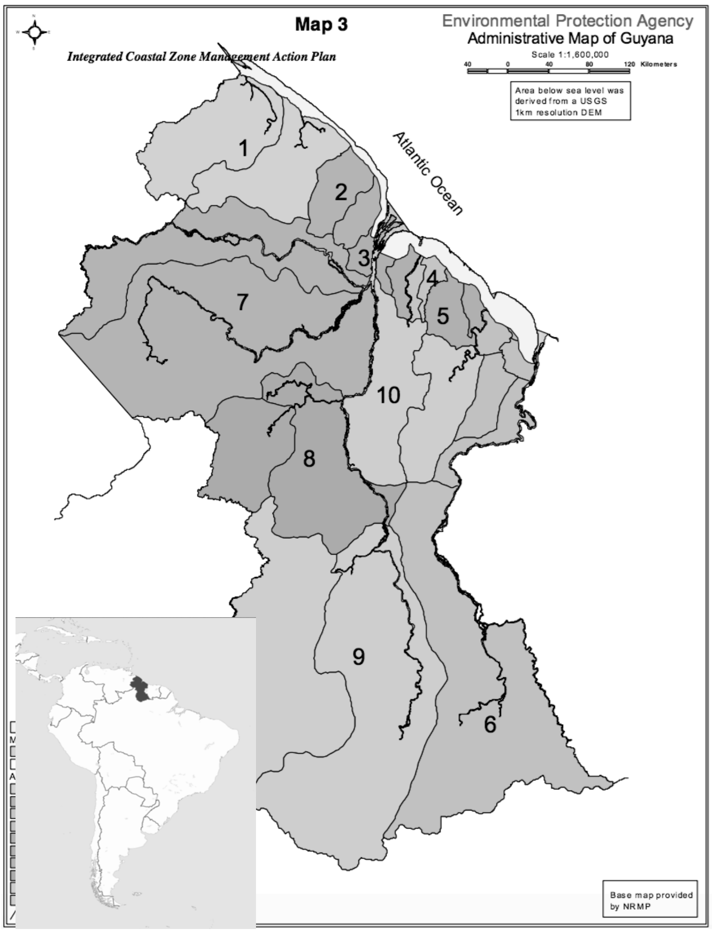
General information

Guyana is located in the North Eastern part of South America and has an area of 214,970 square kilometres. The coastline stretches for 430 kilometres and varies in width from 26 km to 77 km. It lies about 1.4 meters below the mean high-tide level of the Atlantic Ocean, making the area particularly vulnerable to flooding in heavy rainfalls and storm surges.

The coastal zone of Guyana consists of a low-lying system of marine and riverine deposits that formerly comprised an extensive network of tidal deltas. In many areas along the shore it is 0.5 – 1.0 m and more below sea level, making it prone to ever more severe flooding during the rainy seasons and extremely vulnerable to storm surges and sea level rise. The coastline constitutes only 5% of the country's total land, yet it is where human settlements are most concentrated. In addition to human settlements most of the country's economic assets as infrastructure and agriculture are located at the coastal plain as well.

The climate in the region is equatorial, characterized by seasonal rainfall, high humidity and small variations in temperature and is influenced by El Niño and La Niña Southern Oscillation (ENSO). As partially part of the coastal plain, the region experiences two "wet" seasons, the first with rainfall between 250 – 450 mm per month between May and July and the second "wet" season affects mainly the northern coastal regions with average monthly rainfall between 150 – 300mm in November through January (Hydromed, 2011). Changes in amount and shift in rainfall patterns are recently observed and characterised by shorter wet seasons but erratic rainfalls (Bureau of Statistics Guyana, 2011).

Fig. 3-1: Administrative map of Guyana.



Guyana's economy primarily depends on natural resources such as commodities from agriculture including fishery, livestock and forestry; and extractive industries as gold mining and bauxite. The agricultural sector including fishing and forestry contributed 22.8% of the GDP in 2011 as the second important sector for Guyana's economy after the services sector. Guyana's mining industry has over the years grown to be a key contributor to the country's overall economy with gold being the largest contributor within the sector with a 10.8 % contribution of the GDP in 2011 (Bank of Guyana 2011). The country experienced an economic growth of 2.8% in the first half of 2012 mainly driven by increased mining and quarrying services sector (Bank of Guyana 2012).

Agro-ecological systems in the region of West Demerara, Guyana

West Demerara region is located at the coastal estuarine of Essequibo River and expands approximately 6 195 km^2. Its location at a floodplain makes it particularly exposed to different natural hazards. The climate in the region is equatorial, characterized by seasonal rainfall, high humidity and small variations in temperature and is influenced by

El Niño and La Niña Southern Oscillation (ENSO). As partially part of the coastal plain, the region experiences two "wet" seasons, the first with rainfall between 250 – 450 mm per month between May and July and the second "wet" season affects mainly the northern coastal regions with average monthly rainfall between 150 – 300mm in November through January (Hydromed, 2011). Changes in amount and shift in rainfall patterns are recently observed and characterised by shorter wet seasons but erratic rainfalls (Bureau of Statistics Guyana, 2011).

Under IPCC greenhouse gas emission scenarios (A1B and B1), annual temperature is projected to increase between 1.7°C to 2.6 °C by 2060 and up to 4°C by the end of the century (IPCC, 2014; McSweeney *et al.* 2008). Scenarios indicate decrease in annual mean rainfall, yet variability in temporal and spatial terms, will considerably change, but intensify in fewer days thus likely to increase frequency of weather-related extreme events (SNC, 2012). In parallel projections of sea-level rise show an increase of 26cm by 2031 and up to 51cm by 2071, which poses major threat of inundation of the low-laying coastal areas.

Fig. 3-2: Map of West Demerara region indicating areas affected by 1m in sea level rise. (Environment Protection Agency, 2006)

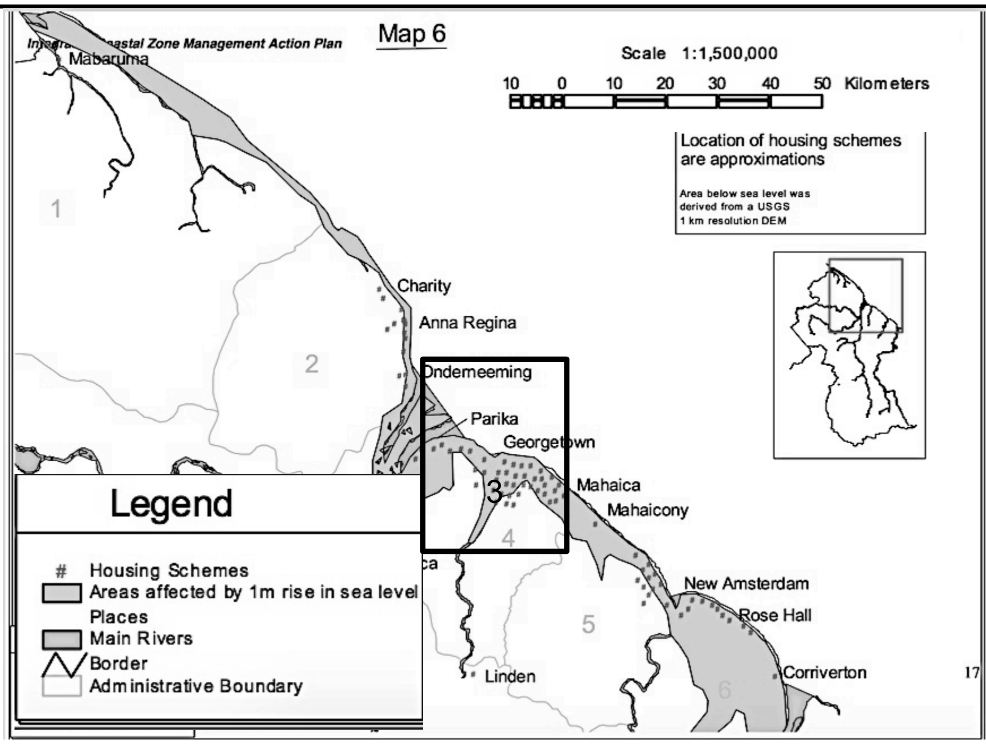
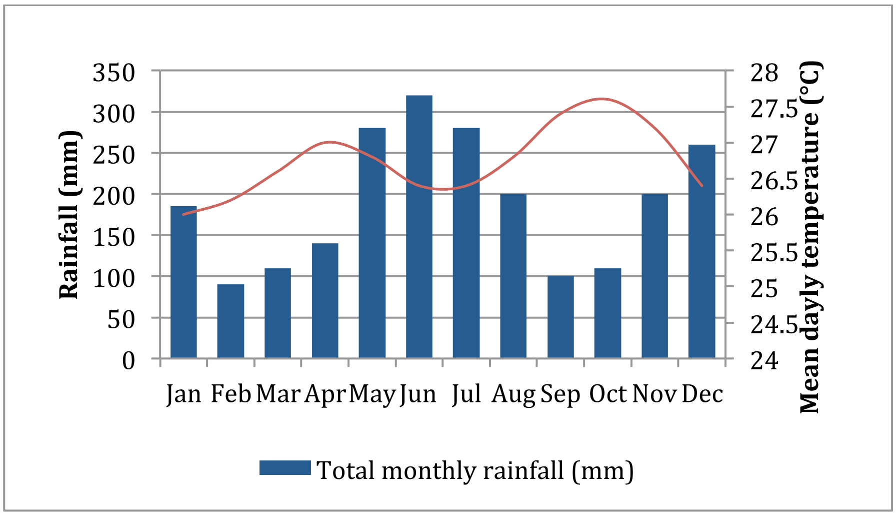


Fig. 3-3: Total monthly rainfall and mean daily temperature for the coastal region in Guyana (*Hydromed, 2011*)



West Demerara is known as administrative Region 3 in Guyana. In 2012 the population of West Demerara region was 107 416 people, which makes it the second most densely populated region (28 people per km^2) in Guyana. Seventy-five per cent of the population is total and migration to the capital of Georgetown or abroad is common. In 2006, about 40% of the population in the region live in poverty and 97.3% has access to water resources. The rural areas are predominantly home to Indo-Guyanese, who has designed their settlements as homesteads and farmsteads to have better access to their farms.

Tab.3-1: Ecological and socio-economic characteristics of smallholder farming systems in West Demerara regions in Guyana (FAO, 2013; WB, 2006)

Characteristics (unit)	
Socio-economic characteristics	
Area (km2)	3 755
Population	107 416
Rural population (%)	80
Small-scale farmers (%)	55
Smallholder farming area (ha)	480
Income source % (self-employed in agriculture)	34.8
Income source % (self-employed in non-agriculture)	23.4
Population in poverty %	40
Ecological characteristics	
Soils type	Clay (Fluvaquent, Hydraquent)
Agro-ecological production system	plantain, cassava, yam, sweet potato bora, cabbage, hot paper, pumpkin, aubergine citrus trees, avocado, mango, pineapple, coconut

The essential livelihood source for this coastal region is fishing and agriculture dominated by rice paddies, fruits and vegetables. Most researchers and stakeholders agree that impacts from climate variability are a major problem for the crop production in the region. Smallholder farming systems in West Demerara are usually between 0,2 ha and 7,6 ha and include some of the most fertile and productive areas in Guyana. Farmers mostly grow non-traditional crops as provisions (e.g. plantain, cassava, yam, sweet potato), vegetables (e.g. bora, cabbage, hot paper, pumpkin, aubergine), and a wide variety of fruits (e.g. citrus trees, avocado, mango, pineapple, coconut) among others. Coastal and estuarine areas, which are not converted in agricultural fields are covered by mangrove and swamp forests, which provide numerous provisioning (e.g. timber materials) and regulating (e.g. hazard mitigation) benefits to the farmlands. The farm systems are labour intensive and the need for constant draining due to their location at the low-laying coastal areas, puts more pressure on the system. Farmers perceive that the highest risk for their agricultural production is erratic rainfalls, as they often exceed the soil-water infiltration capacity and the capacity of the drainage system resulting in damage to agricultural fields.

Fig. 3-4: A smallholder farmer of citrus fruits and small-scale farming system implementing conservation practices in West Demerara region, Guyana (Author).

Guyana has a population of 778,100 as of mid-Year 2010 of which 28,2% is urban population, 60% coastal rural and 11,7% interior rural communities (Bureau of Statistics Guyana, 2011). The Coast takes about five per cent of total area of the country, but is where the vast majority of up to 90% of the population reside and major agriculture crops are grown for the fertile land. The capital of Georgetown is also located on the coast and has shown significant growth in population recent years with an estimated population density of between 360 persons to 700 persons per square kilometre (Bureau of Statistics Guyana, 2011).

In 2010 Guyana ranked 104 out of 167 countries on the Human Development Index covering health, education, housing and sanitation situation in country. According to the Guyana Millennium Development Goals Report for 2007, the proportion of households in extreme poverty comprised 19% of the population (UNDP, 2011).

Table 3-2: Guyana poverty profile by area 2006 (The World Bank and Guyana Bureau of Statistics, 2006).

	Percentage of Poor (%)	*Share of the group in the population (%)*
Urban	18.71	28.20
Rural Coastal	37.04	60.08
Rural Interior	7.47	11.72
Total		100.00

Risks and vulnerability to climate change

As Guyana is affected by Atlantic surges and high intensity seasonal rainfall, the most prevalent hazards in the country is flood. The populated coastal lowlands are protected from high tides and coastal flooding by a network of dikes, sea wall, conservancy dam and sluices. Much of the drainage infrastructure is more than 150 years old and partly deteriorated. As a result of the dynamic interaction between high tides, high rainfall levels, the coastal drainage system and poorly maintained irrigation system supporting the agricultural lands, the population at the coastal plain is exposed to high risk of flood impacts. Apart from floods, Guyana is exposed to drought spells caused by change in rainfall patterns and increase in temperature leading to impacts in the agricultural sector. Table 3-3 shows a list of major drought and flood events with associated economic impacts and affected people in the last 20 years. Data availability of natural disaster impacts is limited in the responsible institutions.

Over the last decade, natural disasters are observed to occur more often in Guyana. Devastating floods in 2005, 2006 and 2008 affected more than half of the population and resulted in thousands of million US dollars of damages to the economy. The flood in 2005 alone devastated the coastal area and affected 274 774 people or 37% of Guyana's population. The flood was caused by a combination of extended heavy rainfall, malfunctioning of drainage canals and high tides, which contributed to the accumulation of 3 to 5 feet of water in some areas. The damages from the flood resulted in total loss of 60% from GDP of the country (ECLAC 2011).

Tab.3-3: Socio-economic statistics of natural disasters in Guyana in the period 1995 – 2010

Disaster	***Year***	***Affected people (N)***	***Cost (thousand US$)***
Floods			
	2008	100 000	n/a
	2006	35 000	169 000
	2005	274 774	465 000
	1996	38 000	n/a
Droughts			
	2010	n/a	14 700
	1997	607 200	29 000

Source: University Catholique de Louvain, 2011

The agricultural sector in Guyana includes fisheries and forestry and is one of the most important sectors in the economy, contributing approximately 22.8 % to the GDP in 2011 (Bank of Guyana, 2011). Agriculture is the most practiced activity on the coastal zone because of its favourable soil and climate for lowland crops such as sugar cane, rice, and non-traditional crops. Apart from sugarcane and rice, which is a plantation activity, the other crops are mainly produced by small-scale farmers cultivating predominantly a wide variety of fruits and vegetable. The agricultural sector is not only an economic asset but also a subsistence activity supporting livelihoods in rural regions.

The agriculture sector is highly exposed to climate vulnerability and associated impacts and factors most likely to affect agriculture in Guyana are temperature changes, increased rainfall intensity, drought, increased sea level and salt water intrusion. Such a climate-induced event may cause severe damage to livelihoods of rural communities and the economy of the country. The flood from 2005 is an example of the damage caused on agricultural sector and its economic losses with rice crops experiencing the greatest damage and highest cost of US$ 8.8 million (ECLAC, 2011).

Analysis of adaptation policy framework

The first phase of the methodology consists of identification of key legislative documents and strategies at national and local level in the specific reference to land use planning and ecosystem management, agriculture, climate change and disaster risk reduction. The development policy framework of Guyana is formulated by the Low Carbon Development Strategy (LCDS)[1], which is a national level policy document that articulates the overarching vision for sustainable development of the country. The strategy is built around the maintenance of Guyana's ecosystems. This policy vision addresses climate change from a mitigation perspective, and is limited in its policy direction on climate adaptation though it makes provision for the preparation of a priority adaptation and resilience plan.

[1] Office of Climate Change. 2011. Low Carbon Development Strategy: http://www.lcds.gov.gy

Tab. 3-4: Adaptation objectives in short – medium-long-term (Adapted from Ministry of Environment, Guyana, 2012).

Second National Communication on Climate Change	*National Adaptation Strategy to Address Climate Change in Agricultural Sector*
Short-term measures	
• Mapping and assessing vulnerability of existing agricultural lands to impacts of climate change • Revisiting and where necessary updating the adaptation in agriculture study undertaken in 2007 on behalf of the Caribbean Community Climate Change Centre, in light of more recent climate change projections and vulnerability assessments	• Develop, where possible, environmental management systems for agriculture. • Provide economic incentives to reduce wasteful freshwater practices in the sector. • Conduct investigations on the impacts of climate change on the most notable and important pests and diseases affecting the sector. • Reconstruct and retrofit approximately forty (40) km of the most critical sea and river defenses in coastal regions. • Link the national Climate Change Policy with the national Water Policy
Medium-term measures	
• Undertaking research to identify climate-proof crop types (resilient to drought, high temperatures, saline soils, etc.), suitable for cultivation in Guyana • Assessing the feasibility of large-scale agriculture in inland areas (soil conditions, access, etc.) and identifying suitable crop types and investment needs in infrastructure, etc. • Creating awareness amongst farmers of the impacts of climate change on agricultural production	Showcase best management practices through the establishment of public funded demonstration farms to research and demonstrate cutting edge technologies, in areas such as plant breeding, agrochemicals and fertilizer application, plant husbandry, and water conservation and management.
Long-term measures	
• Promoting large- scale farming in inland areas • Crop substitution (hybrid or replacement varieties) that are tolerant to drought, salinity, and pests	Engage the main stakeholders on the implications of climate change, encouraging them to pursue best farm management practices, inclusive of water use efficiency, plant breeding, agrochemicals and fertilizer application, and integrated pest management (IPM).

The country has introduced sectoral initiatives and action plans such as the National Adaptation Strategy for the Agricultural Sector, which relate directly to climate adaptation measures in agriculture. Land-use planning in Guyana is a recent concept its contribution to the policy framework was manifested by the Land National Land Use Plan, which was published in 2013[2].

[2] Guyana Lands and Surveys Commission. 2013. Guyana Land Use Plan. URL: http://www.nre.gov.gy/Guyana%20National%20Land%20Use%20Plan.pdf

3.2 Dojran Lake, Macedonia

The case study for Macedonia explores the actual benefits of direct use of ecosystem services by humans. Such services describe the end products of certain ecological processes, which generate provisioning (e.g. crops, fish) and cultural services (e.g. recreation activities and tourism). In the attempt to better understand how did the ecological transformation at Dojran Lake affect ecosystem services and human wellbeing, the research conducted using a combination of literature review, semi-structured interviews and participatory workshop with local stakeholders.

This case study is part of the project "Integrated Water Resource Management at Dojran Lake" implemented by Euro-Mediterranean Centre for Climate Change (CMCC) and financed by the Critical Ecosystem Partnership Fund (CEPF).

Geography

Lake Dojran (41–12'N, 22–44'E, 144 m a.s.l.) is a transboundary lake between Macedonia and Greece and the smallest of the three lakes in Macedonia, Lake Ohrid and Lake Prespa. The total watershed area of the Lake is 271.8 km^2 out of which 32% belongs to Macedonia. The water surface area of the Lake at normal elevation is 42.2 km^2 out of which 63.6% belongs to Macedonia (Popovska et al. 2014). The lake is a remnant of the ancient Peonsko Lake and belongs to the Peon group of natural Balkan lakes. Small rivers, creeks and springs, originating from Belasica Mountain, are the major recharging sources for the lake and water loss occurs only through evaporation. Hot and dry summer (June - September) and mild and humid winter (November - February) characterizes the local climate regime and the estimated annual evaporation sum is almost twice of the annual precipitation sum (Sotiria and Petkovski, 2004).

Dojran basin is situated in an arid zone and the lake is a significant hydrological resource for the settlement and agricultural surrounding areas (Griffits et al. 2002).

The lake is characterized by flat-bottomed morphometry, which determines its annual water balance. Preliminary assessments show that the total water recharge by groundwater and surface inflows and net evaporation plus water use result in deficit in the mean annual water balance. This is an evidence of the high sensitiveness and linear response of the lake to climate and environmental change (Francke et al., 2013; Gasse et al., 1997; Fritz, 2008).

The South East region of Macedonia, where lake Dojran is situated is identified to be of highest vulnerability (3rd NCCC, 2014). According to climate projections this region is likely to experience significant increase on annual precipitation in the coming decade. Projected change in temperature is likely to affect biodiversity in the region, particularly common reeds (*Phragmites australis)* zones and other aquatic macrophytic vegetation, which is as well present in Dojran lake (NCCC, 2014).

Transboundary issues and historical perspective

The total watershed area of the lake is 271.8 km^2 out of which 32% belongs to Macedonia and the other 68% to Greece (Popovska et al. 2014). As a transboundary area, the management of Dojran Lake encounters several problems of cooperation relations. One of the major issues is lack of information exchange and monitoring, which are fundamental elements in developing the background conditions for designing an integrated water management plan at watershed scale. Despite the existence of many ministries and institutions involved to a certain extend in the water resource management in both countries, integrated approach to address current and future threats.

In the summer of 1988, there has been an agreement between Greece and Macedonia, granting access to Greece to use a certain amount of water from the lake for agricultural irrigation, which resulted in a sudden outflow of 20 million m^3 from the Djol-Ajak channel from the Greek side. This resulted in 60 cm drop in lake level (Stojanovski, 1991). The constant water extraction, resulted in the water level of the lake to reach 3.7m in 2002, a recession of lake's margins up to 100 m from the main settlement, the disappearance of much of the western littoral zone and significant biodiversity loss (Georgievska and Matevska, 1996; Griffiths et al., 2002) and eutrophication and algal blooms (Stojanovski et al., 2001). Overall water volume losses for this period were estimated to reach 118,000,000 m^3, i.e. ca. 45% of the lake's water (Andrejevic, 1991; Griffiths et al., 2002). The lake continued to shallow in the following years possibly due to continued water pumping for crop irrigation in combination with the unusual hot summers and dry winters in this period (Ristevski, 1991). The water level recovered to 6.7 m in 2010 due to decrease in water use and additional water transfer from nearby wells with 20 km long Gjavato – Dojran channel into the lake (Popovska and Bonacci, 2008; Stojov, 2012). Nevertheless research shows that there is clear evidence for a significant long-term change in lake properties as eutrophication.

A recent example of the transboundary Prespa Lake between Greece, Macedonia and Albania, demonstrates that it is not sufficient to only depend on existing regulations even if it is existent in all three countries, integrated water resource management requests additional collaborative efforts (Mylopoulos, Y.A. and Kolokytha, E.G. 2008). Greece is a member of the European Union (EU) and thus it complies with the obligations of the EU Water Framework Directive, while Macedonia as an EU candidate country considers adopting the main principles of the Directive. This is a good starting point to be explored for future steps towards cooperation.

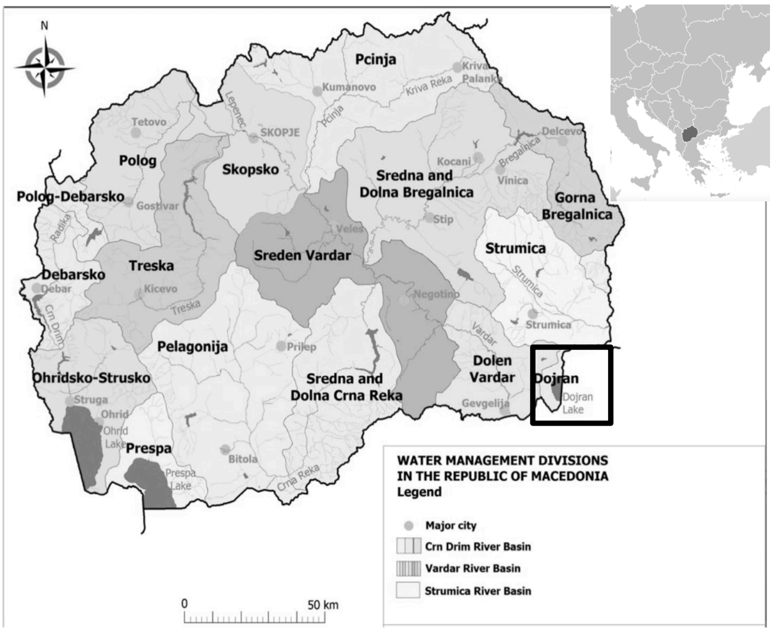
Livelihoods

Municipality of Dojran has a population of 3.426 inhabitants. Livelihoods in the region mostly dependent on provisioning ecosystem services (e.g. fishing and agriculture and cultural ecosystem services (e.g. tourism and recreational activities). Although there have been several studies on the lake's conditions, so far little has been done to understand how the ecological disturbance has affected local livelihoods. Doing so, will contribute to better link the interaction between the social and ecological elements of the system.

Lake Dojran is known for its unique fishing methods. Local population has used the reeds to prepare traditional fish traps, different in form, design and size (*mandra)*. The fishermen used the assistance of aquatic birds to bring the fish inside the traps. This traditional fishing technique has proven to be very efficient, as only a single *mandra* could catch from 20,000 to 30,000 kg of fish a year. The reduction of the water level and deterioration of its quality has exerted a negative impact on the traditional fishing method and the *mandras* are being deserted. An overall economic downturn for the local community is associated with collapse of the local fisheries industry and decreased tourism.

Fig. 3-5: Photograph of Dojran Lake, Macedonia (Author).

Fig. 3-6: Watershed map of Macedonia



Apart from its importance to the social-economic system, lake Dojran was an important site for biodiversity and habitat to a number of endemic taxa. In the waters of Lake Dojran live exclusive fauna that reside there permanently, or stop at the lake during migration periods - 36 species of birds. Pelecanus crispus (EU Bird Directive, Annex I); Phalacrocorax pygmeus (EU Bird Directive, Annex I) ; Oxyura leucocephala (EU Bird Directive, Annex I);; Recurvirostra avosetta (EU Bird Directive, Annex I); Circus aeruginosus (EU Bird Directive, Annex I); Pelecanus onocrotalus (EU Bird Directive, Annex I); Ardea purpurea (EU Bird Directive, Annex I); Lanius nubicus (EU Bird Directive, Annex I). The area is well known for its biodiversity of dragonfly species - Lindenia tetraphylla (EU Habitat Directive Annex IV);Coenagrion ornatum (EU Habitat Directive Annex II). In the waters of the lake live 18 species of fish, Cyprinus carpio (native populations); Rhodeus sericeus ammarus (EU Habitat Directive Annex II); Alburnoides bipunctatus(Bern Convention Annex III); Silurus glanis (Bern Convention Annex III).

Amongst the groups investigated, endemics have been reported amongst the diatoms (Stojanovski, 1991), sponges (Hadzisce, 1953), oligochaetes (Hrabe, 1958), cyclopoid copepods (Petkovski, 1954), gastropod Mollusca (Radoman and Stankovic , 1978), leeches (Georgevitch, 1955) and ostracods (Petkovski, 1958). While there are number of investigations on the current state of the endemic species after the major ecological change, there is high controversy and little evidence of the overall loss of habitat across the lake and the impact on endemic species diversity.

Impact and climate change vulnerability in the water resources sector

Estimation shows that temperature and precipitation will likely affect the water available on the territory of Macedonia. Projections suggest that by 2050 mountainous regions will experience 15% less rainfall, the southwest of the country 20-23% less and the rest of the country as much as 40% less rainfall than currently. Since the most water resources available are formed within Macedonian territory, the drop in precipitation is likely to result in severely limited water supplies in the future.[3]

On the other hand diminishing precipitation will lead to lower discharge rates in river basins across the countries. Already there has been a declining trend in the quantity of water, which flows out of Macedonia. This will be a result partially due to increased temperatures, and partially due to increased water withdrawals. Water levels in two major lakes (Dojran and Prespa) have already experience decline in water levels between 1986 and 2002, after which point levels have slowly risen again. Yet it is projected that the territory of both lakes is located on the most vulnerable territories with high risk of droughts.

Increased droughts and flash floods is projected to result in socioeconomic impacts, especially in ruralr areas where the main income is from farming. Major flooding in 2004 caused significant economic losses (91.3% of which were agricultural[4]), while a drought in 1993 resulted in damages to agricultural yields, which was equivalent to 7.6% of GDP. Generally poor financial, institutional, technical and legal capacities mean that Macedonia has significant problems dealing with severe droughts and floods. [5]

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[3] Ministry of Environment and Physical Planning, 2008

[4] Report of the State Commission, 2004

[5] Climate Vulnerability Assessment, Macedonia

Analysis of adaptation policy framework

Fig 3-7: A box showing details on the National Climate Change Adaptation Strategy and Action Plan (Ministry of Health Republic of Macedonia, 2011).

The National Climate Change Health Adaptation Strategy and Action Plan

The Ministry of health in cooperation with the World health Organization developed the National Climate Change health Adaptation Strategy and Action Plan of the Republic of Macedonia[1].

The Strategy aims to propose numerous measures and actions, y for adaptation and response of the public health to risks related to climate change, with emphasis on risk groups; y to provide guidelines for capacity building of the health system and health care providers; y exploring the need for multi-sectoral cooperation, through inclusion of the institutions and y monitoring and evaluation.

As part of the Plan, a web site has been created (www.toplotnibranovi.mk) to monitor heat-wave announcements in the Republic of Macedonia. This web site has a service for heat wave announcements, which can be automatically delivered via sms or e-mail to the people responsible for implementation of the plan. Each of the responsible persons or institutions, upon receipt of the announcement, undertakes the appropriate measures for each phase, according to the defined procedure.

In order for the heat-wave announcement system to function, the Hydrometeorological Institute has divided the territory of Macedonia into five zones and monthly threshold temperatures have been determined for each zone above which the heat-wave announcement alarm activates.

The hydro-meteorological Institute of the Republic of Macedonia uses the Gaius (normal) allocation for determining threshold air-temperature values. These values are reference values for announcing emergency, dangerous and catastrophic weather within the net of major meteorological stations.

NGOs play an important role in the system, particularly in the part of access to information of the population with social risk factors. The obtained database will provide extrapolation to the future expected climate change.

1 National Climate Change health Adaptation Strategy and Action Plan of the Republic of Macedonia

2 The early warning and the alert system for heat waves is a tool which is aimed for prevention and early warning on negative impact of the thermal environment on the health of the people during heat waves, Government of the Republic of Macedonia, Ministry of health of the Republic of Macedonia, 2011.

3.3 Rationale for sites selection

Rural development context: Both study sites represent a dynamic social-ecological system in rural development areas with similar needs for identification of adaptive management strategies at local scale to address global changes.

Highly vulnerable areas: West Demerara region in Guyana and Dojran region in Macedonia are both identified as vulnerable areas to climatic changes and natural hazards.

Social-ecological system disturbance: The SES in both case studies have experienced a certain kind of disturbance - weather-related natural disaster (in the case of Guyana) and ecological disaster (in the case of Macedonia), thus providing a foundation for the analysis of drivers, pressures and impacts.

Ecosystem services: The analysis incorporates different ecosystem services and gives the chance to understand the challenges for the different types of ecosystem services to be integrated in decision-making processes.

3.4 Methods and data collection

The collection of data was conducted using variety of methods such as unstructured and semi-structured interviews, analysis of documents and stakeholder engagement in order to draw a holistic picture of the challenges and opportunities to incorporate ecosystem services in decision-making. Following this holistic approach in data collection both from literature review across disciplines and field visits, I could identify the major issues for the current ecological status, the social-economic conditions and the legislation framework for both study sites. A stakeholder analysis helped to identify the main interest groups, such as community members, local and national government, agriculture sector, NGOs, fisheries and tourism.

Stakeholder engagement

Data for this research were collected applying a range of participatory methods selected based on their relevance to context of the study sites and their suitability to address the research questions. The research engages stakeholders from local and national scale for both study sites using a snowball technique (Creswell 2014). Both in Guyana as well as in Macedonia, the stakeholder engagement undertook two stages – community stakeholders and national stakeholders. Moreover in the case of Dojran Lake, a one-day workshop was organised. The purpose of the workshop was to encourage a collective action in the community of Dojran, to contribute to the improvement of water management and governance of the area and to raise awareness about water resources issues, facing climate change adaptation needs. The workshop consisted of capacity building session focused on water management planning and the role of ecosystem services to strengthen present knowledge and provide a basis for following discussions and participatory activities. Three sets of participatory activities included participatory mapping, elicitation of important elements for the natural resource management in Dojran and elicitation of most important ecosystem services.

Analysis of data

A combination of qualitative data methods was used to analyze the data in Chapter 4. For the development of mental models both Cmap and Vensim were used to demonstrate the complex relationship and interactions between the elements of the social-ecological system under exogenous and endogenous drives in a context of a global change scenario.

4. Analysis of risks and vulnerabilities: Incorporating ecosystem services approach

The objective of this chapter is to illustrate the process of integrating a participatory approach in the presented vulnerability conceptual framework. Through the methodological steps, it aims to translate the relationships between ecosystem services and vulnerability and perform preliminary qualitative assessment of the vulnerability of the defined social-ecological system. Framing and analysing the problem incorporates a good understanding of this aspect and is a vital step to identify the drivers of change of the system. As an initial step in the NetSyMoD approach this marks the beginning of the decision-making process.

The analysis in this chapter is based on findings from robust literature review, collected field data, semi-structured interviews and participatory workshop with local stakeholders in the case study of Dojran lake. The assessment methodology corresponds to Step 2 and 3 as presented by the methodological framework in Chapter 2. The problem framing and analysis is performed using cognitive mapping and stakeholder analysis, which are tested on both case studies – Dojran lake and West Demerara. While the case study on West Demerara in Guyana focuses on agro-ecological services as system's components to reduce vulnerability to floods, the case study of Dojran lake in Macedonia explores ecosystem services from wetland to cope with drought.

Chapter 4 seeks to answer research question 2: How undertaking ecosystem approach contributes to better understand vulnerability of social-ecological systems? To respond to the question this chapter follows three steps: (1) define the social-ecological system: boundaries, ecosystem characteristics, stakeholders and disturbances, (2) describe the components of system's vulnerability and their current state and (3) understand the causal relationships.

4.1. Role of ecosystem services in identifying key vulnerabilities of agro-ecological farming systems: The case of West Demerara, Guyana

4.1.1 Drivers of vulnerability

Situated at the estuarine of Essequibo River, smallholder farmers in West Demerara live at high risk of flooding. Heavy rainfall often results in floods, which local farmers perceive to be the major risk for their agricultural production and livelihoods. As farmers in this area cultivate on less than 4 ha for subsistence, they are particularly vulnerable to stress caused by extreme weather events. An example of such an event is the flood in 2005, which is an evidence of the scale of impacts affecting the farmers. In January 2005, the intensity of rainfall in the coastal region reached unprecedented levels and let to one of the most severe flooding in the century, which affected 2 000ha of agriculture in West Demerara region of which 481ha belonged to smallholder subsistence farmers cultivating non-traditional crops (ECLAC, 2005). Total losses for these farmers were estimated to reach 1.3 % of GDP and for West Demerara region in particular were valued at EUR 7 million (ECLAC, 2005).

To assess vulnerability of smallholder agricultural systems in West Demerara region to current and future disturbances, the study follows the vulnerability conceptual framework presented in Chapter 2. Therefore the vulnerability of agro-ecological systems is presented as a function of three components: (1) the current state of the social and ecological components of the agro-ecological system, which determine its susceptibility; (2) the capacities of the agro-ecological system, referring to coping and adaptive capacities and the extend to which they can strengthen the ability of the system to sustain livelihoods and adapt to stress, and (3) ecosystem resilience of agro-ecological systems, referring to the ability of the agro-ecosystem to recover key functions to support productivity (Holling *et al.* 2001).

To better understand the constituents unfolding the vulnerability of the smallholder farming systems, the study presents a set of components described by indicators relevant to coping and adaptive capacity of the socio-ecological system. Table 4-1 shows the list of proposed indicators. The indicators are selected on the basis of thorough literature review and consultation with community members. Due to the high complexity of defining adaptive and coping capacities, the selected indicators demonstrate more qualitative than quantitative characteristics.

Tab. 4-1: Proposed indicators for vulnerability of smallholder agricultural system in the coastal region of West Demerara, Guyana (*Source: Author*).

Vulnerability component	Indicator	Unit
Susceptibility		
Social conditions		
Intensity of Human – Agriculture relationship	Dependence on on-farm income	[%]
Ecological conditions		
	Agricultural production	[kg ha^{-1} y^{-1}]
	Soil quality	
Coping capacity		
Social coping capacity		
Flood risk management	Inefficiency of D&R system	Average score on ordinal scale
	Risk awareness	Average score on ordinal scale
Social bonds and networks	Farmer membership of farmer association	%
	Farmer's sense of attachment to land	Average score on ordinal scale
Self-sufficiency	Food security	Months with food shortage, absent = 0; frequent = 1–3 months, severe > 3 months High
	Poverty	Poverty index
	Dependency on market	%Farm products sold in markets, high > 75%, medium = 25–75%, low < 25% Harvested
Social adaptive capacity		
Local and traditional knowledge	Soil-water management practices	Average score on ordinal scale for implemented practices
	Source of crop variety	Mainly traditional varieties, both, improved varieties
	Cultural heritage	-
Sense of ownership	Land tenure	High = most farmers 'own' land (>80%), medium = 20–80% own land, low < 20% own land High
Ecosystem resilience		
Land	Diversification of farm land use	No. land use categories, low < 5, medium = 5–8, high > 8
	Crop variety	Mean number of crops per farm/household
	Buffer zones of critical ecosystem conservation	%
Soil properties	Soil water holding capacity	
	Soil fertility	High, medium, low

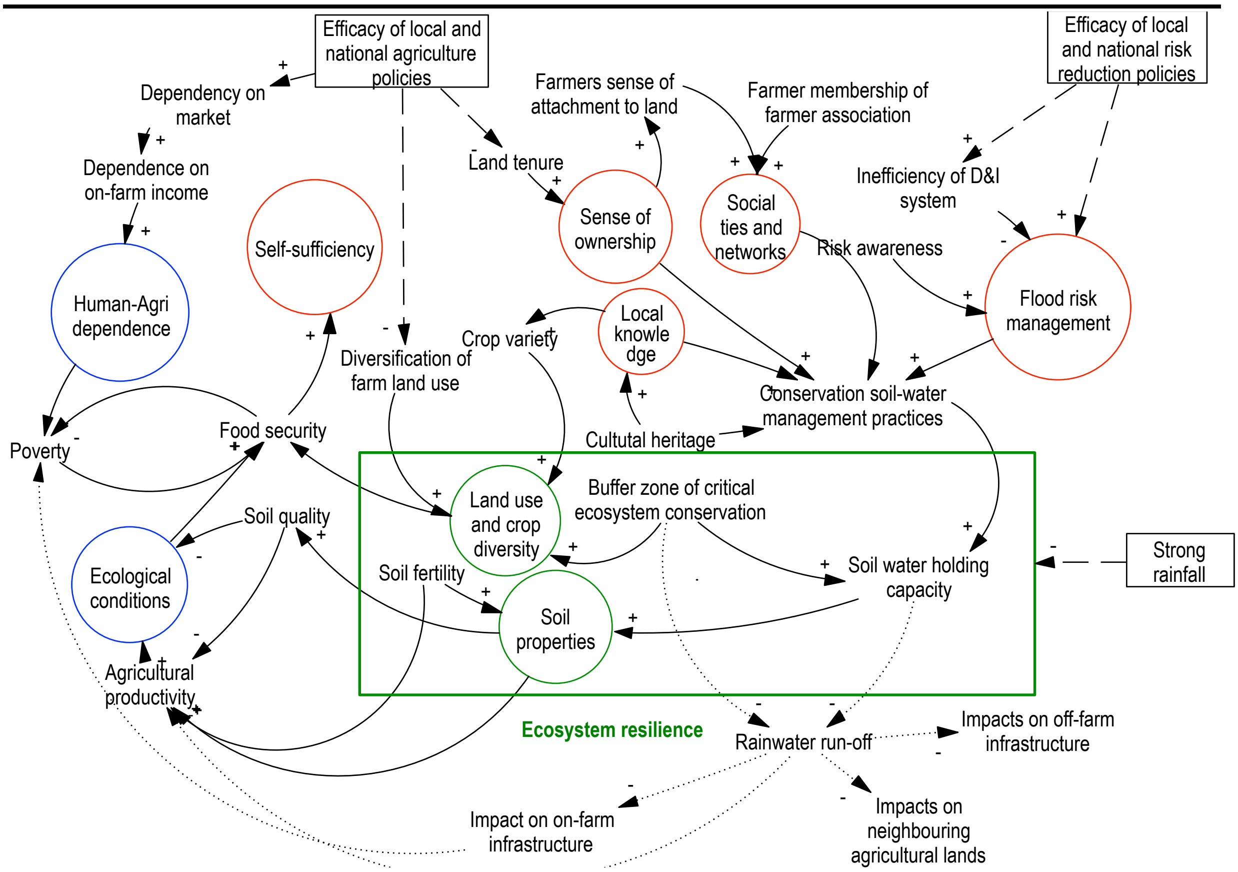
In order to explicitly demonstrate how ecosystem services contribute to vulnerability analysis, applying conventional indicators would present only the limited dimension of ecosystem state and will not embrace the human dimension. Therefore, the selected indicators aim to represent the multi-dimensionality of the agro-ecological system and the determinants for its risk and vulnerability, accounting for the spatial and temporal scales (Turner and Daily, 2007; De Groot *et al.,* 2010; Bockstaller *et al.* 2003).

4.1.2 Integrated problem analysis

To grasp the dynamics of an agro-ecosystem and the key drivers leading to its vulnerability, it is essential to define all variables and achieve a comprehensive understanding of which variables are endogenous and exogenous (Walker et al. 2002). The study focuses on the system behaviour under a risk of flood and three major factors are identified in the context of this system to induce the risk: a) *increased frequency and severity of rainfall events*; b) *governance system of risk management and agricultural policies* and c) *efficacy of local and national agricultural policies*. These external drivers are defined as variables that act at different scale and may directly or indirectly influence flood impacts at farm level.

This section demonstrates the application of the vulnerability conceptual framework, presented earlier in this research, in the context of agro-ecosystems, with emphasis on determinants of system's vulnerability incorporating the role of ecosystem services. The system analysis is represented in a form of a causal loop build upon the theoretical foundation of system dynamic modelling (Forrester, 1995). The formalization of the conceptual model will provide a better understanding of interactions and functional dependencies of the key system variables. Figure 4-1 represents the defined agro-ecological system using the defined indicators and depicts some direct and indirect causal relationships among them.

Fig. 4-1: The figure illustrates the key variables and casual loop that determines vulnerability of agro-ecological systems in West Demerara region. Circles refer to the identified indicators and describe the key vulnerability components: (a) susceptibility, referring to variables in blue circles; (b) social coping and adaptive capacities, referring to variables in red circles and (c) ecosystem resilience referring to green circles. The arrows are defined by polarity (+/-), which indicates the change of the variable due to a cause (Author)



The problem analysis integrates the vulnerability components with their indicators (Tab.4-1): 1) *susceptibility*, 2) *social coping and adaptive capacities* and 3) *ecosystem resilience.* These vulnerability components are tangled into complex system interactions and represented applying the causal loop analysis.

Although the representation of the social-ecological system is based on a number of hypotheses about the functional structure of an agro-ecosystem, the diagram is not exhaustive and some dimensions are not being captured. The objective is however to develop a conceptual model, which reflects the behavior and state of the system and emphasizes the role of ecosystem services in an agro-ecosystem. For the purpose of this exercise the choice of processes, which are incorporated in the model, were decided to be complex enough to distinguish the effects of the drivers on the system and the different factors affecting the system.

Observing the role of each component and its influence in the system dynamics contributes to determining the state of vulnerability and provides good understanding of the relationships between the human dimension (e.g. institutional and organizational processes, knowledge networks, land-use practices) and the ecological dimension (e.g. ecosystem capacity, functions and flow of services). The following analysis of a) susceptibility; b) coping and adaptive capacities and c) ecosystem resilience, aims to provide a holistic picture of the state of the agro-ecological system and its vulnerability to natural hazards and climate variability described by the set of agreed indicators in Tab 4-1.

a. Analysis of susceptibility

"Intensity of human-agricultural dependence" describes the nature and dynamics of human-environment relationship. With this regard, small-scale farmers in West Demerara regions show that their income is diversified and more than 60% of their income comes from sources other than their farms. Therefore, in the case of crop yield loss due to flooding event, farmers are to an extend able to substitute income loss with other non-agricultural related income. "Agricultural production" and "soil quality" are components describing the ecological condition, as factor defining susceptibility of the ecological system. "Soil quality" at smallholder farms at coastal zones in West Demerara is characterised as highly fertile, thus contributing to stable "agricultural production", yet highly susceptible to salinization due to sea water soil penetration.

b. Analysis of coping and adaptive capacities

"*Self- sufficiency"* in this analysis is referred to food security and poverty, which are considered in defining the system's coping capacity. Poor communities such as most of the smallholder farmers in West Demerara, where more than 50% of the population lives below absolute poverty line are more likely to demonstrate low coping capacity. Farmers in the region are predominantly subsistence producers and ensuring food security is essential for their livelihoods, in this respect the farmers demonstrated to support diversified agricultural production, which contributes to strengthening food security in moments of crisis.

Farmers in West Demerara region cultivate less than 4 ha of land but only half of the farmers own these lands, while the rest of them leases or rents them. Tenure rights for agricultural land define the *"sense of ownership"* of farmers. The lack of land ownership for some farmers makes it difficult to adequately undertake improvements in soil and water management practices such as raising the levels of planting beds in order to reduce impacts of flooding events. Tenure rights as well provide available options to farmers to access loans, purchase equipment and encourages them to implement changes to the land. It is therefore considered that tenure rights contributing to strengthen coping capacity and thus decrease the level of vulnerability of the system.

Guyana has gone through a history where risk has been accepted as reactive strategy in flood control management. Although a seawall is following the coastal edge of the country to protect what is beyond it, rural communities were overlooked in any additional measures to address flood risk (Pelling, M., 1999). At present however *"flood risk management"* at a national level is particularly well developed through national and sectorial strategies and plans, yet there is no existing legislative framework for DRM at the national level. National Multi Hazard Preparedness and Response Plan, National Early Warning Systems, Flood Response and Preparedness Plan demonstrate the country's responsiveness to a long history of flood events, yet the appropriate implementation and effective functioning of these plan on the ground needs to be assessed. In 2015 an Agricultural Disaster Risk Management Plan (ADRM) was developed to highlight the major risks to agriculture and in combination with the National Agriculture Adaptation Plan, the agricultural sector has an established pathway in the efforts to address projected climate impacts. However at a regional level, West Demerara region does not have a thorough analysis of the coastal flood management system and flood control is managed on an emergency basis, overlooking the need for risk reduction and preparedness. This contributes to consistent inefficiency in the functioning of the D&I system, which often is blocked provoking overflowing and thus contributing to the formation of floods. Efforts are focused on responding to immediate needs rather than taking precaution strategies, which negatively affects the coping capacity of the communities in the region (World Bank, 2006). The strengthening of this element may contribute to promotion of conservation management practices as a response to mitigate flood risk.

Small-scale farmers have been living in unpredictable environments in the coastal region of West Demerara, for several centuries. This experience resulted in the development of coupled social-ecological systems such as small-scale agricultural systems, defined by strong cultural identity and "*social ties and networks". *Generating a variety of *"local and traditional knowledge*" and technologies plays an essential role in strengthening adaptive capacity in the face of increasing uncertainty and risk. Risk management and adaptive solutions for agricultural communities are often found upon traditional knowledge on soil and water management.

c. Analysis of ecosystems resilience

Ecosystem resilience is analysed through the lenses of adaptive capacity of the ecosystems to retain key functions in a period of disaster crises. In the specific case of cultivated lands in flood-prone area, the type and variety of vegetation and soil properties are key defining characteristics to determine the adaptive capacity of the ecosystem (Pivot et al. 2002). Flooding often leads to waterlogging in the soil for longer periods and therefore causing anoxia for the crops. Depending on the crops characteristics to survive under such conditions and the "soil properties" and capacity to water water would demonstrate the capacities of the ecosystem to mitigate flood impacts. West Demerara is characterised by clay soils, which have the characteristic to be difficult to manage especially under extreme wet and dry seasons. However, appropriate conservation soil-water management practices, which are implemented by smallholder farmers, have proven to enhance the soil-water holding capacity of the system.

The natural coastal environment in Guyana has been transformed during the post-colonial development strategies. During this period, substantial part of coastal wetlands has been drained and seawalls, drainage and irrigation canals in line with human settlements have replaced the rich mangrove forests characteristic for this area (Bynoe, 2011). Therefore the natural coastal "buffer zone", which mitigates flood impacts has been drastically degraded, thus decreasing the ability of the ecosystem to deliver hydrological regulating services. At present coastal mangrove forests in Demerara region account for 5,240 ha and are under conservation status (NMMAP, 2010).

Figure 4-1 illustrates agro-ecological systems as benefiting as wella s generating ecosystem services. Besides provisioning and cultural services, agro-ecosystems are acknowledged to generate important regulating services for instance hydrologic services, flood regulation and erosion protection (Swinton *et al.,* 2007; Zhang *et al.,* 2007). Flood regulation services can be defined by the capacity of an ecosystem to decrease flood hazard through reducing the surface runoff (Fohrer et al., 2001). The capacity of the ecosystem to influence the frequency and magnitude of a flood event depends on the composition of vegetation and land use patterns, which define the landscape. Intensive land use and absence of forest negatively affect the flood regulation capacity. Ecosystem services do not generate benefits only on-farm, but as well to off-farm settlements and neighboring farms. High soil-water retention capacity in combination with natural buffers reduces rainfall runoff thus contributing to mitigation of flood impacts at different scales.

4.1.3 Exploring of existing and proposed local adaptation responses in West Demerara, Guyana

Farmers in Guyana have long been exposed to climate variability and have long been implementing adjustments in farm management practices in response to climate stimuli. Yet, smallholder-farming systems use low level of technology and are labour intensive, they often follow traditional practices. Changes in agricultural practices take time and are at slow pace thus often stay unnoticeable and unrecognised by farmers as an autonomous adaptation response to environmental variations. Some of the most commonly used adaptation techniques involve changes in cropping patterns and improved farm and water management. Interviews with farmers from West Demerara region in Guyana provide the evidence for adaptation practices used by farmers, which could be grouped in three major categories. The responses of small-scale farmers in West Demerara region identified the adaptation practice undertaken in their farm. While some farmers rely on a single adaptive agricultural practice, majority implement a combination of the listed practices.

a. Improved farm management

This is a common practice to plant on raised beds, in order to protect plants from floods. The soil is cultivated to depth of up to 30 cm and then formed like narrow beds. Soil from the furrows positioned down each side of the beds is thrown onto the tops of the beds, resulting in an increase in the height reaching between 15 – 30cm (Beecher, G. et al. 2005). Raised beds function as drainage tool aimed at decreasing waterlogging and increasing crop yields. Agriculture systems in the low-lying areas of the region have complex drainage systems, which makes them particularly prone to flash floods and water stagnation. The long rainy season, between May and July, and the shorter one between November to January, brings erratic rains in the region and farmers would leave their land fallow. This measure contributes to avoiding the excessive water stagnation, which otherwise would cover the crops with water for up to 4-5 days and damage them. It is practiced mainly for planting vegetables such as bora and kalalu

b. Diversification of crops

Diversifying crops is the other major practice among farmers. It is quite common to find vegetables being cultivated along the embankment of small-scale rice fields, as rural families seek to bolster their incomes and diversify their production base, thus spreading their risks. Commonly used crops at the banks of rice fields are bora, kalalu, okra and small trees as plantains and papaya to erosion.

c. Improved water management

Farmers often experience floods and need to drainage the fields to control the excess of water as it impacts the root zone of a growing crop and also decreases the salt intrusion in the soil. As subject of such climatic variability, it is crucial for farmers to adopt sustainable water management systems to answer their need and help them cope with such risks. Farmers would use various methods to pump out the water from the field in order to preserve the crops. One such measure is when the water in the canals is blocked and kept in trenches running parallel at both sides of the field. In long drought periods a kind of furrow irrigation method is used which derives water from the canals and let it seep under the ground. This practice is possible because of the topographic characteristic of the areas providing a slight gradient, which facilitates the irrigation systems (Personal communication, 2012).

4.2 Ecosystem services and social-ecological system vulnerability: The case of Dojran Lake, Macedonia

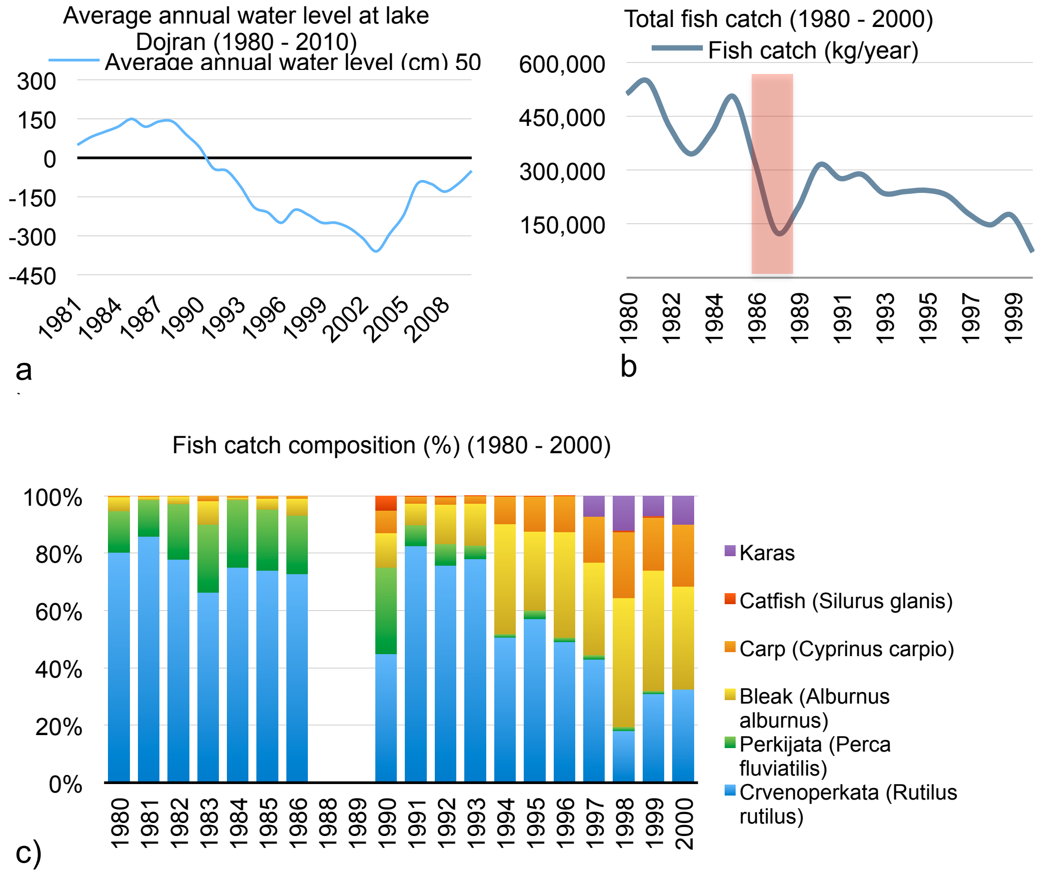
4.2.1 Understanding the drivers, pressures and impacts on the ecosystem services in Dojran: a hystorical perspective

To better understand and analyse the drivers and pressures on the ecosystem services in the region of Dojran municipality, it is important to identify the problems. For this purpose, stakeholders were approached with open-ended questions to collect their views of past and current problematic issues in the region. The study attempts to explore the impact that an ecological disturbance has on the social-ecological system through the lenses of ecosystem services. The "ecological disaster" described above resulted in disturbance of ecological processes and aquatic habitat at lake Dojran, which directly affected the generation of ecosystem services.

Available historical data indicates changes after the "ecological disturbance" in provisioning services (e.g. fish catch and diversity, freshwater), cultural services (e.g. tourism and recreation activities) and regulating services (e.g. water quantity and quality). Figure 4-5 illustrates the state of a) water level at Dojran lake, b) total fish catch and c) fish catch composition. A major consequence of the "ecological disaster" is the sudden drop in mean annual water level with almost 6.5 m, with the lowest water level in 2002 reaching only 3.7m depth. At present the water level of lake Dojran has stabilized and even recent events of overflowing due to heavy rains has been observed.

However, such a drastic drop in water level resulted in some long-lasting and even irreversible changes in the ecosystem. The fish stock was highly affected and total fish catch experienced a three-fold decrease in 1989, followed by an increase due to the introduction of new fish species. Although linking biodiversity and ecosystem services is complex, it has, likewise, been acknowledged in literature that biodiversity has a key role in ecosystem services generation (Balvanera et al., 2006; Costanza et al., 2007). Therefore species loss could disturb ecological processes and lead to decrease in ecosystem services supply and thus threaten human well-being (Díaz et al., 2006, 2005).

Fig. 4-2 : Representation of historical and current for Dojran lake: a) Time data series of average annual water levels for Dojran Lake at the Nov Dojran hydrological station for the period 1980–2010, b) Total fish catch from Lake Dojran for the period 1980 – 2000 and c) Composition of annual fish catch at Dojran (Adapted from Bonacci et al. 2013; Ministry of Agriculture, Forestry and Water, Macedonia, 2011).



Certainly the loss of large numbers of aquatic invertebrates had an impact on fisheries. Fish catch at Lake Dojran decreased substantially since 1980s and from approximately 500 tones annual fish catch, it decreased to 70 000 kg in year 2000 (Naumovski, 1991). Figure X shows the total fish catch for the period 1980 – 2000. The important commercial fish species include *Rutilus* spp., *Perca fluviatilis*, *Carassius auratus*, *Cyprinus carpio* and *Alburnus alburnus*. After the ecological shift, not only the amounts of fish catch substantially decreased but as well its composition changed (Fig. 4-2): *Rutilus* decreased from 74.2 % to 33.5% and *Perca fluviatilis* from 15% to less than 1%, while Cyprinus increased from less than 1% to 21.6%. Since late 90s, *Carassius auratus* is added to the composition of fish catch and makes up to 10% of the annual catch (Griffits et al. 2002). Data for both fish catch and composition for the year 1987/1988 is not available and was extrapolated for total annual fish catch. Such increase in zoo-benthos and zoo-plankton feeding fish is explained to be common in eutrophic waters, and on its turn contributes to a enhancing of the trophic cascade and consequently results in further deterioration of water quality (Griffits et al. 2002).

The lake's endemic life is suggested to be irreversibly impacted, yet little is known on the present status of its ecology. Although the two endemic ostracod taxa were listed in a survey in 1989, more recent studies did not find specimens of either Candona paionica or Graecoanatolica macedonia which leads to the conclusion that both taxa are extinct (Saprakev et al. 1991; Ryan and Griffiths, 2001). There was slight evidence of eutrophication based mainly on relative increase in Aulacoseira granulate, but no evidence of a major change in diatom species assemblage composition over time (Griffiths et al., 2002). Stojanovic and Krsitc (1995) reported major habitat loss, with the development of black sapropel and a shift towards dominance by pollution-tolerant diatoms such as Hantzschia amphioxis and Navicula pygmaea. These latter taxa are rare in the sediment core. It may be summarised that while major ecological change was clear at the sampling sites used for monitoring, the overall loss of habitat across the lake as a whole was less extensive than it appeared in these studies.

In parallel are cultural services referred to in the MAE (2005) as "the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences". In particular tourism and recreational activities are another major source of income for the local population at lake Dojran. In practice however they are difficult to address and rarely assessed in empirical research. The ecological disturbance resulted to shift in tourist visits to the lake after the year of 1989, when they drastically decreased from 300 000 tourist nights to 100 000 in 1990 and only 8 000 in 1998. Most recent data sets for the last 10 years shows an increase in tourist visits reaching 87 000 in 2005 (Ministry of Agriculture, Forestry and Water, Macedonia, 2011). Data on tourism is collected only from registered tourists in the area, however many tourists use private accommodation and are not registered.

4.2.2 Stakeholders and their perception of ecosystem services at Dojran Lake

Stakeholder analysis

Stakeholder analysis is used for framing and analysing complex situations in natural resource management, and other initiatives that influence variety of actors, hence, demand their participation (Grimble and Wellard, 1997). Stakeholder analysis is used in this research applying ecosystem services approach to identify the direct and indirect beneficiaries and producers of ecosystem services. The list of key stakeholders, including both organizations and individuals from a variety of sectors, who affect and/or are affected by the design of natural resources management, is determined through documents review and interviews, using snowball technique (Bryman, 2001). The process undertakes as a foundation the methodological approach outlined in Chapter 2 for the identification of the stakeholders based on their relationship to the identified ecosystem services in the region.

The role and interests of stakeholders in the use and management of wetland resources are diverse and defined by the spatial distribution of the ecosystem service (Kramer et al. (1995). Ecosystem services in particular are relevant for all stakeholders and at different levels (Berkes and Folke, 1998). The key identified ecosystem services providing benefits to the stakeholders in Dojran are: i) provision of fish and agricultural products, ii) nursery service for fish species, and iii) recreation activities.

The benefits of the provisioning services may favor stakeholders at different institutional levels, yet community level stakeholders are often the most important beneficiaries as they are involved in fishing and the harvest of the products. When provisioning goods are produced or consumed at a larger scale, then as well the interest of the stakeholders shift as in the case of selected fish species, wild mushrooms and olive oil produced in the area.

The regulating service of nursery for fish species is provided at an ecosystem scale and generates relevant benefits to stakeholders at various institutional scale – from community level to national level. The fish concessionaire is local to the area and benefits from this regulating service with a high economic value. At a national level, the Fishery Department and Environment Department are responsible for the regulation and monitoring of the state of this service in compliance with nationally and internationally approved conservation targets.

Tab.4-2: Characteristics of stakeholders in Dojran municipality (Author).

Stakeholder group	Interest / Role
Community level	
Smallholder farmers	Cultivating fruits and vegetables (mainly for home consumption). Interested in water quantity supply and quality as well market opportunities for traditional products.
Other farmers	Cultivating olive and grape plantations. Interested in water quality and quantity.
Fishermen	Interested in fish stock and diversity. Fishing for recreational activities, home consumption and market
Wild plant collectors	Harvesting for home use and income generation
Lake concessioner	Increase in fish stock and water quality
Primary school teachers	Opportunities for environmental education and student field visits
Local NGO	Conservation of lake flora and fauna
Tourist service providers	Attraction for transit tourism, any improvements of tourist offer
Municipal level	
Tourist center	Improvement and attraction of tourist offer through sport-oriented activities

Water utility services	In charge for water supply, wastewater and waste. Interested in water quality and quantity.
National level	
Fisheries department	Conservation of fish stock and diversity
Environment department	Interested in conservation of biodiversity, water quality and opportunities for eco-tourism
Water department	Interested in water quality and quantity
Academia	Research on water quality and quantity
National tourism association	In charge of promotion of the site for national and international tourists. Interested in tourist attractions and capacity at the site
Conservation NGOs	Conservation of biodiversity, capacity building
Tourists	Biodiversity and landscape
International level	
International NGOs, Foundations, IGO	Conservation of biodiversity

Recreation activities at lake Dojran, is an important cultural service and at community level it involves the benefits from aesthetic and recreational quality of surrounding area. The cultural service relating to nature-based tourism benefits stakeholders at a larger municipal and national scale. The conservation of biodiversity is most relevant to stakeholders at national as well as international stakeholders, however as the benefits of biodiversity are multiple, they contribute to enhancement of the cultural services. As these ecosystem services are particularly sensitive to local context, different stakeholders attach different values to the relevant benefits they receive.

b. Identification of ecosystem services and their current state

As part of the project "Integrated Water Resource Management at Dojran Lake", one-day workshop was organised entitled "Strengthening capacity for community, adaptive resource management at Dojran Lake" in September 2014 in Old Dojran, Macedonia. The workshop had the objective to identify and prioritize ecosystem services generated in the area, understand their state and spatial distribution through participatory mapping. They indicated a number of benefits associated with lake Dojran, which were classified as 9 ecosystem services that contribute to human well-being and corresponded to the MEA (2005) classification (Table 4-3).

Tab. 4-3: Stakeholders' identification of key ecosystem services and perceived changes in the last 10 years. Arrows represent the changes observed by users in ecosystem services, ↑ = increase; ↓ = decrease; → = maintenance (Author).

Type	Service	Changes perceived	Indicators
Provisioning	Water supply	↑	Water storage capacity[m^3/m^3]
	Food production	↓	Fish stock [kg/m^3]
	Fruits and grains	→	Yield [kg/ha]
	Herbs/Wild plants	↓	Yield [kg/ha]
Regulating	Erosion control	→	Infiltration capacity [mm/h]
	Water purification	↓	Nitrogen amount[kg/ha] Total dissolved solids [kg/m^3]
	Nursery service for range of fish species	↓	Endemic species [number]
Cultural	Recreational activities	↑	Recreational value [$/visit]
	Inspirational	↓	Cultural identity
	Education	→	Books and paintings

As a result of the workshop, participants identified major provisioning, regulatory and cultural ecosystem services. Participants were asked of their perception of change (increase / decrease / no change) in the provision of ecosystem services for the last 10 years after the ecological disturbance and the potential future threats.

Participants expressed high reliance on provisioning services associated with provision of fish and agricultural production. Provisioning services have an important role in adapting to global changes as they contribute to food sovereignty and diversification of income sources for local people (Adger, 2000). Among the provisioning services identified by the participants was *fish stock* in the lake, which has an overall decrease due to two factors – reduced water quality and overfishing. In contrast *water* quantity was considered by most participants that has increased in recent period. Regulating services are perceived as potentially the most important services for their capacity to enable ecosystems to sustain the flow of benefits as the provisioning service, thus enhancing the resilience of the system (Kinzig et al., 2006; MAE, 2005). An example of such service is its water purification function, which ensures *water quality.* Participants highlighted that *water quality* has remained low after the ecological disaster due to current pressures from land-based pollution.

In addition to the identified ecosystem services, the stakeholders recognized biodiversity as a benefit provided by the local habitat and surrounding landscape. Research has acknowledged that biodiversity enhances resilience by triggering ecological processes and hence the generation of ecosystem services (Chapin et al., 1997). Among the cultural services participants considered highly relevant are *recreational activities*, which were observed to increase in recent years.

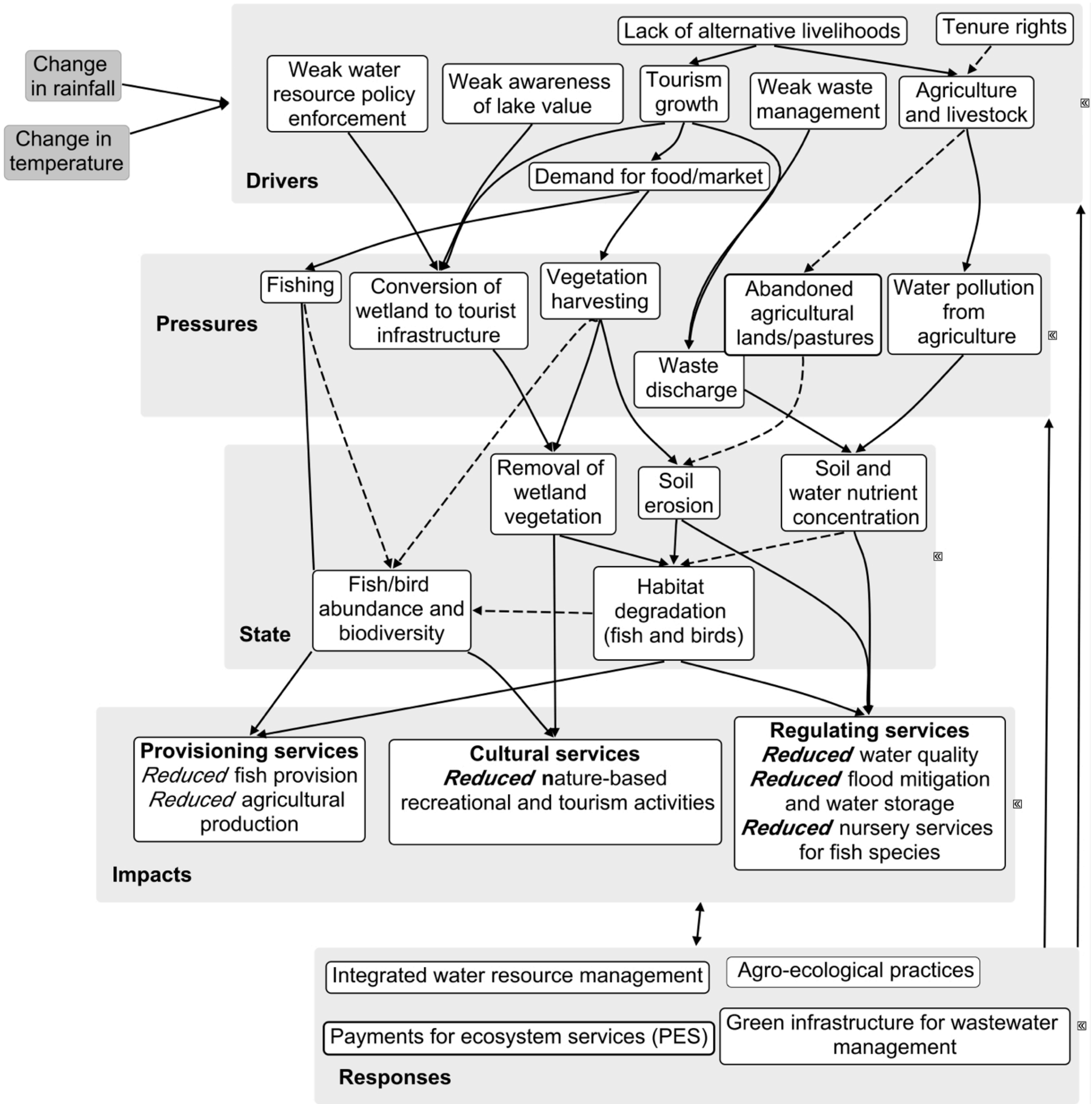
4.2.3 Integrated problem analysis

Based on observations, the information elicited from the workshop and expert knowledge, a causal network diagram using the Drivers–Pressure–State–Impact–Response (DPSIR) framework is developed. The analysis of the local system dynamic relationships was developed integrating the notion of ecosystem services (Fig. X) guided by Niemeijer and De Groot (2008). Drivers are identified in the analysis as social, economic and governance processes, which influence directly or indirectly the lake ecosystem creating Pressures to the system. The changes of processes and components (e.g. soil, water, lake fauna and flora) are describing State of the system, the consequences of which, defines the associated final Impacts on the flow of ecosystem goods and services. The described DPSIR components and their causal relationship represent elements of the social-ecological system, which define its vulnerability to global changes. The vulnerability conceptual framework outlined in Chapter 2 is used for reference in understanding the susceptibility, social coping and adaptive capacities and ecosystem resilience of the SES of Dojran lake.

a. *Drivers and pressures on ecosystem services*

The DPSIR diagram represents the local economy as an aggregate of income from agricultural production, tourism and fishing. It suggests a strong link between the local economy of Dojran and ecosystem services provision. The income generation for the region is largely based on fishing, agriculture and tourism activities, which are defined as the drivers of change in the ES. External biophysical stressors or exogenous drivers of ecosystem loss have an origin out of the unit of system analysis.

Fig. 4-3: Causal network analysis through adapted DPSIR framework. Dashed lines - reducing effect and full lines – enhancing effect (Author)



The sustainable management of such areas is acknowledge to contribute to reduce soil erosion, yet not using these lands for agriculture affects the provision of food, which is a driving force in the system. Tenure rights for arable land remained unclear after the change in political regime in late 1980s, leaving large agricultural areas, previously owned by cooperatives, abandoned and some of them converted to pastures.

A parallel growth in tourism represents a main driving force for employment and wealth generation for the local community, yet it contributes to conversion of lake shores into tourist infrastructure and as well increases wastewater discharge into the lake in high season periods. Tourism increases as well the demand for local fish. The other major livelihood activity is agriculture and livestock, which is a potential source of land-based water pollution due to fertilizer use.

Wetland management is as well identified as driver for ecosystem change. District and national level institutions are responsible for implementation of conservation and water resource policies, yet limited human resources and capacity leads to poor compliance of regulations and thus mismanagement of resources. Additional pressure on these processes originates from the limited awareness of local community on the conservation value of the wetland. Results from the workshop revealed that stakeholders are not aware that the lake has a status of National Monument of Nature, thus neglecting management requirements under this conservation status of the lake. Additional exogenous drivers in the system are weather-related variability such as change in rainfall duration and intensity and change in temperature. As previously discussed the area is highly vulnerable and both climatic factors influence the system posing pressure on its state and resulting in impacts on ecosystem services.

The state of the system is defined by: fish and bird abundance and biodiversity, level of habitat degradation, removal of vegetation, soil erosion, amount of soil and water nutrient concentration and characteristics of abandoned agricultural lands. The state determines the ecosystem functioning of the system, when deteriorated, then provision of ecosystem services is low.

b. Impacts on ecosystem services

Dojran lake and surrounding landscape provide a variety of ecosystem services, yet the analysis of this causal network focuses on the key regulation, provisioning and cultural ecosystem services identified by the stakeholders.

Regulating services provided in the area refer to: i) water quality, ii) flood mitigation and water storage, and iii) nursery services for fish species. Water quality is directly or indirectly dependent on the capacity of the ecosystem to purify wastewater flow from tourism and potential pollution from agriculture. On the other hand as the area is characterised by low agricultural activities and diverse natural vegetation, which enhances the regulating services as flood mitigation and water storage, if vegetation harvest do not contribute to high degree of soil erosion. In parallel increase in tourist infrastructure if not planned according to conservation requirements, may result in habitat loss, important for biodiversity and specially nursery areas for fish, thus decreasing the provision of this service.

Provisioning services include fish provision and agricultural production. The generation of both goods is potentially reduced due to loss of habitat as a result of wetland conversion and overfishing activities.

Cultural services are presented as nature-based tourism, the capacity of which is reduced due to disturbance of aesthetic beauty in terms of landscape integrity due to conversion of wetland areas to tourist infrastructure. This service is highly dependent as well on biodiversity in the area, thus decrease in fauna and flora abundance would reduce the attractiveness of the area for such tourism activities. This service also depends on the lake water quality, as, traditionally, tourism at Dorjan has been focused on offering recreational-water related activities.

c. Adaptive response options

A typology of response strategies can be assessed to understand whether the stakeholders prefer coping, adaptation or transformative strategies. The coping strategy is described by short-term decisions and practices where the disturbance is assumed to be a one-time event and will not be repeated and the system may retain its structure (Folke 2006). While adaptation strategies take a long-term track to adjust and meet the disturbance. The transformation strategy is a response where the system changes to a degree that it results in a shift from one kind of system to another.

The workshop explored stakeholders' interests in different future social-ecological pathways. Results from the workshop show common interest and visions among wetland users, associated with ecosystem services and human activities. Four possible adaptive response options integrating ecosystem services approach are highlighted in the analysis: i) *integrated water resource management (IWRM)*, ii) *agro-ecological practices*, iii) *green infrastructure for wastewater management*, and iv) *payments for ecosystem services (PES).*

The response options are not a stand-alone solution and would be most efficient in combination with one another or other adaptation and natural resource management instruments. This research will further assess the one of the proposed adaptive management pathways – payments for ecosystem services, in order to understand its potential to address drivers and pressures of the system and reduce its vulnerability to climate variability.

5. Scenario analysis: Payments for Ecosystem Services (PES) as adaptation response

The objective of this chapter is to discuss the meaning of valuing ecosystem services, the existing framework for valuation and its role in framing policy decisions for adaptation to global changes. This chapter demonstrates the integration of the concept of ecosystem services in the NetSyMoD methodological framework under step 4. This step implies the process of designing adaptation responses undertaking analysis of the suitability of Payments for Ecosystem Services (PES). While in the case of West Demerara in Guyana the proposed PES design is explored as an Ecosystem-based Adaptation option in development policy context, in parallel, in Dojran lake case the proposed PES design explores such an option in a transboundary context.

This chapter has the aim to address research question 3: How to integrate ecosystem services in designing responses to address vulnerability of social-ecological systems? In analyzing this question, the research has distinguished common factors between PES and adaptation efforts to demonstrate the links that can be established to consider PES as EbA approach.

5.1 Valuing ecosystem services and its role in decision making

5.1.1 Social, ecological and economic valuation of ecosystem services

Ecological valuation is acknowledged to be strategic in the attempts to mainstream biodiversity and influence policy-making to prevent ecosystem degradation. Recognizing the value of ecosystems and the services for human livelihoods is an essential prerequisite for foster conservation measures. Understanding the ecological, social and economic values of ecosystem services provides a reference framework to guide their integration in decision-making processes for nature conservation.

Ecological values often refer to the causal relationships between ecosystem components to support vital processes and sustain the livelihoods of communities (Faber *et al*. 2002; MA, 2003). An example of indicator to measure an ecological value is integrity of ecosystem components or their resilience, which determines thresholds and underpins the provision of ecosystem services. Yet, as such indicators are rather complex and represent indirect representation of measurable values, they are often overlooked in the economic valuation, yet their key purpose of supporting life on earth needs to be acknowledged (Faber *et al.* 2002).

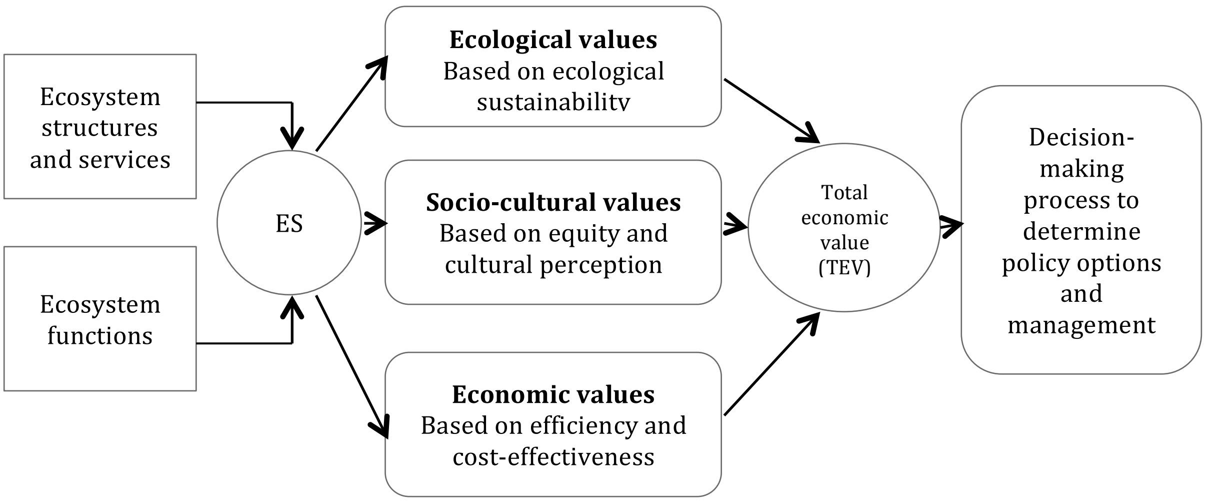
Socio-cultural values refer to the non-material welfare as ethical, spiritual and religious values, provided by natural systems. Such values are different for the stakeholders and often are a reflection of their attachment and sense for ownership of land and interaction with nature (Lamarque *et al.* 2011). It is often argued that socio-cultural values are not reflected in economic valuation studies and it is mostly due to the unsuitability of economic technique to capture such values (Scholte *et al.* 2015). Nevertheless, social values need to be complemented by other valuation approaches and be taken into consideration in decision-making to demonstrate inclusiveness.

The economic benefits of ecosystem services can be defined as four distinct types depending on the nature of their use: i) *direct use values*; ii) *indirect use values*; iii) *non-use values* and iv) *option values*. The direct use values refer to the values, which has consumption-related or non-consumption related purpose of the ecosystem services and goods (e.g. water for irrigation and natural beauty for recreation). The indirect use values reflect most regulating services provided by an ecosystem such as flood protection or erosion control, which indirectly benefit society. The non-use values are expressed by the awareness that an ecosystem service exists (existence value), or others are using it (altruistic value) or the service will be used in the future (bequest value).

The Economics of Ecosystems and Biodiversity (TEEB) is an initiative, which aims to demonstrate ecosystem and biodiversity values using indicators focusing primarily on the measurement of economic values and the assessment of costs and benefits (TEEB, 2010). The TEEB approach aims to recognize diverse ecological, socio-cultural and economic values of ecosystem services and convert them in economic terms to be further captured and incorporated in policy-making processes at different scales. TEEB classifies ecosystem services in categories resembling those described in MA (2005) with difference in substituting "*Supporting services*" with "*Habitat services*". With this in mind, Haines-Young and Potschin (2010) define the approach for analysis promoted by the TEEB framework as a "*habitat-based approach*", which although describing the overall picture of the status of services provided by a habitat, can provide little information for the individual ecosystem services.

In the process of ecosystem valuation, the TEEB undertakes a pluralistic approach and applies the Total Economic Value (TEV) framework, which incorporates both use and non-use values, (TEEB, 2010). Spatial heterogeneity of service flows is an important factor in the assessment of ES and their valuation, therefore both TEEB shows spatially explicit variation in ES values and recognize tangible ecological or physical boundaries of ecosystems at different scales (TEEB, 2010). The importance of distinguishing between functions and services in the valuation process is incorporated in the framework, it is certain that services rather than functions will be considered in valuation processes, as functions prove to be difficult to value and could lead to double counting (Turner *et al.* 2003).

Fig. 5-1: Process of ecosystem valuation adapted by de Groot et al. (2002).



Economic valuation of ecosystem services may be used to guide manifold policy processes including i) assessment of potential trade-offs of different land use options; ii) representation of the interest of diverse stakeholders; iii) comparison of benefits to wellbeing from ecosystem-based approaches or physical developed measures and iv) monitoring of quality and quantity of ecosystems, among others. Laurance *et al.* (2013) undertake an analysis of 5,028 references to determine the use of economic valuation in literature. The study concluded that there are three major categories of the use, which include decisive (e.g. determining trade-offs, developing criteria for ecosystem management), technical (e.g. establishing level of damage compensation; price setting of a policy instrument) and informative (e.g. awareness rising).

However, economic valuation still faces a number of limitations to guide decision makers. A major obstacle being highlighted is the methodological approach and credibility of attached values. Apart from methodological barriers Barde and Pearce (1991) mention as well that political, ethical and philosophical obstacles have arisen on discussions about monetary values attached to natural assets.

5.2 Payments for Ecosystem Services as an adaptive management strategy

5.2.1 Payments for Ecosystem Services (PES) in theory and practice

The prominent appearance of Payments for Ecosystem Services (PES) was triggered by need for an innovative funding mechanism for conservation of natural resources. The statement of the MEA (2005) on the importance and urgency to maintain the ecosystem services accelerated the evolution of PES. A common objective of PES is to support ecosystem services that are at risk of degradation due to overexploitation or threatened by global change, using a mechanism, which enables the provision of these services at a cost-efficient manner, over a long time. In doing so, PES schemes pursue to valuate ecosystem services and provide a monetary value, in the attempt to contribute to behavioural changes and sustainable land use practices. Since the end of 1990s, various PES schemes have been implemented for hydrological services mainly in Central and South America and focussing on the role of forests for the provision of these services (Corbera et al. 2007; Pagiola, 2008; Wunder and Albán, 2008).

As a policy solution, PES pursues to integrate ecosystem services into markets reflecting their social and economic values (Wunder, 2005). The concept underlines a straightforward objective to provide incentives to land stewards to undertake conservation actions resulting in improved provision of ecosystem services (Milder et al. 2010; Nelson et al. 2010). Compared to public policy instruments such as taxes and regulations, PES is considered a user-driven, alternative and sustainable financial mechanism (Swallow et al. 2009). The concept of PES in economic terms is central for defining the scope of the instrument and the various stakeholders involved. PES is formalised as: "(a) a voluntary transaction where (b) a well-defined environmental service (or a land use likely to secure that service) (c) is being *bought* by a (minimum one) service buyer (d) from a (minimum one) service provider (e) if and only if the service provider secures service provision (conditionality)" (Wunder 2005).

There is no general definition of how a PES scheme should be designed and applied; rather it is categorized based on the ecosystem services of interest and the type of payments. Such approach contributes to increase in benefits and addresses different beneficiaries. A prominent example is the PES case of Costa Rica where the watershed protection incorporates carbon sequestration services, biodiversity conservation and scenic beauty (Rojas and Aylward, 2003). Yet, ecosystem services considered in a PES scheme can be characterised whether they are rival or excludable, which would as well influence the structure of payments. A rival service or good refers to an ecosystem service which, when used or consumed by one person would compromise its availability for other people (Daly and Farley, 2004). An ecosystem service or good is excludable when a policy or institution prevents it from being used (Daly and Farley, 2004). Whether ecosystem services are rivalry or excludable would determine whether or not payments would be an effective option to support their provision.

The theoretical economics foundation of a PES scheme follows the Coasean theory to integrate ecosystem services into markets and establishes a central role of the private property rights as an incentive for the actors to support a functioning mechanism (Engel et al. 2008). Conceptual discourses highlight that this element in the Coasean theory, makes the approach more effective than the Pigouvian approach and the role of a government intervention as implied in environmental taxes for instance (Wunder, 2008).

Yet, in practice little evidence of existing PES schemes consisting solely of voluntary market mechanisms can be recorded and in many cases governmental involvement is required (Jack et al., 2008; Muradian et al., 2010; Schomers and Matzdorf, 2013). In some examples from local level PES schemes as described by Schomers and Matzdorf (2013), it has been proved difficult to distinguish between Coasean or Pigovian approach as the role of the municipalities is key and payments from beneficiaries (e.g. water fees) are not precisely on a voluntary basis. Thus, it is argued that PES schemes face many practical implementation constraints when they are designed as strictly market-based mechanism particularly in developing countries (Muradian et al., 2010).

Based on the relationship between the provider and buyer, there are three key types of PES designs to be distinguished:

(1) *User-financed schemes*, which refer to bilateral agreements or voluntary agreements (Bennett et al., 2013; Tognetti et al., 2006). These schemes are typically local initiatives.
(2) *Government-financed* or known as public-payment-schemes. These schemes are usually national scale initiatives and undertake the responsibility to pays on behalf of the society as the beneficiary.
(3) *Trading schemes* function mostly for the markets for pollution.

Diverse arguments are being discussed in favour of PES schemes to overcome the limitations of other conservation policy instruments. According to Engel et al. (2008), PES differs from command-and-control mechanisms in that it may promote alternative livelihoods for communities and can be applied specifically to a targeted ecosystem services with high value. In additions PES schemes have proved to be suitable for countries with weak governance in development context. The mechanism has however raised concerns for its approach to market ecosystem services thus resulting in changing the perception of people for nature (Muradian et al., 2010; Kosoy and Corbera, 2010).

Two major criteria are argued to describe the effectiveness and efficiency of PES schemes - conditionality and additionality. Conditionality entails that the service provider should demonstrate the desired outcomes from the pre-defined actions taken to maintain the ecosystem services in order to receive a payment (Wunder, 2005; Engel et al., 2008). Yet, as it can be noticed, PES schemes mostly aim at adoption of alternative land use practices which are being monitored, rather than the outcomes from them (Engel et al. 2008). Additionality on the other hand, entails the additional improvements to a hypothetical reference of what would have occurred without PES scheme and as it is difficult to be determined, Tacconi (2012) argues that it should be defined for the whole PES design and not on individual providers.

Although a PES mechanism is based on economic valuation of ecosystem services, it goes beyond pure economic perspective and integrates the complex aspects of ecological and socio-cultural values. Therefore, Muradian et al. (2010) highlights that PES schemes especially in a development context brings much more benefits than just perceived from an economic tool and embraces social equity and embeddedness. Consequently Muradian et al. (2010) proposes different definition of PES:

"as a transfer of resources between social actors, which aims to create incentives to align individual and / or collective land use decisions with the social interest in the management of natural resources."

Therefore, apart from the on-site individual benefits, the off-site benefits to a larger group of beneficiaries from resource and land-use can be more explicitly considered for decision-making contexts. The definition moreover emphasizes the synergistic element of pursuing ecological sustainability while addressing social goals, which is of highest importance in the context of adaptation to climate variability and change.

5.2.2 PES as an ecosystem-based adaptation pathway

Multiple efforts of scientists and practitioners aimed to provide evidence of the role that ecosystem services play in sustaining human welfare. In recent years a growing interest has developed around the potential of certain ecosystem services to contribute to reduce human vulnerability to global change (Sudmeier-Rieux *et al.*, 2006). As adaptation gained the attention in the latest UNFCCC negotiations, ecosystem-based adaptation (EbA) reached the international agenda (Pielke, *et al.* 2007).

EbA is acknowledged as a cost-effective adaptation measure, which complements other adaptation efforts (Vignola *et al.,* 2009; Campbell *et al.,* 2009). Payments for ecosystem services may target specific services of high adaptation value and thus contribute to enhancing adaptation efforts. Hence, PES may appear to be an appropriate policy mechanism for implementing EbA objectives (Vignola *et al*., 2009; ten Brink *et al.,* 2011).

Conceptual linking of PES and adaptation

Yet, there is insufficient theoretical and practical foundation to ascertain the potential of PES to address adaptation needs (Locatelli et al., 2008; Van De Sand, I., 2012). Following the vulnerability framework adapted from Turner *at al.* (2003) and presented at an earlier stage of this research, presented that most ES affects vulnerability through influencing certain components of adaptive and coping capacities as well as sensitivity of the social-ecological system.

As the conceptual understanding of adaptation refers to reducing vulnerability, the PES design should therefore be targeted at enhancement of coping and adaptive capacity in the context of climate change (Adger *et al*., 2004; Fussel, 2007). In doing so, PES schemes have to undertake a gradual change in their focus and seek to a) incorporate climate information in their design and b) aim at implementing activities, which address impacts associated with climate change (Klein, *et al.* 2007). Three key linkages between PES and adaptation can be identified: (1) Enhancing ecosystem services with high adaptation value; (2) Strengthening adaptive capacity and (3) Adopting adaptation measures

(1) Enhancing ecosystem services

The link of ecosystem services and socio-ecological vulnerability has been discussed earlier in the research in the proposed conceptual framework. Locatelli et al. (2008) and MEA (2005) argue that ecosystem services influence vulnerability through the characteristics of adaptive capacity and sensitivity. In this perspective every kind of ecosystem service plays different role in reducing vulnerability. While regulating services can to an extend act as buffer for impacts from natural hazards and provisioning services contribute to reducing impacts with providing alternative sources of income.

(2) Strengthening adaptive capacity

Apart from enhancing the provision of ecosystem services, appropriately designed and implemented PES measures have the potential to strengthen adaptive capacity of ES buyers and providers. Van de Sand (2004) has identified several factors that are said to determine adaptive capacity as: (i) institutional setting; (ii) social and knowledge network; (iii) access to financial resources.

Strengthening the institutional setting with the implementation of PES can take form either in support of the legal framework or enhanced local planning and management, both of which results in improved decision making. Local-level PES schemes usually appear, where policy is not efficiently designed and implemented. As tenure rights are a key prerequisite for undertaking different land use practices, PES may contribute for establishing local tenure rights.

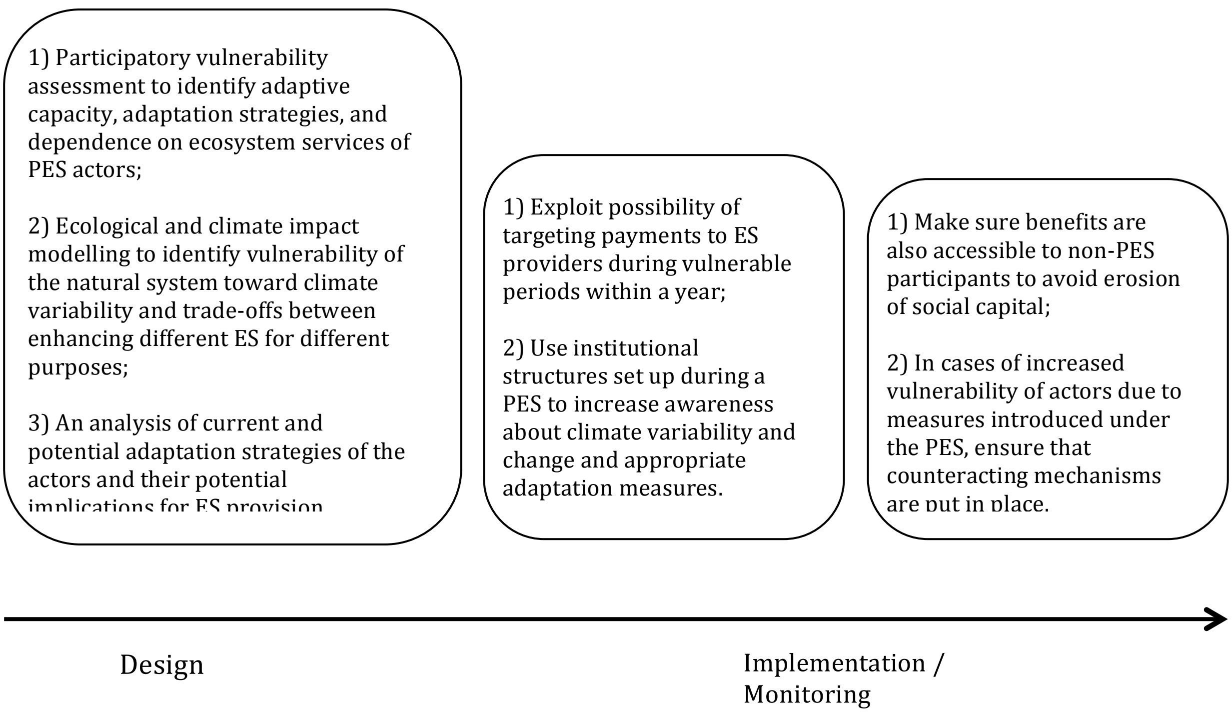
Social and knowledge network refers to improved communication among stakeholders and exchange of information as PES requires cross-sector and cross-demographic dialogues it provides space for under-represented communities to participate in decision making. On a different scale, the scheme may enhance networks among institutions and support communication in between.

Access to financial resources can be analyzed through both strengthen local economy and human capital.

Designing PES for adaptation

At present, many PES schemes generate "pro-poor" benefits and in order to shift to a more ambitious "pro-adaptation" approach, PES designs should seek to maximize synergies and minimize trade-offs with the adaptation framework. In the analysis of possible path of such transition, Van De Sand, I., (2012) concludes with a list of recommended steps and instruments to be taken at different stages of PES scheme to incorporate the adaptation aspect (See Fig.5-2).

Fig. 5-2: Recommended steps and instruments to integrate at each stage of PES design (adapted from Van de Sand, I. 2012).



These steps demonstrate the complexity PES should embrace in its design and implementation to address climate adaptation needs. Yet, in exploring the links between both processes, the focus remains on the social system and how pro-adaptation PES addresses its vulnerability. It is however argued that PES should seek to strengthen ecosystem resilience in line with the social system and avoid focusing on only one service. Examples show that targeting only one ecosystem service may impede certain ecosystem processes and lead to trade-offs, thus failure to deliver adaptation benefits (Redford and Adams, 2009). Therefore, it is vital to identify the linkage between generation of ecosystem services with high adaptation value and the effect they have on vulnerability of socio-ecological systems to global changes and aim at minimizing any trade-offs.

5.3 PES in a development context: Ecosystem-based Adaptation Options for Guyana

5.3.1 PES for hydrological ecosystem services: Experiences from Latin America

Classifying PES for agriculture proves to be challenging as often such initiatives are commonly accepted as agri-environmental schemes and policies. A major difference between both concepts is that PES targets ecosystem services while agri-ecological measures promote certain agricultural practices. This difference can however be narrowed once conservation practices are aimed at enhancing specific ecosystem services (FAO, 2011). This section represents a comparison of case studies in South and Central America in order to provide a feasible context and position the proposal of PES design for Guyana among other implemented PES projects.

Martin-Ortega, J. et al. (2012) developed a comprehensive compilation of 39 cases on payment schemes for water ecosystem services in Latin America to analyze and construct a database on the tendencies in design and implementation of this mechanism. The majority of schemes are implemented on a local scale (73.7%) while only little fraction of the PES schemes (8%) is implemented on a national scale and the rest (18.4%) has been difficult to define. Results from this systematization show that majority of the schemes propose forest conservation and restoration actions and only few cases of watershed conservation (10.5%) and change in agricultural practices and agroforestry (18.4%). Fig. 5-2 shows details on the PES cases in Latin America, which include actions on change in agricultural practices, targeting a wide range of ecosystem services among which: i) water supply; ii) flood and sediment regulation; iii) cultural services. Three of the six PES schemes in Colombia, El Salvador and in Guatemala, presented in Tab.5.1 are of special interest as they target flood regulation generated by agro-ecological systems.

Many of the PES examples in the study do not provide information on how the decision-making has been taken (Martin-Ortega, J. et al. 2012). Yet, Tab.5.1 demonstrates that most of the PES schemes for agricultural systems are at local level, but with the vision that they will transform into national –level schemes. Examples of such tendency are Nicaragua and El Salvador through the Program for Sustainable Agriculture on the Hillsides of Central America (PASOLAC). This is an interesting observation on the potential of PES to act as a mainstreaming tool for ecosystem services approach in decision-making at national level.

The agricultural practices proposed by PES schemes in Latin America propose i) soil and water conservation management techniques as in the example of Nicaragua, ii) agro-forestry as in the case of Honduras and iii) silvopastoral schemes in the cases of Colombia and Nicaragua. Key factor challenging the comparison are the different scale, scope and objectives.

Tab. 5.1: List of PES schemes for hydrological services and including agro-ecological practices in Latin America.

Site	Scale	Targeted water service	Sellers	Buyers
Fuquene, Colombia[6]	Local	Water supply, Flood and sediment regulation	Farmers	International NGO
Lake Coatepeque, El Salvador[7]	National	Improvement of water supply and quality; Flood and sediment regulation, cultural services	Public, private and cooperative landowners	Domestic water users, fishermen
Las Escobas, Guatemala[8]	Local	Water supply, Flood and sediment regulation	National NGO	Domestic water users, hydropower producer
San Pedro del Norte, Nicaragua[9]	Local	Water supply and quality	Landowners	Domestic water users
Rio Segundo, Costa Rica[10]	Local-National	Water supply	Farmers	Domestic and other commercial water uses
Jesús de Otoro, Honduras[11]	Local	Water supply and quality	Farmers	Domestic water use

Although PES has attracted a lot of scientific and political attention in recent years, discussion on how this approach could be beneficial for smallholder farmers both to adapt to climatic variability and ensure provision of ecosystem services is rather new. Literature highlights that in order for agricultural practices from PES to correspond to ecosystem-based adaptation principles, they should be based on nature and biodiversity conservation values. Evidence from Nicaragua, demonstrates that implementing sustainable land management practices (e.g. vegetative strips, cover cropping) results in enhancing ecosystem services as soil formation and reduction of runoff. These practices are in line with EbA principles and lead to improving the ecological resilience of the farm to natural hazards (Holt-Giménez 2002).

However in a development context, there is tendency in governmental and international initiatives to encourage more technological rather than ecological responses to natural hazards and climate change (Eakin, 2005). Adaptation efforts in Guyana are following a similar path promoting among others engineered flood-tolerant seeds inadequate for smallholders needs.

[6] Tognetti and Johnson (2008); Greiber (2009)

[7] Porras and Neves (2006)

[8] Corbera et. al (2007)

[9] Kosoy et al. 2004 (2007); 2008

[10] Kosoy et al. (2007); Barrantes and Gómez (2007)

[11] Kosoy et. al. (2007)

5.3.2 Proposal for local-scale PES design in West Demerara, Guyana

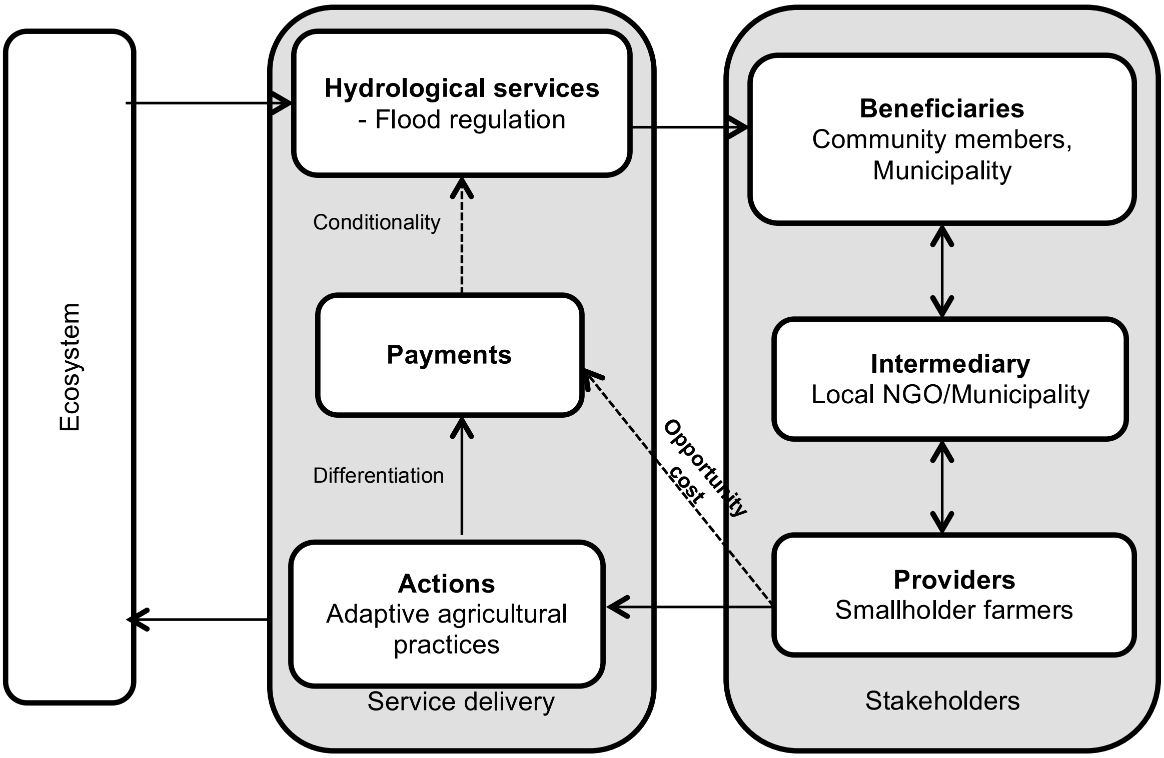
The Government of Guyana has promoted a number of initiatives to support the farmers in their adaptation efforts. The National Adaptation Strategy for the Agricultural Sector (2011) focuses at three major activities to strengthen the capacity of farmers to manage risk: (i) develop and promote new bio-technologies; (ii) reconstruct river defenses in coastal regions; (iii) shift to adaptive farm management practices. Although these activities are needed, the first two initiatives are hard to be implemented in short-term, as they require economic incentives and infrastructure.

Shifting to adaptive farm management practices however, is an immediate response to ensure that smallholder farmers will sustain their livelihoods while addressing stresses caused by climate variability. Such practices can follow an ecosystem-based adaptation approach to enhance the generation of ecosystem services and thus increase farmer's resilience to natural hazards (van Noordwijk et al., 2011; Wezel et al., 2014). A design for a PES scheme is proposed as potential response option to integrate an incentive for nature conservation while incorporating the elements of adaptation practices to better address projected climate variability in the region.

In order to promote these ecosystem-based adaptation practices under a PES scheme, a participatory decision-making process is essential, with this in mind a multi-stakeholder management committee can supervise and monitor the payment scheme. Through this committee the providers and the beneficiaries will be part of all decisions thus developing ownership, transparency and increased trust, all sensitive issues in the context of Guyana's political situation. This scheme consists of a fixed payment per year by the beneficiaries to a designated fund, which is then used for support of the ES providers in implementing ecosystem-based agricultural adaptation measures.

The proposed PES design involves the participation of stallholder farmers as providers of ecosystem services with special interest in *flood regulation.* The beneficiaries of these services are members of the community who are at constant risk of flooding settles at the riparian flood plain. The PES design suggests a user-funding scheme to provide incentives to stallholder farmers to undertake soil and water conservation agricultural practices and enhance flood regulation. In the proposed PES design, opportunity cost plays a central role to motivate farmers to participate in the PES scheme. The opportunity cost is the amount that a farmer will incur if changes in land management take place and might lead to decrease in production. Figure 5-6 illustrates the functionality of the PES scheme.

Fig. 5-2: Payments for Ecosystem Services scheme proposal for West Demerara, Guyana (Author).



As this PES design is proposed for the development context of West Demerara, in Guyana, it is beneficial to explore and incorporate as well a pro-poor aspect of the scheme. With this aspect in mind and the objective to demonstrate the potential role of PES in adaptation efforts, the proposed design focuses on the three factors linking PES and adaptation (1) Enhancing ecosystem services with high adaptation value; (2) Strengthening adaptive capacity and (3) Adopting adaptation measures to demonstrate that PES represents an ecosystem-based adaptation option.

1) Linking PES and adaptation through enhancement of ecosystem services

As presented in the table, there are several agricultural practices, which directly relate land use and generation of hydrological services. All of the proposed seven agricultural practices contribute to reduction of run off, yet only agroforestry practices and appropriate soil management affect water holding capacity, while hydrological regulation is affected as well by grass strips and living barriers. Table 5-2 represents a list of conservation agricultural practices which contribute to flood mitigation described through enhancement of the ES services: (i) run off reduction; (ii) water holding capacity and (iii) hydrological regulation (Altieri and Nicholls, 2013).

Tab. 5-2: Example of agro-ecological practices affecting hydrological ecosystem services (Altieri and Nicholls, 2013).

Agricultural practices	Run off reduction	Water holding capacity	Hydrological regulation
Diversification			
• Intercropping	◆		
• Agroforestry	◆	◆	
• Intensive sylvopastoral system	◆		◆
Soil management			
• Cover cropping	◆	◆	◆
• Mulching	◆	◆	
• Conservation agriculture (organic no till)	◆		
Grass strips/ living barriers	◆		◆

(2) Linking PES and adaptation through strengthening of adaptive capacity

This sub-section describes the factors under which the PES design in West Demerara is analyzed to demonstrate how activities from the scheme will contribute to strengthen adaptive capacity.

The ecosystem-based agricultural practices to be considered under this PES design option target the provision of regulating services and in particular flood regulation in order to mitigate climate change impacts. The two stakeholders to this proposed PES scheme are smallholder farmers as ES providers and the Government of Guyana as the main beneficiary.

Smallholder farmers are providers as well as beneficiaries of hydrological services to mitigate flood. They are interested to get involved in a PES scheme as long as it demonstrates that it is contributing to the improvement of their livelihoods, offers adequate opportunity costs and promotes equality.

Recent floods have caused tremendous damages at local and national level and the support of any activities in line with national adaptation needs and objectives, the Government will presumably support. An example of mainstreaming ecosystem services in climate change policy making in Guyana is the implementation of Reducing Emissions from Deforestation and Forest Degradation (REDD+) and is the only example of PES-like mechanism being implemented in Guyana. This example demonstrates the willingness of the state to engage in such innovative mechanisms.

The climate change policy context in Guyana was strengthened through the recent integration of climate change into national development planning through the LCDS and other sectoral policies as agriculture and disaster risk reduction. While these developments have played an important policy progress, there is a gap in developing mechanisms for successfully implementing the proposed objectives. Yet, given the high vulnerability of the country and the urgency of adaptation action there is lack of strong and adequate policy framework to guide national initiatives and ensure the mainstreaming of adaptation measures in all sectors and affected regions.

The institutional capacity to address climate change in Guyana was strengthened, in the recent years, however the institutional framework remains fragmented and climate adaptation is not sufficiently mainstreamed across the sectors. A major barrier is the lack of common platform for data sharing and linkages between activities of different agencies, hence resulting in higher costs and mismanagement. Capacity constraints within agency also represent a concern as the limited availability of skilled personal is a barrier to successful implementation, monitoring and evaluation of policy actions.

5.4 PES in a transboundary context: An ecosystem-based adaptation option for Dojran Lake, Macedonia

5.4.1 Payments for ecosystem services: Transboundary experiences

In the long history of transboundary environmental policy, it has been attested that successful collaboration is based on mutual interests rather than on rights and necessities. It is the shared interest that acts as an incentive for collective work (Mumme 2000; Susskind *et al*. 2002; Hoffman 2006; Wolf 2007). The ecosystem services concept stipulates such a shared interest for sustaining human well-being and provides a suitable framework for transboundary conservation efforts. For the development of a PES scheme in a transboundary ecosystem context, it is of great importance that all interested governments are involved and their values reflected. Such programs slowly are emerging but acknowledging the complexity they involve; at present only two initiatives have demonstrate achievements.

The Danube river, which crosses 13 countries in Europe represents a case study of transboundary PES schemes led by WWF. As the case study of Dojran lake is located in Balkan region, this sub-chapter will focus on the identified case studies at the Danube river basin in the region.

Tab. 5-3: Payments of ecosystem services in the Balkan region implemented by WWF Danube-Carpathian Programme (WWF, 2011).

Case-study	Target issue	Buyer	Seller
Rusenski Lom, Bulgaria[12]	Biodiversity conservation through “responsible tourism”	10 small- and medium-sized enterprises and NGOs	“Friends' Club of Rusenski Lom Nature Park” – Non-profit private organisation
Persina, Bulgaria[13]	Watershed regulating services - Regulation of carbon - Provision of biomass - Habitat maintenance	Local company interested in reed harvesting and processing into pellets and briquettes.	Directorate of Persina Nature Park

[12] Todorova, M. 2013. *Payment scheme for aesthetic and biodiversity values of Rusenski Lom Nature Park*. WWF Bulgaria. Sofia

[13] Todorova, M. and Grigorova, Y. 2014. Market Payments for watershed restoration in Persina Nature Park. WWF Bulgaria. Sofia

The case studies from the transboundary initiative WWF Danube-Carpathian Program consist of 6 pilot projects in Romania and Bulgaria. The objective of the projects is to involve agricultural producers of all the sites to participate in the development of market "green" agricultural products to be transformed into tourism products, which contribute to rewards for ecosystem services.

Yet, the experiences of this project do not explicitly demonstrate collaboration between Bulgaria and Romania, rather the pilot studies are isolated from one another. This example ascertains that there is very little evidence found in literature both scientific and grey on existing cases for explicit transboundary PES application.

The major obstacles identified in the process of developing the PES schemes in the regions are the absence of institutions to support such financial mechanisms and the limited or non-existent normative framework to provide conditions for setting up of such a market mechanism. Yet, the limited experience in designing PES schemes in the region has shown that such obstacles can be overcome applying new approaches.

Although the overview of the case studies do not provide a specific information on the transboundary aspect of the PES schemes, key lessons were identified that:

• **Revising and amendment of excising regulations enable the advancement of PES market mechanism.** As the introduction of new legal instruments is unlikely in short-term, this should not constrain the initiation of PES scheme. A major task should be to conduct a comprehensive assessment of gaps and opportunities in the legislative framework and attempt to identify enabling factors to incorporate in the regulations.

• **Monitoring of the agreed land management practices according to the PES** objectives and specifically the change in ecosystem services provision due to the implementation of certain activity is recognized as one of the most important aspects in the development of an operational PES scheme.

5.4.2 Proposal for local-scale PES design in Dojran Lake

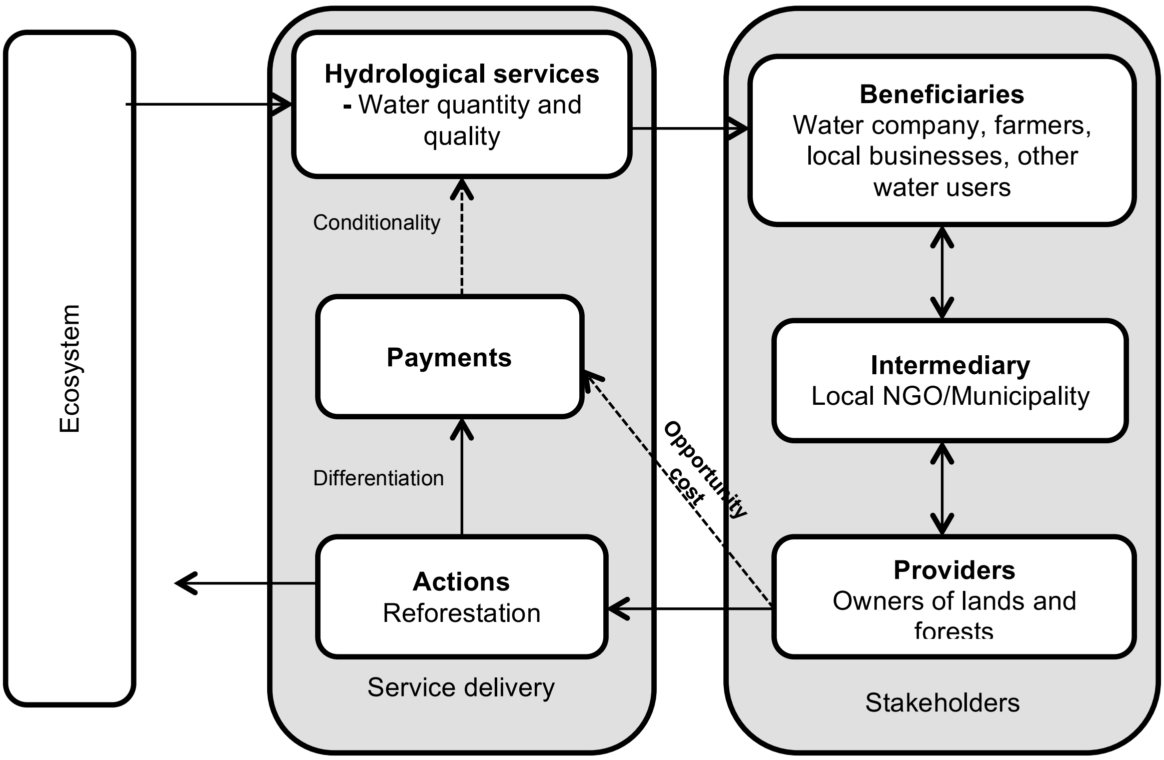
Description of PES design

A major problem to be addressed by PES is the decreased water quantity and quality at Lake Dojran, which are already present due to historical disturbance of the system (Georgievska and Matevska, 1996; Griffiths *et al.,* 2002). Degraded lands, unsustainable agricultural management practices, weak enforcement of laws and projected growth in tourism are the major drivers of change of the ecosystem state. If left unchanged these drivers will generate pressures to further threaten important biodiversity habitats and the provision of ecosystem services sustaining human wellbeing.

Climate variability poses additional risk as an external driver to the system. Climate projections indicate high probability of precipitation variability, which could lead to longer drought periods and at the same time increase in frequency and magnitude of high precipitation extremes (IPCC, 2007, 2014). These changes are expected to significantly affect the agricultural and water sector in the region (IPCC, 2007, 2014). Among the implications of such hydrological changes are the increase in vulnerability of production and water demand for irrigation, thus increased need for water efficiency and conservation measures, land degradation and wind erosion, increased risks of flood hazards and direct negative impacts on soil quality and structure (Fallon and Betts, 2010).

The landscape surrounding Lake Dojran is dominated by a mosaic of agricultural lands with a combination of arable land (700 ha), vineyards (500 ha), grain fields, almonds and olive trees (100 ha) arranged in a mosaic manner among semi-natural areas among other land uses. Low-intensity small-scale agricultural systems are characteristic for the area and are acknowledged as high nature value for agro-biodiversity, but highly vulnerable to weather-related variability and hazards. It is likely that crop productivity loss may reach 30% by 2050s in the Mediterranean region, due to scarce water resources for irrigation (Maracchi *et al.* 2005). Projected flood risks are exacerbated by the soil qualities responsible for soil water retention. The abandoned agricultural areas in Dojran, face even more severe impacts as they are characterised by increased soil erosion, land degradation and decreased ground water recharge and increased runoff, making them highly vulnerable to wildfire and flood risks (Sivakumar and Steganski, 2007; Nuñez, 2005).

Fig. 5-3: Payments for Ecosystem Services scheme proposal for Dojran Lake, Macedonia (Author).



How PES design relates to adaptation needs?

The PES design focuses on the three previously identified factors (1) Enhancing ecosystem services with high adaptation value; (2) Strengthening adaptive capacity and (3) Adopting adaptation measures to demonstrate that PES represents an ecosystem-based adaptation options.

(1) Enhancing ecosystem services

The water quality and quantity in wetland are highly influenced by the integrated functioning of the ecosystem components. The riparian zones are especially vital for the health of wetlands systems for they provide a variety ecosystem services in a very small area (Baker *et al.,* 2006, Luck *et al.,* 2009; Meli *et al.,* 2014). The ecosystem services range from regulating the hydrological regime by mitigating flood and allowing for ground water recharge (Dwire and Lowrance, 2006), to protecting water quality by controlling nitrate removal (Vidon and Hill, 2004), and providing habitat for biodiversity (Naiman *et al.,* 1993). Such interaction between forests and wetlands is highly dependent on site-specific characteristics, climate and tree species, soil properties and terrain (Calder, 2002).

Despite the numerous benefits provided by riparian areas for human well-being and ecosystems, they continue to be degraded by unsustainable land-use management as agricultural practices, deforestation and urbanization (Snyder *et al.,* 2003). Such degraded riparian ecosystems perform with low capacity to regulate water flow and pollution and support biodiversity. Ecological restoration of such areas is acknowledged to present a viable management practice to revive the ecological integrity of wetlands. The restoration may take two general forms – riparian forest restoration and agroforestry.

In the case of Dojran lake, this PES scheme has the objective to protect the water quality and quantity in the aquatic ecosystems, through riparian forest restoration in abandoned agricultural lands or deforested areas or creating shelterbelts in agricultural areas.

At present the vegetation surrounding lake Dojran has been highly influenced by anthropogenic activities. From remaining fragments of vegetation and based on scientific observations it can be concluded that in former times a periodically-flooded forest surrounded the lake. The most common vegetation included *Quercus pedunculiflora* C. Koch., *Fraxinus oxycarpa* Willd., *Alnus glutinosa* (L.) Gaertn., *Ulmus minor* Mill., *U. laevis* Pall., *Platanus orientalis* L., *Vitis silvestris* Gmel., *Humulus lupulus* L., *Periploca graeca* L. etc. (Athanasiadis, et al. 2000) On the Greek site of Lake Dojran, there is a small forest area (59 ha) with Oak trees (Mouries Forest), which is a rare forest and is suggested for Natura 2000. With similar climatic and hydrological characteristics it can be implied that such forest has possibly existed as well on the Macedonian side before the socialist period, when it has been converted to agricultural lands. Apart from the hydrological services in long-term, the reforestation of defined areas around the wetland would contribute for maintaining a scenic landscape, thus generating an additional ecosystem service – recreational benefits for the local population and tourists.

(2) Strengthening adaptive capacity

The scheme will attempt to attract big users of water - companies and private companies, including farmers, to participate in the so-called: "Green fee". A certain percentage of the company's profit could be donated to a local non-governmental organization and / or municipality for afforestation with native species or species less susceptible to climate change and additional commitments in support of abandoned agricultural / grasslands areas. In this scheme providers of ES are owners of lands and forests, who will provide areas for afforestation, maintenance or creation of agro-forestry systems. The beneficiaries of ES are the water company in the municipality, other users of the water as farmers whose lands are irrigated, local businesses, the production of which involves the use of water - the manufacture of a olive oil, fisheries and others.

Additionally beneficiaries are as well the local population. Intermediary can be an organization that has the capacity to administer the scheme as the local NGO or municipality. The scheme can work in two ways: i) on a voluntary basis where interested buyers will collect funds in the form of donation; ii) on a mandatory basis where water company in the municipality and other water user companies will donate a % of their profits for the scheme. The amount of tax for water use can be determined on local level (by municipality) and maybe could in that way support the first PES scheme.

Since PES is to be applied for the first time in the territory of Macedonia no legal precedents to obstruct the implementation of the schemes. The Government is addressing critical environmental issues by means of a National Environmental Investment Strategy for the period 2009-2013 (NEIS). NEIS is based on NEAP and the National Strategy for Environmental Approximation (NSEA). NEIS describes the general envelope of funding allocated to environmental investments.

(3) Adoption of adaptation measures

The two activities that suggested to be undertaken in the PES design option are riparian forest restoration and/or agroforestry.

Riparian forest restoration corresponds to the traditional and newly emerged objectives of wetland restoration for biodiversity, improvement of water quality, flood mitigation, recreation, carbon storage, maintenance of landscape heterogeneity (Zedler, 2000; Comín, F.A. *et al.* 2001). Recent studies consider restoration practices from multi objective perspective often combining water quality, landscape and biodiversity (Comín *et al*. 2001; Thiere *et al.* 2009). Yet, accomplishing these objectives depends on different scales (e.g. wetland, sub-catchment, catchment, landscape) (Bohn and Kershner, 2002).

Literature indicates that improvement in water and soil quality can be achieved at wetland scale, while biodiversity objectives are more suitable at higher scales (Mitsch and Gosselink, 2000; Moreno-Mateos *et al.*, 2008). Effective zoning of restoration activities is crucial specially for influencing habitat potential of the area. Studies show that biodiversity supported by riparian zones decrease with distance and highest diversity has been observed at 51 – 100m from the bank (Randhir and Ekness, 2013).

Agroforestry has been recognized to be a suitable practice, which provides multiple benefits contributing to increase of farmers and ecosystem's capacity to adapt to global changes and environmental risks (Schoeneberger, *et al.* 2012; Lasco *et al*. 2013). As discussed earlier one of the major drivers of change in the system is climate-related variability. Smallholder farmers in floodplain areas face the challenge to strengthen food security and cope with natural hazards while ensuring sustainability of their natural capital (Fallon and Betts, 2010).

A wide range of literature has focused on the ecological functions provided by agroforestry strengthening the evidence that such practice enhances water use and storage (Sileshi *et al.* 2011), soil productivity and erosion control, provide shade and shelter (Verchot *et al.* 2007) and buffer against natural hazards as floods and draughts (Van Noordwijk, *et al.* 2011). Apart from immediate ecological benefits, agroforestry generates economic and social benefits as improvement of farm productivity and diversification of income and nutrient uptake (Verchot *et al.* 2007). Additional benefits are being studied beyond farm level reaching watershed and regional level as enhancing biodiversity conservation and improving watershed management (McNeely and Schroth, 2006).

As the proposed PES option aims to address a transboundary aspect, thus monitoring of proposed activities and their compliance should play a key role in the design of the scheme.

6. Response option analysis: Potential of PES to address adaptation needs

Following the NetSyMoD approach and initial qualitative analysis of risks, vulnerability and design of responses, this step of the methodology aims to analyze the potential of the ecosystem-based response options such as PES to address adaptation needs. The methodological steps described in this chapter is the last step of the NetSyMoD approach Decision support for adaptation to climate variability and change is multidimensional in nature and requires the application of multiple indicators to reflect socio-ecological, economic and political aspects. This chapter aims at demonstrating the application of different analytical tools as SWOT – AHP (Strengths, Weaknesses, Opportunities, Threats – Analytic Hierarchical Prioritization) analysis to facilitate decision making as in the case of Dojran Lake, Macedonia and in-depth decision-makers interviews to identify opportunities for ecosystem services mainstreaming in adaptation policy making as in the case of West Demerara, Guyana.

Although ecosystem services is accepted as a key component in adaptation policies in recent years, methods to systematically analyze the potential benefits of these services especially with regards to contributing to adaptation are still lacking. Decision-making for adaptation options engages multiple stakeholders and objectives on resource use and benefits. In order to develop effective policy, which integrates ecosystem-based adaptation it is important to account for certain factors that may hinder or favor the process. Multi-criteria decision analysis (MCDA) can therefore be a useful tool to bring stakeholders' preferences under discussion and define a decision context through eliciting of ranking criteria.

6.1 Challenges and opportunities for mainstreaming ecosystem-based adaptation in development planning of Guyana

6.1.1 Identifying Strengths, Weaknesses, Opportunities and Threats

A current example of mainstreaming ecosystem services in policy making in Guyana is the implementation of Reducing Emissions from Deforestation and Forest Degradation REDD+. Recent developments in Guyana's market and trade policy have led to expanding of the agricultural sector and thus exerting pressure on forested territories. To avoid the deforestation destiny of many neighboring countries, Guyana became prominent for its commitment to forest conservation in compliance with the newly at that time economic incentive mechanism REDD+.

In 2009, Guyana signed a Memorandum of Understanding with Norway for the implementation of its Low Carbon Development Strategy (LCDS)[14]. The financing of up to USD 250 million for a five-year period until 2015 is conditional upon the implementation of the LCDS. The country pledged to limit its economic development path related to deforestation to up to 4.3 percent (630,000ha) per annum for the next 25 years, which will result in the equivalent 1.5T of avoided greenhouse gas (GHG) emission. The implementation of REDD+ is the only example of PES-like mechanism being implemented in Guyana.

At this stage of the current research aims to develop a comprehensive understanding of weather and how ecosystem services can be potentially incorporated in decision-making

tools for development and adaptation in Guyana. is to explore what are the barriers and opportunities for further mainstreaming ecosystem-services approach. Therefore, the research undertook a qualitative analysis to determine the Strengths, Weaknesses, Opportunities and Threats (SWOT) identified by national decision-makers to incorporate this approach in development policy. This framework analysis is being used as analytical tool in planning of strategic processes since 1960s in diverse contexts (Lozano and Valles, 2007). SWOT encourages the identification of four categories of social, ecological and economic factors determining a response option.

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14

For the purposes of analyzing the potential of proposed PES design to address adaptation needs, the research applied a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis. This framework analysis is being used as analytical tool in planning of strategic processes since 1960s in diverse contexts (Lozano and Valles, 2007). SWOT encourages the identification of four categories of social, ecological and economic factors determining a response option.

While SWOT analysis has proved to be a useful foundation for decision-making, it does not include analytical assessment of the relative importance of the variables selected. To overcome this limitation of the analysis, the research proposes an integration of MCDA analytical tool as Analytical Hierarchy Process (AHP) developed by Saaty (1980). Experiences in integrating SWOT analysis with quantitative approaches as AHP are demonstrated in water resource management (Hajkowicz and Collins, 2007) and agriculture management (Giri and Nejadhashemi, 2014). The role of AHP is to support decision makers in reaching a decision, which best responds to a stated problem, rather than prescribing the concrete decision.

The overall aim of this analysis is to determine whether the proposed PES design options have the potential to meet adaptation objectives. Therefore, the identified factors in the SWOT analysis have the purpose to respond to the following question:

1. Does the proposed PES option is designed in a manner to enhance ecosystem services with high adaptation value?
2. Does the proposed PES design strengthen the adaptive capacity of the community?
3. Does the proposed PES design encourage the adoption of adaptation measures?

The data analysis framework includes semi-structured interviews conducted with national officials and experts involved in or influenced by decision making for ecosystem management and climate change. This analysis would provide a better understanding of the enabling factors for mainstreaming local agro-ecological adaptation strategies. The interviewees were 16 decision-makers and experts representing a range of institutions as governmental agencies, NGOs and academia. Table 6.1 lists the number of interviewees from each group.

Tab. 6-1: Categorization of interviewees and represented institution (N = 16)

Institution	Number of interviewees
Governmental organization	8
Multilateral organization	4
Research institute	2
Non-governmental organizations	2

The engagement with diverse stakeholders provided a rich input in reviling the challenges to mainstream ecosystem services in the adaptation and development agenda of Guyana. The identification of the strengths and weaknesses of the policy and institutional adaptation framework was used as a foundation to better understand where these challenges might stem from. Results of the interviewees on their perception for strengths and weaknesses in the current policy and institutional framework are summarized in Table 6.2.

Tab.6-2: SWOT matrix of current adaptation policy and institutional framework in Guyana and opportunities to mainstream ecosystem services approach.

	STRENGHTS	WEAKNESSES
Internal	***S1:*** Legal and institutional adaptation framework is strong ***S2:*** Integrates all economic sectors and as well geographical zonation in vulnerability ***S3:*** Complements development needs and priorities ***S4:*** Attempts to integrate adaptation with disaster risk reduction strategies	***W1:*** Limited relevance to local needs for adaptation ***W2:*** Limited engagement with communities in the preparation of processes and strategies ***W3***: Strategies do not clearly state the ownership of different adaptation actions ***W4:*** Overlap of objectives from strategies and limited connectedness between them
	OPPORTUNITIES	**THREATS**
External	***O1:*** Adaptation and disaster risk reduction strategies ***O2:*** Spatial planning and land use strategies ***O3:*** Environmental assessment tools e.g. Environmental Impact Assessment (EIA) ***O4:*** Raising awareness for ecosystem services and wellbeing	***T1:*** Insufficient information on the state of ecosystem services ***T2:*** Funding resources ***T3:*** Insufficient human resources with expertise on the topic ***T4:*** Environment versus development paradigm

6.1.2 Implication for decision making

Stakeholders identified altogether ten key weaknesses and strengths, which characterize the policy and institutional adaptation framework. Overall results show that although stakeholders perceive that the policy and institutional frameworks are well established, they highlighted that there is lack of adequate implementation mechanisms.

The stakeholders as well identified a weak coordination of policies not only between national and local level and as well between local planning. Therefore, this weak alignment of policies limits the effective integration of information on ecosystem services. This leads to loss of information in the hierarchal order of planning strategies thus rarely reaching the local context. The lack of policy alignment could be explained by the limited functioning relationships and communication among actors. Stakeholders identified five

key challenges (Table 6.2) to mainstream ecosystem services approach in policy-making in Guyana. Perceived challenges identified by the interviewees to integrating ecosystem approach to adaptation.

Many of the stakeholders identified that insufficient and outdated information on the state of ecosystem services is a major limiting factor. Most of the available information on the other hand does not provide an appropriate scale and thus is irrelevant and often inaccurate to be used for decision-making purposes at local scale. The stakeholders highlighted the difficulty to integrate ecosystem services data in existing planning tools a great challenge for mainstreaming this approach. Insufficient human and financial related resources are barriers for the initiation of additional activities related to mainstreaming ecosystem services. One of the challenging factors was discussed to be the limited understanding of ecosystem services. Although the stakeholders from the environmental sector demonstrated good knowledge of the concept, the rest of the sectors involved acknowledged that the concept is not clear.

The discussions with the stakeholders revealed that the environmental-development paradigm is strongly present in the context of Guyana. Many of the stakeholders have the understanding that both concepts of ‘environment’ and ‘development’ are conflicting. It is the Low Carbon Development Strategy (LCDS) established the nexus between the concepts, yet implementation is seen challenging.

The stakeholder engagement in line with literature research resulted in defining a list of opportunities for mainstreaming ecosystem services in development planning as presented in Table -3. Although mainstreaming efforts for ecosystem-based adaptation are challenging, results demonstrate that defining synergies between ecosystem services and existing policies is an efficient tool to overcome barriers.

Tab. 6-3: Identified opportunities for mainstreaming ecosystem services as defined by stakeholders. Level of consensus: ◆◆◆ high; ◆◆medium; ◆ low.

Opportunities for mainstreaming ecosystem services	Level of consensus on importance
Adaptation and disaster risk reduction strategies	◆◆◆
Spatial planning and land use strategies	◆◆◆
Environmental assessment tools e.g. Environmental Impact Assessment (EIA)	◆
Raising awareness for ecosystem services and wellbeing	◆◆

Stakeholders expressed major interest in finding synergies between ecosystem services practices for adaptation and disaster risk reduction measures. Decision-makers referred to the role ecosystem services could play in contributing to existing disaster risk mitigation strategies. A common reference was wade to the Mangrove Protection Act, which declares certain mangrove forests to be protected areas highlighting their importance for shore protection. This initiative can potentially be incorporated in Guyana's National Disaster Risk Management Strategy, yet current practices are predominantly concentrated on hard infrastructure approaches and awareness rising is essential to achieve shift in thinking. Additionally, strategic restoration initiatives as reforestation focusing on specific ecosystems with high adaptation value were suggested.

Other synergies identified by the stakeholders are between spatial planning and spatial information of ecosystem services, which can reveal explicitly the specific links between environment and development. This synergy provides opportunities to contribute to development of spatial planning incorporating a landscape perspective with ecosystem services information thus minimizing trade offs from favoring certain ecosystem services over others.

6. 2 Potential of PES to address adaptation needs at Dojran Lake, Macedonia

6.2.1 Identifying and prioritizing Strengths, Weaknesses, Opportunities and Threats

This SWOT analysis was undertaken based on expert judgment and consists of altogether 20 factors characteristic for the proposed PES design for Dojran Lake. The representation of the SWOT matrix is shown in Fig. 6-4.

When the SWOT matrix is developed with its criteria and sub-criteria, the hierarchical structure is established and the next step taken is to identify the relative importance of each of the sub-criteria through pair-wise comparison as following the AHP method. First the criteria is compared in pair and secondly between the different factors within each SWOT criteria, followed by assignment of a weight or priority. These numerical priorities demonstrate the relative ability of a decision to achieve the defined goal.

While SWOT analysis has proved to be a useful foundation for decision-making, it does not include analytical assessment of the relative importance of the variables selected. To overcome this limitation of the analysis, the research proposes an integration of MCDA analytical tool as Analytical Hierarchy Process (AHP) developed by Saaty (1980). Experiences in integrating SWOT analysis with quantitative approaches as AHP are demonstrated in water resource management (Hajkowicz and Collins, 2007) and agriculture management (Giri and Nejadhashemi, 2014). The role of AHP is to support decision makers in reaching a decision, which best responds to a stated problem, rather than prescribing the concrete decision.

	STRENGHTS	**WEAKNESSES**
Internal	***S1:*** Promotion and adoption of sustainable agricultural practices ***S2:*** Potential for bundling of ecosystem services at a landscape level ***S3:*** Increase in land value for generation of high returns ***S4:*** Diversification of income ***S5:*** Increased income	***W1:*** The concept of PES is new and not well understood ***W2:*** Inadequate policy and laws ***W3***: Unclear land tenure rights ***W4:*** Low human resource capacity in water sector infrastructure ***W5***: Absence of water resource management plan
	OPPORTUNITIES	**THREATS**

External	***O1:*** Emerging opportunities for inclusion of PES in national policies ***O2:*** Generates co-benefits for the community ***O3:*** Funding opportunities due to increased international interest ***O4:*** Political will for effective implementation of PES ***O5:*** Increased ecosystem resilience	***T1:*** Monitoring effectiveness remains difficult ***T2:*** Limited understanding of the value of ecosystem services ***T3:*** Ecosystem services trade-off ***T4:*** Climate variability ***T5:*** Weak transboundary cooperation

Tab. 6-4: SWOT matrix of proposed PES design for Dojran Lake.

Through applying this approach, the hierarchical arrangement from the SWOT matrix is alienated into three parts: (a) the decision goal (application of PES scheme as adaptation measure), (b) SWOT criteria and (c) sub-criteria for each SWOT criteria. The *Sub-Criteria Priority* refers to the relative importance of each sub-criterion in the SWOT criteria, while *Overall Priority* demonstrates the importance of each of the factors among all the SWOT criteria. Table 6-5 illustrates the hierarchical arrangement of the SWOT matrix (See Annex 1 on Methodology).

The results on ranking for the criteria priority is highlighting that *Opportunities* (45%) has been identified as having the highest weight among the criteria, followed by *Weaknesses* (25%), *Strengths* (17%) and *Threats* (11.9%). Therefore in comparing the ranking of sub-categories in each SWOT group (see Table X), the sub-criteria under Opportunities has weights above average revealing the importance of emerging opportunities for inclusion of PES in national as policies (sub-criteria O1, 12.3%) and the importance of environmental conservation (O5, 8.2%).

On the other hand the *Weaknesses* criteria shows two key sub-criteria to have high importance limiting the implementation of PES and as well its linkage with adaptation efforts. Inadequate policy and laws for the implementation of PES (W2, 6.1%) and unclear land tenure right (W3, 5.1%) are scored with highest priority for relevance.

The Strengths criteria highlights diversification of income as the sub-criteria of highest weigh (5.7%), while *Threats* highlights that Weak transboundary cooperation is a real disadvantage (T5, 6.7%).

Tab. 6-5: Priority scores for criteria, sub-criteria and overall of SWOT-AHP analysis (Author).

SWOT criteria	Criteria priority	SWOT sub-criteria	Sub-criteria priority	Overall priority
Strengths	0.180	***S1:*** Promotion and adoption of sustainable agricultural practices	0.190	0.030
		S2: Potential for bundling of ecosystem services at a landscape level	0.185	0.036
		S3: Increase in land value for generation of high returns	0.130	0.021
		***S4:* Diversification of income**	**0.324**	**0.057**
		S5: Increased income	0.160	0.027
Weaknesses	0.250	***W1:*** The concept of PES is new and not well understood	0.109	0.028
		***W2:* Inadequate policy and laws**	**0.100**	**0.061**
		***W3*: Unclear land tenure rights**	**0.251**	**0.051**
		W4: Low human resource capacity in water sector infrastructure	0.201	0.023
		W5: Absence of water resource management plan	0.100	0.065
Opportunities	0.450	***O1:* Emerging opportunities for inclusion of PES in national as policies**	**0.236**	**0.123**
		***O2:* Generates co-benefits for the community**	**0.315**	**0.060**
		***O3*: Funding opportunities due to increased international interest**	**0.142**	**0.065**
		***O4:* Political will for effective implementation of PES**	**0.172**	**0.067**
SWOT criteria	**Criteria priority**	**SWOT sub-criteria**	**Sub-criteria priority**	**Overall priority**
		***O5:* Increased ecosystem resilience**	**0.160**	**0.082**
Threats	0.119	***T1:*** Monitoring effectiveness remains difficult	0.210	0.020
		***T2:* Limited understanding of the value of ecosystem services**	**0.105**	**0.053**
		T3: Ecosystem services trade-off	0.375	0.032
		T4: Climate change	0.169	0.004
		***T5:* Weak transboundary cooperation**	**0.277**	**0.067**

6.2.2 Implications for decision making

Analyzing the results from this exercise it is helpful to understand how they can help in designing strategies in order to represent a desired outcomes in the SWOT assessment. As management strategies can both focus on external and internal factors and maximize identified strengths and opportunities while aim to minimize weaknesses and threats.

In this context, the SWOT-AHP method resulted in revealing the prioritization of decision-making criteria to assess the potential of a proposed PES scheme to correspond to adaptation needs. An in-depth analysis of these results is conclusive that the implementation of the proposed PES design at Dojran Lake should be guided primarily by the defined *Opportunities* sub-criteria.

Prioritizing these criteria aims at overcoming key *Weaknesses* (inadequate policy and laws; unclear land tenure rights) and *Threats* (climate change and weak transboundary cooperation), while maximizing *Strengths (*promotion and adoption of sustainable agricultural practices; potential for bundling of ecosystem services at a landscape level). However, in deciding on how to prioritize actions, it is important to consider that all of the interventions are significant but have different impacts. Such a road map may support decision-makers in undertaking a range of measures to create external enabling factors to better explore opportunities.

7. Discussion and conclusions

7.1 Discussion and conclusions

This research has an overall goal to demonstrate that acknowledging ecosystem services in decision making for adaptation would result in the design and implementation of effective and sustainable responses. Founded on an assessment of scientific dialogues and evidence from case studies the present dissertation identifies challenges and opportunities to follow an ecosystem services approach to adaptation. Yet, the dissertation enriches the knowledge on possible paths to transform ecosystem services research into rigorous decisions.

The conceptual framework developed for this research (**Chapter 2**) aims at integrating the concept of ecosystem-based adaptation in a vulnerability framework by bringing together the ecosystem services approach and its role in enhancing copying and adaptive capacities of the socio-ecological system. This conceptual framework leads the research through a stepwise analysis. In analyzing existing knowledge and experiences on socio-ecological vulnerability analysis, the element of human livelihoods' dependence on ecosystems often remains overlooked, thus resulting to only limited understanding of the system's state and internal interactions when it is under risk of natural hazards. The presented conceptual framework aimed to close the gap between concepts and demonstrate the potential key role ecosystem services may play in defining local adaptation strategies.

By applying the methodological framework NetSyMoD (**Chapter 2**), the research was structured around four major steps: *(a) Problem exploration and process set up* (**Chapter 3**); *(b) Participatory activities for the analysis of risks and vulnerabilities* (**Chapter 4**); *(c) Scenario analysis: Payments for Ecosystem Services as adaptation responses* (**Chapter 5**) and *(d) Response option analysis: Potential of PES to address adaptation needs* (**Chapter 6**).

Undertaking the NetSyMoD framework to operationalize the designed vulnerability conceptual framework, provided an opportunity to explore its suitability to support local decision-making processes for ecosystem-based adaptation strategies. Throughout its evolution, the research argues that ecosystem services approach should be part in every stage of a participatory decision-making process in an adaptation context. The principle contribution of the research is the proposal of a methodological advancement by incorporating the ecosystem services approach in participatory decision-making processes as demonstrated in each of the chapters summarized below. Each of the stages of the methodological approach attempts to address an identified challenge or opportunity for ecosystem services integration in the decision-making process.

While **Chapter 2** addresses the initial research question *"How do ecosystem services contribute to reducing vulnerability of social-ecological systems to global changes?"* and conceptualizes the role of ecosystem services for vulnerability analysis and adaptation through the application of an integrated decision-support framework, chapter 3 presents the two case studies for this research – Dojran Lake, Macedonia and West Demerara, Guyana. This chapter provides information on the specific characteristics of the two case studies taking into consideration past natural hazards and current vulnerabilities to climate change. The chapter as well presents the adaptation policy framework for the case studies to provide a background of the state of the art in adaptation priorities and the approaches implemented to address them. It is important to notice that even that both case studies are located in different geographical zones, characterized by diverse policy and institutional frameworks and economic conditions, both socio-ecological systems demonstrate high dependency on natural capital and thus high vulnerability to climate variability. It is agreed that both systems urgently need locally relevant adaptation strategies, which would be appropriate and incorporate their strong relation with natural resources for more effective results.

The participatory activities for the analysis of risks and vulnerabilities in the first phase of the methodological application, demonstrated a promising approach to the problem exploration. **Chapter 4** aimed to demonstrate how to incorporate the concept of ecosystem services in identifying stakeholders, drivers of change and impacts on social-ecological systems. This methodological advancement allows for identifying the critical ES in a participatory manner, which is of great importance to support welfare of stakeholders and in parallel contribute to better understand vulnerability to different exogenous and endogenous drivers of change. Involving the stakeholder perspective in this initial step of building a conceptual model, which represents the causal links between elements for the socio-ecological systems in Guyana and Macedonia and has contributed to understand conflicting values and diverse perspectives of the stakeholders. The undertaken process moreover highlights some theoretical challenges regarding the vulnerability assessment. It was validated that conceptual modelling combined with participatory engagement is an effective approach to bring diverse knowledge together and empower local stakeholders to frame interconnected drivers and components of the system dynamics and analyze its multidimensional relations.

The research question addressed in this section is "*How ecosystem approach contributes to better understand vulnerability of social-ecological systems?".* In order to assess vulnerability of the socio-ecological systems in both case study areas, the ecosystem services approach provided key insights on the role of different actors. The analysis identified beneficiaries of hydrological ecosystem services, which are off-site from identified boundaries of analysis - the smallholder farming plots as in the case of Guyana, and neighboring countries as Greece in the case of Dojran Lake. This reveals that the ecosystem services approach is relevant for a wide range of stakeholders directly or indirectly and emphasizes the importance of scale in valuing the benefits of ecosystem services. The key message from this chapter is not to conclude the level of vulnerability of the socio-ecological system, which is being analyzed, but rather to get a grasp of the vital linkages influencing the state of vulnerability.

Chapter 5 builds upon findings from the previous chapter on vulnerability factors and causal relationships between identified variables of the socio-ecological system. This chapter demonstrates a follow up stage of NetSyMoD on scenario analysis for adaptation responses. The chapter aims to demonstrate the awareness of pitfalls in valuation of ecosystem services, yet highlights its importance to translate key economic information in designing Payments for Ecosystem Services (PES) mechanisms.

The chapter further investigates how to maximize the synergies and minimize the trade-offs between PES and adaptation. Through this exploration the research came across a number of key elements, which enable an effective PES design to correspond to adaptation needs by incorporating information on impacts of climate variability on various actors (ES providers and ES beneficiaries) as well as the generation of ES. Another key element at this analysis is the better understanding of the state of ecosystem services, which are particularly vulnerable to climate variability. Such observations contribute to the better model of the actions planned under the PES design and propose adequate measures. Therefore on the basis of these three variables the PES design is aimed at corresponding to three key criteria upon which the potential of the design to meet adaptation needs was evaluated: (i) enhancement of ecosystem services; (ii) strengthening adaptive capacity and (iii) adopting adaptation measures. Complying with these features, the PES design would have profound implications for adaptation effectiveness. The assessment of both case studies validated that it is possible for a PES design to follow adaptation pathway. Nevertheless, it should be noted that the design of PES, which complies with EbA principles and demonstrates adaptation benefits for the communities, needs to take into account the uncertain nature of climate variability, which may affect the PES mechanism as such.

The outcomes of the research provide insights on the barriers, current and potential activities that can promote the implementation of a PES with the potential to foster ecosystem-based adaptation benefits. A major gap identified is between the concept of ecosystem-based adaptation and the practical implementation of related activities. Legal and institutional settings were defined as unstable in West Demerara and Dojran Lake, but of great importance if adaptation measures in the form of PES-like activities are expected to take place in both regions.

Yet, the advancement of adaptation and application of the methodological approach NetSyMoD has certain limitations as the level of participation in the case of Guyana has taken a different more indirect approach due to political complexity, while in Macedonia the participation element is more strongly incorporated. Therefore, the possibility to perform a comprehensive comparative analysis of both studies is compromised.

While the present research touched upon the importance and efforts in incorporating ecosystem services in policy making, the central challenge that faces scientists and decision-makers is to develop a comprehensive understanding on the dynamic relationships that bound ecosystem services and human wellbeing. More research is needed to provide evidence on the feedback processes, which interlink biophysical, ecological and social systems and define their relationship and interdependence in the context of global changes. The spatial analysis of ecosystem services is an arena to be explored in such a context of urgency for adaptation, which play key role in adaptation scenarios, their generation and flow among different scales. It is therefore key to strengthen the evidence for EbA operationalized by PES.

7.2 Policy implications

This research proposed a framework for incorporating ES in decision support cycles and can be interpreted as a road-map to be implemented in development of strategic adaptation to climate change. This road-map can be easily adapted in order to support decision making at different scales of governance (e.g. administrative regions, national or international).

The process demonstrated by this research suggest that there are indeed many obstacles on the road to integrate scientific information on ecosystem services into decision-making process especially in a local development context. Yet, many of the issues identified in the research are potential opportunities. Development planning, which uses ecosystem services lens guided by defined needs for adaptation have the power to form the basis for an integrated adaptive development planning.

8. References

Adger W., 2006. Vulnerability. Global Environmental Change, vol: 16 (3) pp: 268-281

Adger,W.N.,N.W.Arnell and E.L. Tompkins, 2005: Successful adaptation to cli- mate change across scales. Global Environ. Chang., 15, 77-86

Agard J, Dobson AP, Peterson GD: Trade-offs across space, time, and ecosystem services. Ecol Soc 2006, 11:28.

Altieri M., 1999. The ecological role of biodiversity in agroecosystems. Agriculture, Ecosystems & Environment, vol: 74 (1-3) pp: 19-31

Altieri M., 2002. Agroecology: the science of natural resource management for poor farmers in marginal environments. Agriculture, Ecosystems & Environment, vol: 93 (1-3) pp: 1-24

Altieri, M. a., & Nicholls, C. I. (2013). The adaptation and mitigation potential of traditional agriculture in a changing climate. *Climatic Change*.

Amend, T., Brown, J., Kothari, A., Philips, A. and Stolton, S. (Eds) (2008), Protected Landscapes and Agrobiodiversity Values, Values of Protected Landscapes and Seascapes, IUCN and GTZ, Gland.

Andersson, E., 2006. Urban landscapes and sustainable cities. Ecol. Soc. 11 .

Balmford, A., A. S. L. Rodrigues, M. Walpole, P. ten Brink, M. Kettunen, L. Braat, and R. de Groot. 2008. The economics of biodiversity and ecosystems: scoping the science. European Commission, Cambridge, UK.

Bank of Guyana. 2011. Annual Report 2011. Available at: http://www.bankofguyana.org.gy/bog/images/Reports/annrep2011.pdf

Bank of Guyana. 2012. Half Year Report 2012. Available at: http://www.bankofguyana.org.gy/bog/images/Reports/halfyear2012.pdf

Bureau of Statistics Guyana, 2011. *Statistical Bulletin.* Available at: http://www.statisticsguyana.gov.gy/pubs.html#statsbull

Barbier, E. B. (2007) 'Valuing ecosystem services as productive input', Economic Policy, vol 22, no 49, pp177–229

Barde, JP and Pearce, D. 1991. Valuing the Environment. Earthscan.

Bennett E. and Garry D., 2009. Review and understanding relationships among multiple ecosystem services. pp: 1394-1404

Benton, T. G., Vickery, J. A., & Wilson, J. D. 2003. Farmland biodiversity: is habitat heterogeneity the key? Trends in Ecology and Evolution, 18, 182 -188

Berkes F, Folke C. 1998. Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience. Cambridge University Press: Cambridge, UK.

Berkes, F., Colding, J., Folke, C. (Eds.), 2003. Navigating Social–Ecolo- gical Systems: Building Resilience for Complexity and Change. Cambridge University Press, Cambridge, UK

Bockstaller, C., Girardin, P., (2003). How to validate environmental indicators. *Agricultural Systems* 76, 639–653

Bohn, B.A., Kershner, J.L., 2002. Establishing aquatic restoration priorities using a watershed approach. J. Environ. Manage. 64, 355-363.

Bonacci, O., Popovska, C., Geshovska, V. 2013. Analysis of transboundary Dojran Lake mean annual water level changes. Environ Earth Sci .

Brander, L.M., Florax, J.G.M., Vermaat, J.E., 2006. The empirics of wetland valuation: a comprehensive summary and meta-analysis of the literature. Environ. Resour. Econ. 33, 223–250.

Brouwer, R., 2000. Environmental value transfer: state of the art and future prospects. Ecol. Econ. 32, 137–152.

Brouwer, R., Langford, I.H., Bateman, I.J., Turner, R.K., 1999. A meta-analysis of wet- land contingent valuation studies. Regional Environ. Change 1, 47–57.

Bryman A., (2001), Social Research Methods, Oxford, Oxford University Press

Burkhard, B., Petrosillo, I., Costanza, R., 2010. Ecosystem services – Bridging ecology, economy and social sciences. Ecological Complexity 7 (3), 257–259. Burkhard,

Bynoe, P. et al. 2011, Guyana's Forest Resources and Environmental Services. Report delivered to the Guyana Forestry Commission 11 March 2011.

Calvet-Mir L., Gómez-Baggethun E., Reyes-García V., 2012. Beyond food production: Ecosystem services provided by home gardens. A case study in Vall Fosca, Catalan Pyrenees, Northeastern Spain. Ecological Economics, vol: 74 pp: 153-160

Campbell A., Kapos V., Chenery A., Kahn, S.I., Rashid M., Scharlemann J.P.W., Dickson B. 2009. *The linkages between biodiversity and climate change adaptation.* UNEP World Conservation Monitoring Centre.

Cardinale, B.J., Duffy, J.E., Gonzalez, A., Hooper, D.U., Perrings, C., Venail, P., Narwani, A., Mace, G.M., Tilman, D., Wardle, D. A., Kinzig, A.P., Daily, G.C., Loreau, M. & Grace, J.B. 2012. Biodiversity loss and its impact on humanity. *Nature.* 486 (7401), pp. 0–9.

Chapin, F. S. I., Kofinas, G. P. and Folke, C. eds. 2009. Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing. Springer, New York.

Comín, F.A., Romero, J.A., Hernandez, O., Menendez, M., 2001. Restoration of wetlands from abandoned rice fields for nutrient removal, and biological community and landscape diversity. Rest. Ecol. 9, 201-208.

Corbera, E., Kosoy, N., and Martínez Tuna, M. 2007. Equity implications of marketing ecosystem services in protected areas and rural communities: Case studies from Meso-America. *Global Environmental Change*, 17(3-4):365–380.

Cutter S., Carolina S., Boruff B., Shirley W., 2003. Social Vulnerability to Environmental Hazards. vol: 84 (2)

Daily, G. (Ed.), 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington DC.

Daly, H. E. and Farley, J. 2010. *Ecological Economics: Principles and Applications*. Island Press, Washington, D.C., 2nd edition.

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. *Ecological Economics*, *41*(3), 393–408.

de Groot, R. S., Alkemade, R., Braat, L., Hein, L., & Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological Complexity*, *7*(3), 260–272. doi:10.1016/j.ecocom.2009.10.006

Dwire, K.A., Lowrance, R.R., 2006. Riparian ecosystems and buffers— multiscale structure, function, and management: introduction. J. Am. Water Res. Assoc. 42, 1–4.

Eakin, H., C.M. Tucker and E. Castellanos, 2005: Market shocks and climate variability: the coffee crisis in Mexico, Guatemala, and Honduras. Mt. Res. Dev., 25, 304-309.

Engel, S., S. Pagiola and S. Wunder. 2008. Designing payments for environmental services in theory and practice: an overview of the issues. Ecological Economics 65:663–674

ECLAC, 2011a. An Assessment of the Economic Impact of Climate Change on the Agricultural Sector in Guyana.

ECLAC, 2011b. An Assessment of the Economic Impact of Climate Change on the Coastal and Human Settlement Sectors in Guyana.

ECLAC, 2011c. An Assessment of the Economic Impact of Climate Change on the Health Sector in Guyana.

EPA, 2007. National Capacity Self-Assessment in Guyana: Cross-cutting capacity issues

EPA (Environmental Protection Agency). 2001. Guyana's National Vulnerability Assessment to Sea Level Rise.

EPA (Environmental Protection Agency). 2010. Forth National Report to the Convention on Biological Diversity. Available at: http://www.cbd.int/doc/world/gy/gy-nr-04-en.pdf

Faber, SC; Costanza R; Wilson, MA, 2002, Economic and ecological concepts for valuing ecosystem services. *Ecological Economics* 41(3): 375-392

Fallon, P., Betts, R. 2010. Science of the Total Environment Climate impacts on European agriculture and water management in the context of adaptation and mitigation — The importance of an integrated approach. Science of the Total Environment 408 (23), 5667-5687

Universite Catholique de Louvain, Brussels, Belgium. "EM-DAT: The OFDA/CRED International Disaster Database. Available at: http://www.preventionweb.net/english/countries/statistics/?cid=73

World Bank, 2006. Where is the Wealth of Nations. New York. Available at: http://siteresources.worldbank.org/INTEEI/214578-1110886258964/20748034/All.pdf

Fisher J., Patenaude G., Giri K., Lewis K., Meir P., Pinho P., Rounsevell M., Williams M., 2014. Understanding the relationships between ecosystem services and poverty alleviation: A conceptual framework. Ecosystem Services, vol: 7 pp: 34-45

Fohrer, N., Haverkamp, S., Frede, H.G., 2005. Assessment of the effects of land use patterns on hydrologic landscape functions: development of sustainable land use concepts for low mountain range areas. *Hydrological Processes* 19 (3), 659–672.

Folke, C., 2006. Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change*, 16(3), pp.253–267.

Forman, R. T. T. 1995. Land mosaics: The ecology of landscapes and regions. Cambridge University Press, Cambridge, UK.

Forrester J.W., 1995. The beginning of system dynamics. The McKinsey Quarterly Issue 4, p4-16.

Füssel, H-M 2007. Adaptation planning for climate change: concepts, assessment approaches and key lessons. Sustainability Science 2:265–275

Fussel, H.M., Klein, R.T.J., 2006. Climate change vulnerability assessments: an evolution of conceptual thinking. Climatic Change 75, 301–329.

Garbach, K., Lubell, M., & DeClerck, F. a. J. 2012. Payment for Ecosystem Services: The roles of positive incentives and information sharing in stimulating adoption of silvopastoral conservation practices. *Agriculture, Ecosystems & Environment*, *156*, 27–36.

Ghazoul, J., Garcia, C., Kushalappa, C.G. 2009. Forest Ecology and Management Landscape labelling : A concept for next-generation payment for ecosystem service schemes. Forest Ecology and Management 258, 1889-1895

Giupponi, C. 2014. *Decision Support for Mainstreaming Climate Change Adaptation in Water Resources Management* in WATER RESOURCES MANAGEMENT, vol. 28, pp. 4795-4808

Goulder LH and Kennedy D. 1997. Valuing ecosystem services: philosophical bases and empirical methods. In: Daily G, editor. Nature's Services. Washington, DC: Island Press. p 23–48.

GFC (Guyana Forest Commission). 2011. Guyana REDD+ Monitoring Reporting and Verification System (MRVS) Interim Measures Report. Available at: http://www.forestry.gov.gy/Downloads/Guyana_MRVS_Interim_Measures_Report_16_March_2011.pdf

Government of Guyana 2010. A Low Carbon Development Strategy. Transforming Guyana's Economy While Combating Climate Change, May 2010. Office of the President, Republic of Guyana. Available at: http://www.lcds.gov.gy/images/stories/Documents/Low%20Carbon%20Development%20Strategy%20-%20May%202010.pdf

GoG (Government of Guyana). 2000. *Guyana National Development Strategy 2002 – 2010.* Avalable at: http://www.guyana.org/NDS/NDS.htm

GoG (Government of Guyana) 2001. First National Communication to UNFCCC.

GoG (Government of Guyana) 2012. Second National Communication to UNFCCC. Available at: http://unfccc.int/resource/docs/natc/guync2.pdf

GFC (Guyana Forest Commission). 2010. Mangrove Management Plan. Second Draft. Available at: http://www.forestry.gov.gy/Downloads/Mangrove%20Action%20Plan.pdf

Guyana Forestry Commission, 2010. Forest Sector Information Report. Annual Review 2010.

Greiber, T. and Schiele, S., editors (2011). *Governance of Ecosystem Services: Lessons Learned from Cameroon, China, Costa Rica, and Ecuador*. Number 79. IUCN, Gland, Switzerland.

Grimble, R. and Wellard, K. 1997. Stakeholder Methodologies in Natural Resource Management: a Review of Principles, Contexts, Experiences and Opportunities. Agricultural Systems, Vol.55, No.2 pp.173-193.

Gunderson, L.H. 2002. Why systems of people and nature are not just social and ecological systems. In: Panarchy. Understanding Transformations in Human and Natural Systems,ed. L.H. Gunderson & C.S. Holling, pp. 103–119. WashingtonDC, USA: Island Press. Williams,

Hajkowicz, S., Collins, K., 2007. A review of multiple criteria analysis for water resource planning and management. Water Resources Management 21, 1553–1566

Haines-Young, R., and Potschin, M., 2010. Proposal for a Common International Classification of Ecosystem Goods and Services (CICES) for Integrated Environmental and Economic Accounting (V1). *Report to the European Environmental Agency Centre*

Hein, L., van Koppen, K., de Groot, R.S., and van Ierland, E.C., 2006. Spatial scales, stakeholders and the valuation of ecosystem services. Ecological Economics 57, 209-228.

Holling, C. S. (2001). Understanding the Complexity of Economic, Ecological, and Social Systems. *Ecosystems*, *4*(5), 390–405. doi:10.1007/s10021-001-0101-5

Holt- Giménez E., 2002. Measuring farmers' agroecological resistance after Hurricane Mitch in Nicaragua: a case study in participatory, sustainable land management impact monitoring. Agriculture, Ecosystems & Environment, vol: 93 (1-3) pp: 87-105

Hydro-meteorological service, Guyana. Available at: URL: http://www.hydromet.gov.gy/climate.html

Jack, B. K., Kousky, C., and Sims, K. R. E. 2008. Designing payments for ecosystem services: Lessons from previous experience with incentive-based mechanisms. *Proceedings of the National Academy of Sciences of the United States of America*, 105(28):9465–70.

Jones, C., Baker, M., Carter, J., Jay, S., Short, M., Wood, C., 2005. Strategic Environmen- tal Assessment and Land Use Planning: An International Evaluation. Earthscan, London.

Kajanus, M., Leskinen, P., Kurttila, M., Kangas, J., 2012. Making use of MCDS methods in SWOT analysisdlessons learnt in strategic natural resources management. For. Policy Econ. 20, 1 - 9.

Klein, R.J.T., Eriksen, S.E.H., Naess, L.O., Hammill, A., Tanner, T.M., Robledo, C., O'Brien, L. 2007. 'Portfolio screening to support the mainstreaming of adaptation to climate change into development assistance', Climatic change 84:23-44.

Kosoy, N., Corbera, E., 2010. Payments for ecosystem services as commodity fetishism. Ecol. Econ. 69, 1228–1236

Kremen, C., Iles, A., Bacon, C., & Editorial, G. (2012). Diversified Farming Systems : An Agroecological , Systems-based, *17*(4).

Kumar P., Brondizio E., Elmqvist T., Gatzweiler F., Gowdy J., Groot D., Pascual U., Reyers B., Smith R., Sukhdev P., 2010. TEEB - Chapter 7; Key Messages and Linkages with National and Local Policies. pp: 1-33

Lamarque, P., Quetier, F., Lavorel, S., 2011. The diversity of the ecosystem services concept and its implications for their assessment and management. *C.R. Biologies* 11, 791– 804.

Lambin, E.F., Turner II, B.L., Geist, H.J., Agbola, S.B., Angelsen, A., Bruce, J.W., Coomes, O., Dirzo, R., Fischer, G., Folke, C., George, P.S., Homewood, K., Imbernon, J.,

Lasco, R. D., Delfino, R.J.P., Catacutan, D.C. Simelton, E.S. and Wilson, D.M. 2013. Climate risk adaptation by smallholder farmers: the roles of trees and agroforestry. Current Opinion in Environmental Sustainability 6, 83-88.

Laurans, Y., A. Rankovic, L. Mermet, R. Billé., R. Pirard. 2013b. Actual use of ecosystem services valuation for decision-making: questioning a literature blindspot. Journal of Environmental Management 119: 208-219.

Leemans, R., Li, X., Moran, E.F., Mortimore, M., Ramakrishnan, P.S., Richards, J.F., Ska ˚nes, H., Steffen, W.L., Stone, G.D., Svedin, U., Veldkamp, T.A., Vogel, C., Xu, J., 2001. The causes of land use and land-cover change: moving beyond the myths. Global Environ. Change: Hum. Policy Dimension 11, 261–269.

Locatelli, B., Kanninen,M., Brockhaus,M., Colfer, C. J. P.,Murdiyarso, D. and Santoso, H. 2008.Facing an uncertain future: how forest and people can adapt to climate change. Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Loreau, M. & de Mazancourt, C. 2013. Biodiversity and ecosystem stability: A synthesis of underlying mechanisms. *Ecology Letters.* 16, pp. 106–115.

Luers A., Lobell D., Sklar L., Addams C., Matson P., 2003. A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico. Global Environmental Change, vol: 13 (4) pp: 255-267

Maracchi G, Sirotenko O, Bindi M. 2005. Impacts of present and future climate variability on agriculture and forestry in the temperate regions: Europe. Clim Change 70, 117–35

Martin-Ortega J (2012) Economic prescriptions and policy applications of the European Water Framework Directive.

Massol, F. and Petit, S. 2013. Interaction Networks in Agricultural Landscape Mosaics, 49, 291-338

McNeely JA, Schroth G. 2006. Agroforestry and biodiversity conservation-traditional practices, present dynamics, and lessons for the future. Biodivers Conserv 15, 549-554

McSweeney, C., New, M., Lizcano, G. 2008. UNDP Climate Change Country Profiles: Guyana.

Milder, J. C., S. J. Scherr, and C. Bracer. 2010. Trends and future potential of payment for ecosystem services to alleviate rural poverty in devaloping countries. *Ecology and Society* 15 (2):4.

Ministry of Health, National Climate Change Health Adaptation Strategy and Action Plan of the Republic of Macedonia, 2011

Mitsch,W.J., Gosselink, J.G., 2000. The value of wetlands: importance of scale and landscape setting. Ecol. Econ. 35, 25-33.

Moreno-Mateos, D., Mander, U., Comín, F.A., Pedrocchi, C., Uuemaa, E., 2008. Relationships between landscape pattern, wetland characteristics, and water quality in agricultural catchments. J. Environ. Qual. 37, 2170-2180

Munang, R., Thiaw, I., Alverson, K., Goumandakoye, M., Liu, J., & Kingdom, U. (2013). Using Ecosystem-Based Adaptation Actions to Tackle Food Insecurity, (April), 37–41.

Muradian, R., Corbera, E., Pascual, U., Kosoy, N., and May, P. H. 2010. Reconciling theory and practice: An alternative conceptual framework for understanding payments for environmental services. *Ecological Economics*, 69(6):1202–1208.

Mylopoulos, Y.A. and Kolokytha, E.G. 2008 Integrated water management in shared water resources: The EU Water Framework Directive implementation in Greece Physics and Chemistry of the Earth 33, 347–353

National Mangrove Management Action Plan, 2010. Available at URL: http://www.gcca.eu/sites/default/files/catherine.paul/national_mangrove_management_action_plan_2010-2012.pdf (Referred to: 12 October 2014)

Naiman RJ, Decamps H: The ecology of interfaces: riparian zones. Annu Rev Ecol Syst 1997, 28:621-658.

Nedkov S. and Burkhard B. 2012. Flood regulating ecosystem services— Mapping supply and demand, in the Etropole municipality, Bulgaria. Ecological Indicators 21:67-79.

Nelson, E. J., & Daily, G. C. 2010. Modelling ecosystem services in terrestrial systems. *F1000 Biology Reports*, *2*(July), 53.

Niemeijer, D., De Groot, R.S., 2008. Framing environmental indicators: moving from causal chains to causal networks. Environment, Development and Sustainability 10, 89–106.

Nuñez L. 2005. Tools for forecasting for warning as well as hazard assessment to reduce impact of natural disasters on agriculture, forestry and fisheries. In: Sivakumar MVK, Motha RP, Das HP, editors. Natural disasters and extreme events in agriculture— impacts and mitigation. Berlin: Springer Verlag. p. 71–92.

O'Brien,K., R. Leichenko,U.Kelkar,H.Venema,G.Aandahl,H. Tompkins,A. Javed, S. Bhadwal, S. Barg, L. Nygaard and J.West, 2004: Mapping vulnera- bility to multiple stressors: climate change and globalization in India. Global Environ. Chang., 14, 303-313

Olsson, P., Folke, C., Berkes, F., 2004. Adaptive co-management for building resilience in social-ecological systems. Environmental Management 34, 75–90.

Ostrom E., 2009. A general framework for analyzing sustainability of social-ecological systems. Science (New York, N.Y.), vol: 325 (5939) pp: 419-22

Pagiola, S. (2008) Payments for environmental services in Costa Rica. *Ecological Economics*, 65, 712–724

Pascual, U., Perrings, 2007. Developing incentives and economic mechanisms for in situ biodiversity conservation in agricultural landscapes. Agriculture, Ecosys- tems and Environment 121, 256–268.

Pert, P.L., Butler, J.R., Brodie, J.E., Bruce, C., Honzak, M., Kroon, F.J., Metcalfe, D., Mitchell, D., Wong, G., 2010. A catchment-based approach to mapping hydro- logical ecosystem services using riparian habitat: a case study from the Wet Tropics, Australia. Ecological Complexity 7, 378–388

Pelling, M. (1999). The political ecology of flood hazard in urban Guyana, *Geoforum*, *30*: 249–261.

Pielke R., Prins G., Rayner S., Sarewitz D., 2007. Lifting the taboo on adaptation. *Nature,* 445, 597-598.

Pimentel, D., P. Hepperly, J. Hanson, D. Douds, and R. Seidel. 2005. Environmental, energetic, and economic comparisons of organic and conventional farming systems. Bioscience 55 :573–582

Pivot, J.-M., Josien, t., and Martin, P. 2002. Farms adaptation to changes in flood risk: a management approach, *Journal of Hydrology*, 267, 12–25

Porras I.G.M. and Neves N. 2008. All that glitters: A review of payments for watershed services in developing countries. Natural Resource Issues No.11. International Institute for Environment and Development, London.

Power A., 2010. Ecosystem services and agriculture: tradeoffs and synergies. Philosophical transactions of the Royal Society of London. Series B, Biological sciences, vol: 365 (1554) pp: 2959-71

Raudsepp-Hearne, C., Peterson, G. D. & Bennett, E.M. 2010. Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. Proceedings of the National Academy of Sciences of the United States of America, 107, 5242–5247. Walker,

Randhir, D., Ekness, P. 2013. Water quality change and habitat potential in riparian ecosystems. Ecohydrology & Hydrobiology 13, 192–200

Redford, K.H., Adams, W.M., 2009. Payment for ecosystem services and the challenge of saving nature. *Conservation Biology* 23, 785–787.

Redman C., Grove J., Kuby L., 2004. Integrating Social Science into the Long-Term Ecological Research (LTER) Network: Social Dimensions of Ecological Change and Ecological Dimensions of Social Change. Ecosystems, vol: 7 (2) pp: 161-171

Reed M., Podesta G., Fazey I., Geeson N., Hessel R., Hubacek K., Letson D., Nainggolan D., Prell C., Rickenbach M., Ritsema C., Schwilch G., Stringer L., Thomas A., 2013. Combining analytical frameworks to assess livelihood vulnerability to climate change and analyse adaptation options. Ecological Economics, vol: 94 pp: 66-77

Reid, W.V., Mooney, H.A., Cropper, A., Capistrano, D., Carpenter, S.R., Chopra, K., Dasgupta, P., Dietz, T., Duraiappah, A.K., Hassan, R., 2005. Millennium Ecosystem Assessment Synthesis Report. Island Press, Washington, DC.

Reyers B., Biggs R., Cumming G., Elmqvist T., Hejnowicz A., Polasky S., 2013. Getting the measure of ecosystem services: a social–ecological approach. Frontiers in Ecology and the Environment, vol: 11 (5) pp: 268-273

Roberts, D., Boon, R., Diederichs, N., Douwes, E., Govender, N., Mcinnes, a., … Spires, M. (2011). Exploring ecosystem-based adaptation in Durban, South Africa: “learning-by-doing” at the local government coal face. *Environment and Urbanization*, *24*(1), 167–195.

Rodriguez JP, Beard TD Jr, Bennett EM, Cumming GS, Cork S, 26.

Rojas, M. and Aylward, B. 2002. Cooperation between a small private hydropower producer and a conservation NGO for forest protection: The case of La Esperanza, Costa Rica. *Technical report, Food and Agriculture Organization (FAO) of the United Nations*, Rome.

Rosset P., Sosa B., Jaime A., Lozano D., 2011. The Campesino-to-Campesino agroecology movement of ANAP in Cuba: social process methodology in the construction of sustainable peasant agriculture and food sovereignty. The Journal of peasant studies, vol: 38 (1) pp: 161-91

Rounsevell, M.D.A., Dawson, T.P., Harrison, P.A., 2010. A conceptual framework to assess the effects of environmental change on ecosystem services. Biodiversity and Conservation 19 (10), 2823–2842.

Saaty, T.L., 1980. The Analytic Hierarchy Process. McGraw-Hill, New York.

Sileshi, G., Akinnifesi, F., Ajayi, O.C., Muys, B. 2011. Integration of legume trees in maize-based cropping systems improves rain use efficiency and yield stability under rain-fed agriculture. Agricultural Water Management 98, 1364-1

Schoeneberger M, Bentrup G, de Gooijer H, Soolanayakanahally R, Sauer T et al. 2012. Branching out: Agroforestry as a Climate Change Mitigation and Adaptation Tool for Agriculture.

Scholte, S. S. K., Teeffelen, A. J. A. Van, & Verburg, P. H. 2015. Integrating socio-cultural perspectives into ecosystem service valuation : A review of concepts and methods. *Ecological Economics*, *114*, 67–78.

Schomers, S. and Matzdorf, B. 2013. Payments for ecosystem services: A review and comparison of developing and industrialized countries. *Ecosystem Services*, pages 1–15.

Scott, J. 2000. Social Network Analysis: a Handbook. London: Sage.

Sivakumar M, Stefanski R. 2007. Climate, extreme events and land degradation. In: Sivakumar MVK, Ndegwa N, editors. Climate and land degradation. Germany: Springer- Heidelberg. p.105–35.

Snyder, C.D., Young, J.A., Villella, R., Lemarie, D.P., 2003. Influences of upland and riparian land use patterns on stream biotic integrity. Landscape Ecol. 18 (7), 647–664.

Sudmeier-rieux, K., & Ash, N. (n.d.). *Environmental Guidance Note for Disaster Risk Reduction Healthy Ecosystems for Human Security*.

Sundaravadivel M, Vigneswaran S: Constructed wetlands for wastewater treatment. Crit Rev Environ Sci Technol 2001, 31:351-409.

Swallow, B. M., Sang, J. K., Nyabenge, M., Bundotich, D. K., Duraiappah, A. K., & Yatich, T. B. (2009). Tradeoffs, synergies and traps among ecosystem services in the Lake Victoria basin of East Africa. *Environmental Science & Policy*, *12*(4), 504–519.

Swinton, S.M., Lupi, F., Robertson, G.P., Hamilton, S.K., 2007. Ecosystem services and agriculture: Cultivating agricultural ecosystems for diverse benefits. *Ecological Economics* 64, 245–252

Tansley, A.G., 1935. The use and misuse of vegetational concepts and terms. Ecology 16, 284–307.

TEEB, 2010. The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recom- mendations of TEEB.

ten Brink, P., 2011, The Economics of Ecosystems and Biodiversity in National and International Policy Making. An output of TEEB: The Economics of Ecosystems and Biodiversity. Earthscan. London.

Thiere, G., Milenkovski, S., Lindgren, P.E., Sahlen, G., Berglund, O., Weisner, S.E.B., 2009.Wetland creation in agricultural landscapes: biodiversity benefits on local and regional scales. Biol. Conserv. 142, 964-973.

Tognetti, S. S., Aylward, B., and Mendoza, G. 2006. Markets for Watershed Services. *Encyclopedia of Hydrological Sciences*.

Turner, B.L., R.E.Kasperson, P.A.Matson, J.J.McCarthy, R.W. Corell, L. Chris- tensen,N. Eckley, J.X.Kasperson,A. Luers,M.L.Martello, C. Polsky,A. Pul- sipher and A. Schiller, 2003: A framework for vulnerability analysis in sustainability science. P. Natl. Acad. Sci. USA, 100, 8074-8079.

Turner, R.K., van den Bergh, C.J.M., Soderqvist, T., Barendregt, A., van der Straaten, J., Maltby, E., van Ierland, E.C., 2000. Eco- logical–economic analysis of wetlands: scientific integration for management and policy. Ecological Economics 35, 7–23.

Van De Sand, I. 2012. Payments for Ecosystem Services in the Context of Adaptation to Climate Change. *Ecology And Society*, *17*(1), 1–30.

Turner, R. K., & Daily, G. C. (2007). The Ecosystem Services Framework and Natural Capital Conservation. *Environmental and Resource Economics*, *39*(1), 25–35. doi:10.1007/s10640-007-9176-6

Van Noordwijk M, Hoang MH, Neufeldt H, O¨ born I, Yatich T (Eds): How Trees and People can Co-adapt to Climate Change: Reducing Vulnerability Through Multi-Functional Agroforestry Landscapes. Nairobi: World Agroforestry Centre (ICRAF); 2011.

Verchot LV, Noordwijk M, Kandji S, Tomich T, Ong C, Albrecht A, Mackensen J. 2007. Climate change: linking adaptation and mitigation through agroforestry. Mitig Adapt Strat Global Change 12, 901-918

Vermeulen, S., Koziell, I., 2002. Integrating Global and Local Values. A Review of Biodiversity Assessment. IIED, London.

Vidon, P.G.F., Hill, A.R., 2004. Landscape controls of nitrate removal in stream riparian

Vignola R., Locatelli B., Martinez C., Imbach P., 2009, Ecosystem-based adaptation to climate change: what role for policy-makers, society and scientists? *Mitigation and Adaptation Strategies for Global Change* 14(8), 691-696.

Walker, B., Carpenter, S., Anderies, J., Abel, N., Cumming, G., Janssen, M., Pritchard, R. 2002. Resilience Management in Social-ecological Systems : a Working Hypothesis for a Participatory Approach, *6*(1).

Wei, W., Álvarez, I., Martín, S., 2013. Sustainability analysis: viability concepts to consider transient and asymptotical dynamics in socio-ecological tourism-based systems. Ecol. Model. 251, 103–113.

Wertz-Kanounnikoff S., Locatelli B., Wunder S., Brockhaus M., 2011. Ecosystem-based adaptation to climate change: what scope for payments for environmental services? Climate and Development 3(2): 143-158

Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D., David, C., 2009. Agroecology as a science, a movement and a practice. A review. Agron. Sustain. Dev. 29, 503–515.

Willaarts BA, Volk M, Aguilera PA: Assessing the ecosystem services supplied by freshwater flows in Mediterranean agroecosystems. Agric Water Manage 2012, 105:21-31.

Wilkinson, C., Saarne, T., Peterson, G.D., Colding, J., 2013. Strategic spatial planning and the ecosystem services concept – an historical exploration. Ecol. Soc. 18 .

Woodward, R.T., Wui, Y.S., 2001. The economic value of wetland services: a meta-analysis. Ecol. Econ. 37, 257–270.

Wu, J., 2014. Urban ecology and sustainability: the state-of-the-science and future directions. Landsc. Urban Plan. 1–13,

Wunder, S. and Albán, M. (2008). Decentralized payments for environmental services: The cases of Pimampiro and PROFAFOR in Ecuador. *Ecological Economics*, 65(4):685–698.

Zedler, J.B., 2000. Progress in wetland restoration ecology. Trends Ecol. Evol. 15, 402 – 407

Zhang, W., Ricketts, T. H., Kremen, C., Carney, K., & Swinton, S. M. (2007). Ecosystem services and dis-services to agriculture. *Ecological Economics*, *64*(2), 253–260.

ANNEX I

Analytical Hierarchy Prioritization (AHP)

The information gathered from the pair-wise comparison exer- cise can be represented by a square and reciprocal matrix (Saaty matrix – see Eq. (1)), where the a_{ij} represents the relative impor- tance of the analysed elements obtained by comparing sub- criterion i with sub-criterion j while its reciprocal ($1/a_{ij}$) is expressed in the opposite side of the principal diagonal.

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & a_{ij} & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \quad (1)$$

On the other hand, if we assume a perfect consistency of an ex- pert judgement, then a_{ik} ⍰ $a_{kj} = a_{ij}$ for all i, j, k. This characteristic implies that w_i and the numerical ratings of a_{ij} satisfy $w_i/w_j = a_{ij}$ for all i, j. Thus, Saaty´ s matrix can also be expressed in the follow- ing form (see Eq. (2)):

$$A = \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \dots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \dots & \frac{w_2}{w_n} \\ \dots & \dots & \frac{w_i}{w_j} & \dots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \dots & \frac{w_n}{w_n} \end{bmatrix} \quad (2)$$

An eigenvector of the matrix (Saaty, 1980), is used.

$$W = \lim_{k \to \infty} \frac{A^k e}{e^T A^k e} \quad (3)$$

The maximum eigenvalue (k_{max}) can be obtained using the following expression:

$$\lambda_{max} = \sum_i \sum_j a_{ij} w_i \quad (4)$$