Integrating the human dimension in ecosystem based adaptation to global changes

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Abstract

In the quest for adaptation to climate change, ecosystems in good structural and functional status are widely recognised 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). Unfortunately, only limited efforts are in place to integrate ecosystems' and society's adaptive capacities, while instead the potential for synergies is evident. By taking the challenge of including the complex set of natural and human providers and beneficiaries in the dynamic analysis of the SES, a truly holistic approach can be implemented and adaptive effectiveness can substantially improve. Exploring the notion of ecosystem services (i.e. regulating, provisioning, supporting and cultural) and social services (e.g. maintenance and sustainable management of land and resources to limit vulnerability) being an integral part of a unique adaptation response strategy provides an avenue for an innovative approach based upon the notion of socio-ecosystem services (SES-S).

Ecosystem Based Adaptation (EbA) is an already established approach, which we propose to be further developed 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 recognised 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. A consolidated framework for communicating societal and environmental issues can be used to introduce a system dynamics approach can be applied in the DPSIR (Drivers–Pressures–State Change–Impact–Response) framework. The original framework has been further developed by the authors to include exogenous drivers for the formalisation of the adaptation problem according to the notion of SES-S based adaptation. An illustration of the proposed approach provided through the presentation of a case study on the coastal zone in Guyana.

Keywords: *Ecosystem services, ecosystem-based adaptation, coastal ecosystems, Guyana*

1. INTRODUCTION

It is widely asserted that environmental and climatic changes pose most tangible effects on communities highly dependent on natural ecosystems to support their livelihoods [1]. 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 [2]. 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 [3]. 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 approach to adaptation (EbA) is a rather recently introduced concept [4][5]. 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 [6].

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 of SES (here Socio-Ecosystem Services), in which not only the provision of services from ecosystems to humans is considered, but also the services provided by society (e.g. maintenance of land in rural areas to limit vulnerability) and the fluxes between any kind of provider and any beneficiary. 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.

2. STUDY AREA

The coastal zone of Guyana is in many areas 0.5 – 1.0 m and more below sea level, making it prone to strong tidal influences and extremely vulnerable to storm surges and sea level rise. The coastline constitutes only 7% (216,000km2) of the country's total land, yet it is where human settlements are most concentrated and 76.6% (ca. 540 000 people) of the population live predominantly in rural settings [7]. In addition to human settlements most of the country's economic assets e.g. infrastructure and agriculture (e.g sugar cane and rice fields) are located at the coastal plain as well. The coastal area is a mosaic of natural systems (e.g. mangroves, mud banks) and man-made sea defenses (e.g. seawalls, drainage system), which serve to protect the coast from inundation and flooding. It is divided into two zones with different level of impact and developmental status – ***Coastal zone I and II***. ***Coastal zone I*** is densely populated region of eastern Essequibo and up to Berbice and Demerara. ***Coastal zone II*** is the western Essequibo area where the coast comprises largely of natural ecosystems and limited built coastal protection. The coast is characterised by partly degraded ecosystems and extensive engineered coastal protection [7].

Extreme events as floods have been observed to intensify in Guyana over the last decade causing large damage on livelihoods and major economic sectors located at the coastal zone. In the last decade rice production has been observed to decline by almost 30% in the period 1997 - 2009, which is attributed to crop diseases and inconsistent weather [8]. The damages from the flood in 2005 alone resulted in total loss of 60% from GDP from which agriculture e.g. rice crops, experiencing the greatest damage and highest cost of US$ 8.8 million [8]. Adaptation measures in the form of coastal protection and agricultural intensification has been implemented in the past, yet threats from natural hazards continue to increase exposing communities dependent on subsistence agriculture to more severe impacts. Climate projections reveal economic losses to reach US$150 million by 2030 [9]. Based on IPCC scenarios, projections show loss of agricultural land to be between 48,393 ha and 85,585 ha by 2031 resulting in estimated economic cost between USD$ 794 - 1,577 million for rice and USD$ 144 - 300 million. Subsistence agriculture is expected to be highly impacted and endangering livelihoods [8].

3. METHODS

By taking the challenge of including the complex set of natural and human providers of services and beneficiaries in the analysis a truly holistic approach can be implemented and operational effectiveness can substantially improve. The integration of this approach into the complex scene of adaptation efforts would be analysed through system dynamic modeling of the socio-ecological setting with the intention to explore the behavior of the system and inform decision-makers. The system analysis will take form of four consecutive steps build upon the theoretical foundation of system dynamic modeling[10]. An initial step is the development of Cognitive Map describing the system, with its endogenous and exogenous elements in the form of a DPSIR (Drivers–Pressures–State Change–Impact–Response) framework. The initial application of DPSIR would provide an opportunity to explore key elements and their functionality in a system boundary and enable a better understanding and communication in the policy-making arena [11]. Build upon this knowledge the causal loop diagram will provide an overview of interactions and functional dependencies of the key system variables, which will be further applied in the development of a stock and flow map. Such a conceptual map will characterize the system and generate information upon which policy decisions can be formulated and tested. The modeling steps will be performed using the visual modeling tool VENSIM.

The development of this concept can be illustrated with a case study of the coastal socio-ecological system in the context of highly vulnerable predominantly rural agricultural setting in Guyana. Outcomes would provide a scientific framework for policy making to integrate such approach in the development of a national adaptation strategy to provide a coherent and effective response to climate-related impacts..

4. PRELIMINARY ANALYSIS

Tropical coastal social–ecological systems differ from other social–ecological systems (SES) due to the higher degree of risk and uncertainty associated with coastal and marine resource extraction, land use change and natural hazards. Analysisng the elements of the coastal system and their causal relationships applying the DPSIR approach as a framework will provide a systematic analysis of the environmental changes and potential responses in a holistic manner [12]. The preliminary analysis aims to integrate the ecosystem-based adaptation as a response addressing pressures and drivers to facilitate the communication of the role of maintaining and restoring ecosystems and their services in adaptation measures in Guyana. Tables 1 and 2 illustrate the socio-ecological elements of the DPSIR framework for the coastal zone of Guyana taking into account exogenous drivers as sea level rise (SLR). The framework illustrates the role of ecosystem services as defined by Millennium Ecosystem Assessment (2006) (e.g. Supporting, Provisioning, Regulating and Cultural) in reducing the vulnerability of the system. Ecosystem-based adaptation practices analysed in the framework include:

a) Ecosystem approach to fishing,
b) Sustainable harvesting,
c) Agro-environmental measures,
d) Restoration of ecosystems,
e) Monitoring & research and
f) Extension of protected areas

These practices are only a fraction of the possible ecosystem-based adaptation measures, yet they represent the major principles of the concept and provide an image of their role in the system. The approach provides a systematic analysis of the two coastal zones - *i) Coastal Zone I and ii) Coastal Zone II* thus visualising the difference of the elements and links under different scenarios.

The cognitive map in Figure 1 shows the DPSIR elements and causal links of the socio-ecological system of *Coastal Zone I* in Guyana, characterized with high population density, developed economic activity, intensive agricultural fields and fishing industry with a mixed urban and rural landscape, where the capital of Georgetown is also located.

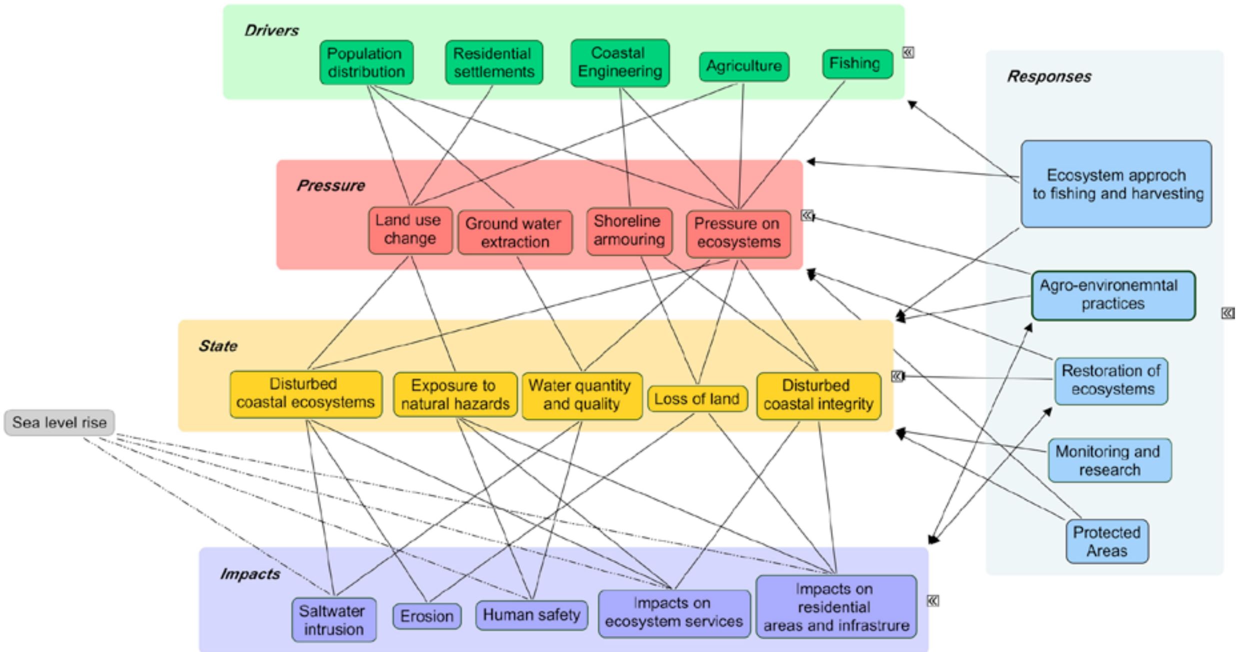

Fig 1: A conceptual map for DPSIR framework for Coastal Zone I in Guyana: From top to bottom *i) Drivers, ii) Pressures, iii) State, iv) Exogenous driver – Sea level rise, v) Impacts and EbA Responses*

Major endogenous socio-economic drivers of the system are population distribution due to migration from hinterland to the coast thus resulting in demand for additional residential settlements in areas with high exposure to floods. Coastal engineering is present at large in the area and often being a reason for disturbance in coastal ecosystems which are under pressure from intensive agriculture (e.g. monoculture) and fishing practices lead to pressures on the coastal ecosystems as well. Harvesting of mangroves is not a major driver in this area due to better awareness and monitoring of the forests.

The conceptual map in Figure 2 illustrates the elements of the DPSIR framework of the *Coastal Zone II* of Guyana characterized by relatively low population density, rural landscape and sustainable small-scale agriculture and subsistence fishing.

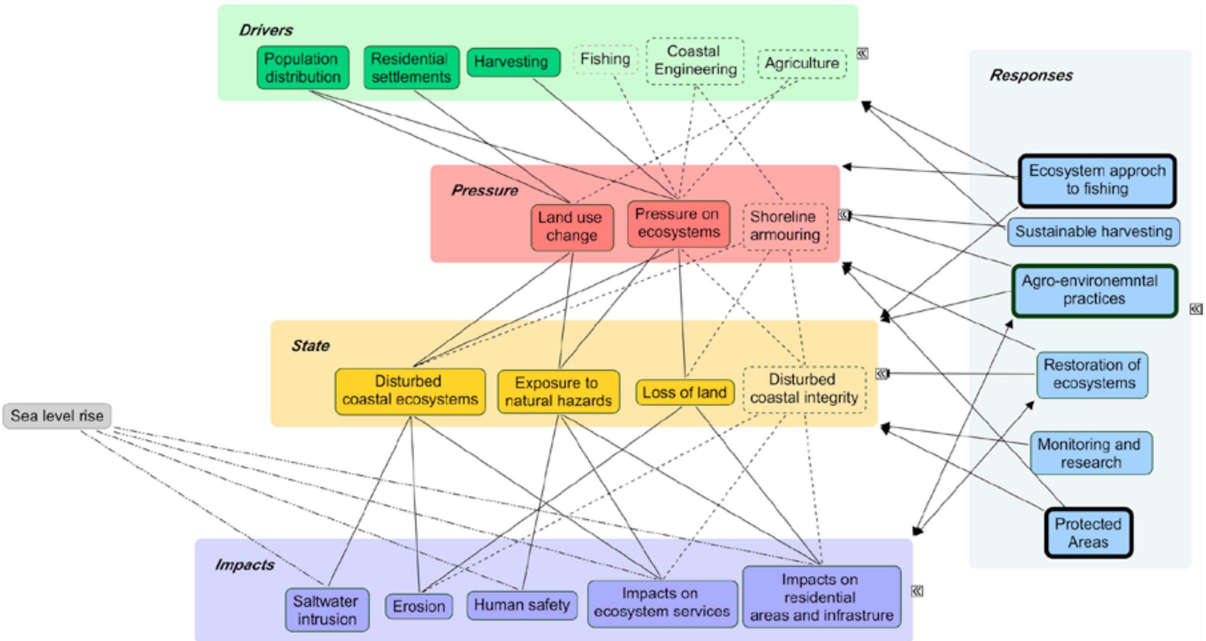

Fig 2: A conceptual map of DPSIR framework for Coastal Zone II in Guyana: From top to bottom *i) Drivers, ii) Pressures, iii) State, iv) Exogenous driver – Sea level rise, v) Impacts and vi) EbA Responses*

Coastal ecosystems are disturbed through unsustainable harvesting of predominantly mangrove trees. Fishing and extensive agriculture in this region is at present not at large scale yet it is a potential threat in the path to economic development these elements to turn to driving forces. Hence, these components and related outcomes are presented in dotted lines. It can be observed in the previous conceptual map for Coastal Zone I that the existence of the additional drivers would lead to more pressure in the socio-ecological system and negatively alter its state making it unstable and vulnerable. The highlighted practices are the ones already applied to a certain scale by the coastal communities providing an example of an autonomous adaptation process integrating both the notion of social and ecosystem services.

5. FURTHER RESEARCH STEPS

For the purpose of developing the next steps in the system dynamic analysis and develop causal loop with focus on climate change impacts in the agricultural system and factors affecting its stability and enhancing resilience. The system dynamic model will analyse proposed ecosystem-based adaptation efforts emphasising on the human dimension of managed agri-environmental measures as agroecology.. In the process of developing the model quantification could either be based on hard-source data or qualitative data could be converted.

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