



Safe Havens

Protected Areas for Disaster Risk Reduction and
Climate Change Adaptation

Edited by Radhika Murti and Camille Buyck



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Introduction

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1. The Scope and Purpose of This Book

This publication presents 18 case studies to demonstrate *how* Protected Areas (PAs) can be better managed for disaster risk reduction (DRR) and climate change adaptation (CCA). The chapters vary from scientific studies to good practices, as well as (existing or required) policy frameworks that enable appropriate management. The book presents approaches from different regions and aims to cover a range

of hazard events as well as a variety of ecosystem types. Emerging practices, lessons learnt and key recommendations are also included in all chapters, and are summarized in the concluding chapter.

The information for each chapter was collated using a template that guided the authors in answering key questions, presented in Table 1.

While the book aspires to present the case studies for demonstrating the role

of PAs in both, disaster risk reduction (DRR) and climate change adaptation (CCA), in most cases, the two issues have been presented together (and sometimes synonymously). This may be due to the fact that all hazards covered are climate related. It could also be an indicator of the currently limited knowledge on how ecosystems can be managed simultaneously for DRR and CCA for immediate and long term resilience of communities as well as ecosystems.

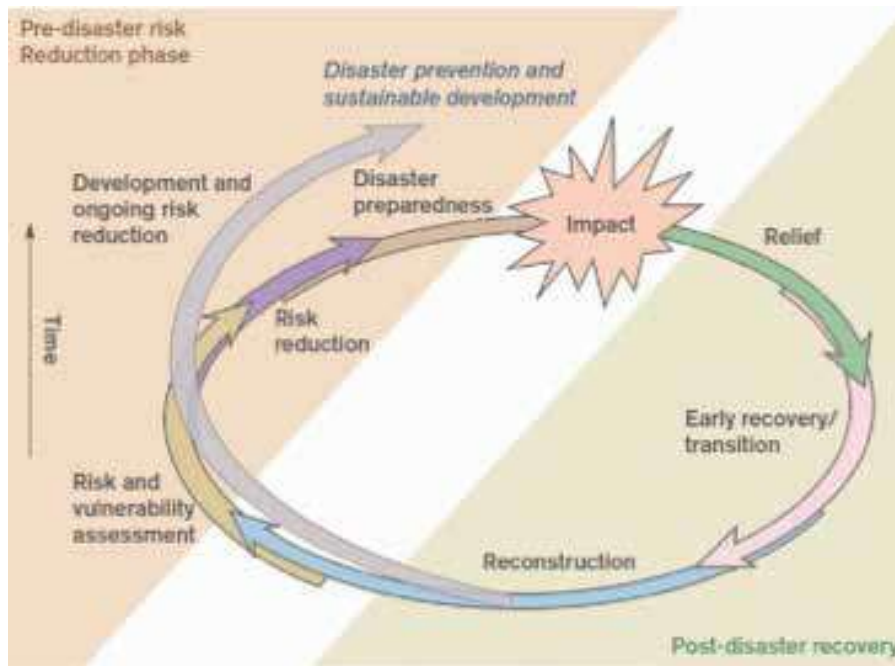
Table 1: Key Guiding Questions for Case Studies.

Methodology	Results	Discussion
What actions have been implemented?	What was achieved (or not) in practical terms?	Identification of triggering factors or causes of success or failure (categorised into key priority issues for example governance, capacity development, individual commitment, stakeholders that should be involved, institutional mechanisms, resource needs, etc.)
What tools/ techniques/ approach have been used?	What are the expected long-term impacts or outcomes? (Include illustrations of how activities contribute to risk and vulnerability reduction; use examples, direct quotes, indicators, etc to provide clear evidence of results / impacts)	Factors that need to be taken into account to allow replication of the process.
If a participatory approach was used: Who were involved in the process? How have the communities been affected by the initiative (positively/negatively)?	Did activities have an impact on livelihoods/ poverty reduction/ human wellbeing/ economy locally or otherwise?	Controversies that the initiative generated (if any)
What particular successes/ difficulties did you encounter during the implementation of the project/ initiative?	Did the activities change people's perception of the role of protected areas for DRR and CCA?	Analysis of the cost-effectiveness of the measure, or economic valuation, or comparison to alternative solutions.

2. The case studies

Country	National Park	Title	Type of Ecosystem	Hazard
Australia	Wet Tropics World Heritage Area	The ecosystem service value of protected areas for cyclone protection in Australia.	Wetlands/ Mangroves	Cyclones and coastal hazards
Barbados	Folkestone Marine Park	Economics of climate adaptation in Barbados - facts for decision-making	Coastal/ Marine	Wind, storm surge and inland flooding
Cambodia	Peam Krasaop Wildlife Sanctuary mangrove forest	Reducing disaster risks to mangrove forest livelihoods through watershed-based protected area management	Coastal	Coastal hazards and sea level rise
Canada	Kouchibouguac National Park	Coastal ecosystems in Kouchibouguac National Park of Canada: adaptation possibilities for traditional knowledge of a local community	Coastal	Storm surges and sea level rise
Guatemala	Monterrico Multiple Use Natural Reserve	Thinking outside the protected area boundaries for flood risk management: the Monterrico Multiple Use Natural Reserve in Guatemala	Coastal	Floods
India	Bhitarkanika Conservation Area	Mangrove forests enhance rice cropland resilience to tropical cyclones: evidence from the Bhitarkanika Conservation Area	Coastal	Cyclones, storms
India /Bhutan	Royal Manas National Park	Traditional knowledge, ecosystem services and disaster risk reduction in Manas World Heritage Site and Biosphere Reserve, India	Forest/River	Soil erosion and floods
Italy	Delta Po	Adaptation to Climate Change and Disaster Risk Management in the Po River Delta Protected Area	Coastal	Sea level rise, salt intrusion, coastlines erosion, heat waves
Madagascar	Nosy Hara Marine Protected Area	Pioneering climate change adapted Marine Protected Area management in Madagascar	Marine	Climate Change
New Zealand	Christchurch Coastal Parks	Potential roles for coastal protected areas in disaster risk reduction and climate change adaptation: a case study of dune management in Christchurch, New Zealand	Coastal/ Dune	Coastal hazards
Peru	Nor Yauyos Cochas Landscape Reserve	Climate Change Adaptation in the Peruvian Andes: implementing non-regret measures in the Nor-Yauyos Landscape Reserve	Mountain	Drought and intense rainfall
Philippines	Mount Mantalingahan in Palawan	The role of conservation agreements in disaster risk reduction: the case of Mount Mantalingahan Protected Landscape (MMPL) in the Philippines	Mountain	Climate change
Spain	Lagoon A Frouxeira	Human perturbation and environmental governance of the coastal lagoon of A Frouxeira, Spain, for seasonal flood mitigation of suburban dwellings	Wetland	Floods
South Africa	Fish River Nature Reserve, Baviaanskoof Nature Reserve and Addo Elephant National Park	Contribution of protected areas in mitigation against potential impacts of climate change and livelihoods in the Albany Thicket, South Africa	Semi-Arid	Desertification
Uganda	Mt Elgon Ecosystem	Initiatives to combat landslides, floods and effects of climate change in Mt Elgon Region	Mountain	Landslides and floods
US	Gulf of Mexico	Hurricane Katrina, the role of US National Parks on the northern Gulf of Mexico and post storm wetland restoration	Coastal wetlands	Hurricanes, storms
Viet Nam	Cham Islands Marine Protected Area	Building Resilience in Hoi An city, Viet Nam the Cham Islands Marine Protected Area	Marine	Floods, typhoons, saline intrusion, coastal/riverbank erosion
Viet Nam	Phong Nha - Ke Bang National Park	Integration of Climate Change and Disaster Risk strategies into local natural resources management in Viet Nam	Forest/ Mountain	Climate change

Figure 1: Disaster Management Spiral.



Source: RICS 2009.

3. Disaster Risk Reduction (DRR)

The term natural hazard refers to events such as cyclones, earthquakes, tsunamis - events that occur in the physical environment and can potentially cause harm to people and property. However, disasters are defined as “A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources” (UNISDR 2007). It doesn't state any of the hazards we think of (such as tsunamis, cyclones and earthquakes) when we hear the term ‘natural disasters’. Rather disasters are defined by the impacts of these hazards on a society. Therefore, we can say that disasters are mainly social constructs: they are largely determined by how a society manages its environment, how prepared it is to face adversity and what resources are available for recovery. Furthermore, according to the United Nations International Strategy for Disaster Reduction (UNISDR, 2007), DRR refers to “reducing disaster risks through systematic efforts to analyze and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land

and the environment, and improved preparedness for adverse events”.

The disaster management spiral (RICS 2009) is widely utilized to plan risk reduction, relief and reconstruction efforts by the disaster management community (Figure 1). It is based on the theory that if countries are doing effective DRR, the loss and damage from each disaster reduces every time, which enables them to ‘break out’ of the event cycle and progress/spiral upwards towards disaster prevention and consequently sustainable development. This is the model used to promote risk reduction measures as opposed to a continuous cycle of moving from one disaster (impact) to relief, recovery, reconstruction and back to another disaster or impact.

Ecosystems contribute to reducing disaster risk in multiple ways. Wetlands, forests and coastal systems can reduce physical exposure to natural hazards by serving as protective barriers or buffers and thus mitigating hazard impacts. Furthermore, ecosystems can lessen underlying risks such as reducing social-economic vulnerability (Renaud *et al.*, 2013). It is therefore important to recognise both, ecosystems’ protection and hazard regulatory functions and their role in sustaining human livelihoods

and providing essential goods such as food, fibre, medicines and construction materials. Addressing underlying risks through preserving the provisional role of ecosystems is equally important for strengthening human security and resilience against disasters. Findings of the Millennium Ecosystem Assessment (2005) also reaffirm the provisioning and regulating roles of ecosystem services as being critical to DRR and mitigation of climate change impacts.

Ecosystem services and ecosystem management can play a critical role at each stage of the disaster management cycle. The various stages can be used as strategic entry points to introduce actions for investment in ecosystem based solutions. Table 2 outlines some environment management tools that can be applied to each stage of the spiral (Figure 1).

Environmental degradation and poor natural resources management have shown to exacerbate the physical impact of a disaster as well as reduce the ability of communities to cope with the aftermath of such an event (Renaud *et al.*, 2013). Such factors reduce the capacity of ecosystems to meet people's need for food and other livelihood related products, and to physically protect them from death and destruction. Furthermore, growing evidence demonstrates that agricultural fields that are protected by surrounding natural landscapes recover at the faster rate following a disaster when compared to exposed fields, and such delayed recovery further affects the livelihoods of an already distraught community. Ecosystem degradation also reduces the ability of natural systems to sequester carbon which increases the incidence and impact of climate change and climate change related disasters (Sudmeier-Rieux *et al.*, 2011).

4. The Hyogo Framework for Action

The Hyogo Framework for Action (HFA) was established in 2005 as the first global blueprint that guides actions for DRR from 2005 to 2015. It recognised the importance of sustainable ecosystems and environmental management in reducing disaster risk. It also informs the Global Assessment Reports (GAR), which are technical reports on the most pressing issues in DRR (UNISDR 2009 and UNISDR 2011).

Table 2: Ecosystem Management Tools for Disaster Management.

DRR spiral phase	The role of ecosystems	Tools employed by ecosystem managers that can contribute to DRR
Risk & Vulnerability assessment	<p>Risk & Vulnerability assessment methods can:</p> <ul style="list-style-type: none"> • help identify people's exposure to potential natural hazards; • identify the root causes of the hazard and whether they are related to Environmental Management; • Consider environmental dimensions or drivers of vulnerability: Extent, quality and/or usage of natural resources and ecosystems; • Assess risk of ecosystem collapse. • Quantify the role of ecosystems for mitigation. 	<p>Qualitative (Participatory process):</p> <ul style="list-style-type: none"> • CRISTAL; • CARE's Community Vulnerability Capacity Assessments (CVCA) • UNDP Vulnerability Assessment Guidance; <p>Quantitative:</p> <ul style="list-style-type: none"> • IUCN Redlist of Ecosystems; • UNEP RIVAMP - quantifying the role of ecosystems for mitigating impacts
Disaster Risk Reduction and preparedness	<ul style="list-style-type: none"> • Vegetation for stabilizing slopes; • Wetlands & floodplains to control floods; • Mosaic landscape for fire management; • Vegetation management for drought resilience; • Mangroves, saltmarshes and sand dunes as buffers from i.e. storm surges; • Provide climate change mitigation. 	<ul style="list-style-type: none"> • Integrated Coastal Zone Management; • Integrated Water Resource Management (IWRM); • Integrated Fire Management; • Protected Area Management; • Community-based Natural Resource Management
Relief, early Recovery, and Reconstruction	<ul style="list-style-type: none"> • Wetland restoration for i.e. flood mitigation, improved water quality, increased income from fisheries. • Green recovery (GRRT) for Humanitarian Aid. 	<ul style="list-style-type: none"> • Forest Landscape Restoration; • Environmental Needs assessment in post-disaster situation; • Wetland restoration techniques

Following this, the 2009 and 2011 Global Assessment Reports on Disaster Reduction (UNISDR) identified ecosystems decline as one of four major drivers of risk and called for greater protection and enhancement of ecosystem services, a message that was further reinforced by the recent IPCC Special Report on Extreme Events, summary for policy makers (IPCC, 2011). The HFA includes the management of natural resources as a key activity within its Priority for Action 4 – *Reduce the underlying risk factors*. It promotes the sustainable use of ecosystems through better land use planning and development planning, however it focuses on the lack of effective environment management as a problem that exacerbates vulnerabilities and intensifies disaster impacts. It also strives to mainstream DRR into environment management rather than to promote environment management as an incentive for cost effective and no-regrets DRR.

Moreover, UNISDR coordinated a mid-term (2009-2011) self-assessment of countries on the progress made for HFA implementation. The review highlighted that Priority for Action 4 had made the least progress and countries did not report

much progress on *“successfully reducing underlying risk through sustainable natural resource management and the incorporation of disaster risk reduction measures into environment planning and management”* (UNISDR 2011). Some of the constraints highlighted in country reports were:

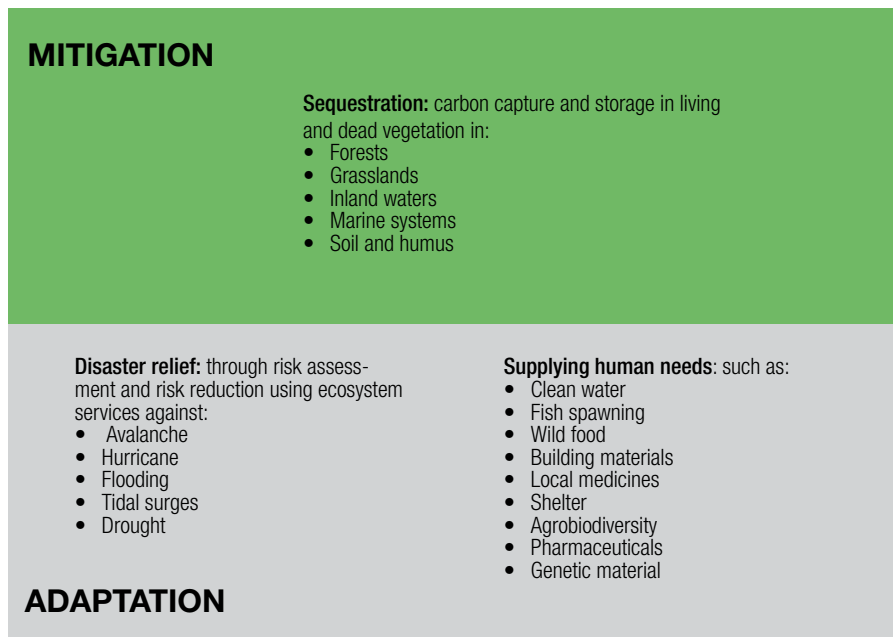
- challenges with obtaining financing for interventions;
- limited technical capacities within DRR sector on implementing natural resource management strategies;
- Lack of coordination amongst DRR, climate change and natural resource management policies leading to lack of institutionalization of interventions;
- Need for capacity building.

It is critical that the role of ecosystem management is embedded in DRR strategies and decision making processes as a *solution* for risk reduction. In order to achieve this, it is important to communicate and promote the contributions of existing environment management strategies/tools to DRR objectives, which are currently overlooked or underestimated. As a key environment management approach, Protected Area (PA) Management can serve as a valuable approach for DRR.

5. Protected Area (PA) Management as a Tool for Disaster Risk Reduction (DRR)

According to IUCN (2012), a Protected Area (PA) is *“a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values”*. Globally protected areas cover less than 12% of land and just over 1% of oceans. However, they provide protection to 80% of threatened species and store more than 15% of global terrestrial carbon stock. IUCN emphasises that protected areas should not be seen as isolated entities, but part of broader conservation landscapes, including wider ecosystem approaches to conservation and sustainable management that are implemented across the landscape. Effectively, Protected Area management 1) contribute towards climate change mitigation by sequestering carbon in vegetation; 2) support local livelihoods through maintained ecosystem goods and services; 3) mitigate climate change-induced hazards and other extreme events by protecting intact natural systems and reducing pressure on land (Figure 2).

Figure 2: The three pillars of protected area benefits.



Source: Dudley *et al.* 2010.

Experience from disasters such as the Western Indian Ocean tsunami in 2004 and the Great East Japan Earthquake and Tsunami of 2011 demonstrates that Protected Areas (PAs) can be effectively managed to help reduce risks posed from natural hazards (Renaud and Murti, 2013). Furthermore, growing evidence published in recent literature also highlights the role PAs play in DRR (such as Dudley *et al.*, 2010). Such green spaces help preserve the integrity of ecosystems and regulate local climate. They assist communities in coping with gradual change (such as in water supplies and agricultural productivity) through the maintenance of essential ecosystem services, including water regulation, pollination and control of soil erosion. Depending on which category an area is classified as, a protected area may serve as an alternative source of resources following a disaster (such as food, fuel, medicine and shelter) and can therefore be an integral part of contingency planning.

Accordingly, PAs operate under a legal or traditional management framework which provides a stable, long-term mechanism for managing land and water resources. The existing governance structures facilitate ecological, social and cultural priorities and thus regulate the pressures on the area. The institutional and social mechanisms in the area can also serve as

a basis for convening the wide range of actors involved in order to safeguard the area for the longer term, collaboratively. This also allows for implementation of local approaches through involving people in a legitimate and effective way. Protected area systems can focus local, national and international attention on a particular area or resource, adding to the protection of benefits from the area or resource (Dudley *et al.*, 2010).

While investing in PAs is strategic for DRR, it can also contribute to the longer term climate change adaptation challenges. In 2007, the Inter-governmental Panel on Climate Change (IPCC) stated the importance of protected areas for mitigation and adaptation strategies. Using forest protection as a demonstrative example, the report highlighted that mitigation activities would not only be low cost but would also provide pathways to creating synergies with adaptation (IPCC, 2007). The Convention on Biological Diversity (CBD) has also recognized the role of protected areas in mitigating and adapting to climate change (Dudley *et al.*, 2010).

6. Climate Change and Ecosystems based Adaptation (EbA)

Over the past two decades it has become increasingly clear that climate is changing

Box 1: Marine Protected Areas in Sri Lanka

Studies carried out in Sri Lanka after the 2004 Tsunami, noted that in Hikkadawa, where reefs are in a marine park and are protected, damages reached only 50 m inland, while in Peraliya, a nearby area, where extensive coral mining degrades reefs, waves were 10 m high and damages and flooding were up to 1.5 km inland.

Source: Dudley *et al.*, 2010.

across the globe. The Inter-governmental Panel on Climate Change (IPCC) published its first assessment report in 1990, highlighting this aspect. Since then, its subsequent reports have continued to provide evidence that human induced climate change has immense effects on human societies and ecosystems. Mitigation and adaptation are the two main strategies that are used effectively to address climate change and its impacts. It is extremely clear that even with current mitigation efforts, changes in climate will continue to happen and therefore there is a need to ensure that adaptation to climate change also takes place.

Ecosystem based adaptation (EbA) is an important strategy to counter the impacts of climate change and natural hazards. Similar to ecosystem based disaster risk reduction, it is an approach that uses biodiversity and ecosystem services as part of a holistic adaptation strategy to assist communities to adapt to climate change. According to the CBD (2009), EbA *“integrates the use of biodiversity and ecosystem services into an overall adaptation strategy, can be cost-effective and generate social, economic and cultural co-benefits and contribute to the conservation of biodiversity.”*

EbA strategies provide benefits such as clean water and food to communities, through the maintenance and enhancement of ecosystem services which are crucial for livelihoods and human well-being. Appropriately designed ecosystem management initiatives can also contribute to climate change mitigation by reducing emissions from ecosystem loss and degradation, and enhancing carbon sequestration.

According to Colls *et al.*, 2009, “Ecosystem-based Adaptation involves a wide range of ecosystem management activities to increase resilience and reduce the vulnerability of people and the environment to climate change.” These activities include:

- Sustainable water management, where river basins, aquifers, flood plains, and their associated vegetation are managed, to provide water storage and flood regulation services;
- Disaster risk reduction, where restoration of coastal habitats such as mangroves can be a particularly effective measure against storm-surges, saline intrusion and coastal erosion;
- Sustainable management of grasslands and rangelands, to enhance pastoral livelihoods and increase resilience to drought and flooding;
- Establishment of diverse agricultural systems, where using indigenous knowledge of specific crop and livestock varieties, maintaining genetic diversity of crops and livestock, and conserving diverse agricultural landscapes secures food provision in changing local climatic conditions;
- Strategic management of shrub lands and forests to limit the frequency and size of uncontrolled forest fires;
- Establishing and effectively managing **protected area systems** to ensure the continued delivery of ecosystem services that increase resilience to climate change;

7. Implementing Protected Area (PA) Management for DRR and CCA

In order to upscale and accelerate the management of PAs for reducing risks and adapting to impacts of changes in climate, there is a need to address the scientific/knowledge gaps, harmonizing policy mechanisms (especially as the issue spans various sectors and communities of practice) and establishing tools, approaches and processes that can facilitate action/implementation.

At the global level, ecosystem management for disaster risk reduction (including PA management) is increasingly recognized by the international community as a critical approach for enhancing human security. Moreover, during the

Box 2: Sanriku Fukko Reconstruction Park, Japan

Japan’s Sanriku Fukko Reconstruction Park was declared following the devastating events of the Great East Japan Earthquake (GEJE) and tsunami from 2011. It aims to link the existing national parks along the Pacific coast which was affected by the tsunami. The Michinoku Coastal Trail within the park consists of a long-distance nature trail, stretching for a total of about 700 km that connects the Pacific coast of Tohoku region from north to south. The trail aims to raise awareness on the impacts of disasters on people and nature. These efforts were facilitated through a policy document – Green Reconstruction Vision that was established by the Ministry of Environment, Japan following the event. The vision is based on three basic principles; 1) make the most of the blessings that nature provides, 2) study the threats from nature, and 3) strengthen interconnections between the forests, rivers, sea and Satoyama (human-influenced natural environments). Implementation of the activities of this vision is ongoing in 2014.

Source: Ministry for Environment, Japan (2014).

course of United Nations Framework Convention on Climate Change (UNFCCC) negotiations for a global climate agreement and in particular since the Conference of Parties (COP) in Copenhagen in 2009, ecosystem-based approaches have been recognized as a key climate change adaptation strategy. Sustainable ecosystem management is therefore increasingly viewed as an effective approach for achieving both, disaster risk reduction (DRR) and climate change adaptation (CCA) priorities. The World Bank, for example, recommends that adaptation programmes integrate an ecosystem-based approach into vulnerability and disaster risk reduction strategies.

At national levels, few examples exist of how countries are able to operationalise ecosystem management (and specifically PA management) for DRR and CCA. A key challenge is the fact that PA management policies and responsibilities are embedded with a ministry that holds the mandate for environmental issues while disaster management strategies are established by a ministry that is responsible for civil protection. Additionally, some countries now have a standalone ministry that deals with climate change, which may not necessarily work with the ministry responsible for natural resources. The Green Reconstruction Vision is a recently established policy mechanism which aspires to implement PA management as a post-disaster reconstruction effort following the Great East Japan Earthquake and tsunami in Japan (Box 2).

8. Practices – Tools and Guidelines

Currently, due to the varying objectives of PA management, DRR and CCA existing tools for each practice requires guidance on how they can be used for an integrated approach towards PAs for DRR and CCA. Implementation and monitoring tools such as the Protected Area Management Effectiveness (PAME) Assessment (Hocking *et al.*, 2000) can be adapted to document and manage the attributes of PAs for DRR and CCA. While it was not designed for this purpose, the emphasis on maintaining ecosystem resilience, the identification of threats and vulnerabilities and the development of management, institutional and governance response are also relevant to DRR and CCA.

Similarly, social vulnerability assessment tools such as CARE’s Climate Vulnerability and Capacity Analysis (CARE, 2009) can be aligned to DRR and biodiversity implementation tools. This would assist in ensuring that the integrity of the ecosystems are not compromised in meeting the vulnerability challenges of the communities, when employing nature based solutions to DRR and CCA.

Such guidance, analyses and possible standards will require a committed and joint effort amongst PA managers, disaster risk reduction practitioners and the climate change adaptation community of practice.

CRiSTAL Parks – a tool for PAs and CCA

CRiSTAL Parks is a decision-support tool that aims to help conservationists and PA managers plan for climate-compatible conservation by giving them a means to identify and address the risks that climate variability and change (climate risks) pose to critical ecosystems and their productive functions:

CRiSTAL Parks aims to:

1. Help conservationists and park managers integrate climate risks into their conservation planning;
2. Support the development of tailored climate adaptation strategies that are designed to reduce the climate vulnerability of protected areas;
3. Understand and harness the potential of the PA to help build adaptive capacity and reduce climate risks.

The tool targets conservation practitioners working within or around PAs and PA managers or consultants in charge of drafting new or updating existing park management plans. It is a freely downloadable computer desktop application accompanied by a user's manual available in English and Spanish. This tool is being piloted in 2014.

Source:iisd, 2014.

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Chapter 1

The ecosystem service value of protected areas for cyclone protection in Queensland, Australia

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Top Left: Source: Bureau of Meteorology (2011). Severe Tropical Cyclone Yasi Satellite Loop. Satellite image for Monday 31 January 2011 05:30 UTC.

Bottom left: Source: Property Causality 360° (2011). Top Disasters of 2011 – Slideshow. Cyclone Yasi Feb. 2 Struck Queensland, Australia as a Category 5.

Main Photo: Source: Smashed boats at the Hinchinbrook Marina. Source: The Courier-Mail

Abstract

Protected areas and the natural environment deliver a wide range of ecosystem services that contribute to human wellbeing. Here we examine the value of protected areas for cyclone and coastal protection in Queensland, Australia. Natural events such as cyclones threaten the health or wellbeing of human society however we can plan to minimize their impacts. Sea level rise, as well as an increase in cyclone intensity and storm surges associated with climate change will result in the erosion of shores and habitats, increased salinity of estuaries and freshwater aquifers, altered tidal ranges in rivers and bays, changes in sediment and transport, and amplified risk of coastal flooding that, in turn, will increase the vulnerability of coastal populations. Coastal wetlands, such as mangroves and floodplains, barrier islands and coastal vegetation all play a critical role in reducing the impacts of floodwaters produced by coastal storm events and tropical cyclones as well as in physically buffering climate change impacts. In an era when mankind's activities are the dominant force influencing biological communities and ecosystems, proper management requires understanding of the pattern and process in biological systems and development of assessment and evaluation procedures that assure protection of biological resources. That assessment must also include the value of ecosystem services and the role they play in disaster and risk reduction.

1. Introduction

1.1 Study area

The Tully-Murray catchment is located in Far North Queensland, Australia and is bordered by the Wet Tropics World Heritage Area (WT WHA) in the west and by the Great Barrier Reef World Heritage Area (GBR WHA) in the east (Figure 1). The study site comprises an area of 278,886 ha and contains six primary and twenty-six secondary land use classes (as defined in the Australian Land Use Management Classification Version 7, 2010¹). The higher elevations and upper

reaches of the rivers and creeks are primarily occupied by tropical rainforest and sclerophyll forests, while the coastal floodplain has largely been cleared and drained for agricultural purposes (Johnson, 1988). Remnant patches of rainforest are found on the alluvial plains and in wetlands and estuaries near the alluvial coast. While 64% of the natural forest in the Tully-Murray catchment is protected and included in the Wet Tropics World Heritage Area, in National Parks or State Forests, as well as in Nature refuges, the remaining 36% of natural forest is under environmental pressure. The area of floodplain vegetation in the catchment is approximately 20.8 km², and has decreased by approximately 80% compared to pre-European settlement (Furnas, 2003) due to increased agricultural development.

Along the mainland coast are low-lying deltas that are periodically inundated during

cyclonic floods. In the past, storm surges and high winds have caused enormous human and economic devastation in these areas. Agriculture, tourism, fishing, ports and transport, as well as ecosystems, have suffered from the impacts of extreme weather. The Wet Tropics bioregion in Far North Queensland is a region of high economic importance and exceptional environmental value (McDonald & Weston, 2004). It contains the highest biological diversity in Australia, and occupies less than 2% of Queensland, yet provides 10% of the State's agricultural activity and 23% of tourism activity.

The Great Barrier Reef (GBR) is one of the largest and most diverse coral reef ecosystems on Earth, spanning 2,300 km along the east coast of Queensland, Australia². The Great Barrier Reef catchment covers 86,602.6 km² (Figure 1). As a World Heritage listed

Figure 1: Location of the Tully-Murray catchment (study area) relative to the Great Barrier Reef and Wet Tropics world heritage areas, Queensland, Australia.



¹ <http://www.daff.gov.au/ABARES/aclump/Pages/land-use/alum-classification-version-7-may-2010/alum-classification-version-7-may-2010.aspx>.

² Great Barrier Reef Marine Park Authority (2009) Great Barrier Reef Outlook Report 2009.

area, the Great Barrier Reef plays an important role in community life. Coastal communities and the Great Barrier Reef have a mutually beneficial relationship: communities benefit from their proximity to the GBR, allowing easy access and a sense of connection to reef ecosystems. In deriving benefits from the GBR, these communities also have impacts on the reef, some of which are negative. The Reef provides local residents, tourists and visitors with a wealth of cultural ecosystem services particularly recreational services including beach combing, snorkelling, diving, whale watching, boating, fishing and island camping. The Reef and its catchment bring AUS\$ 5.77 billion into the Australian economy each year through Reef-dependent industries such as tourism and commercial fishing, and provide jobs for almost 69,000 people³. In 1981 The Great Barrier Reef was inscribed on the World Heritage List in recognition of its unique attributes of Outstanding Universal Value. The Great Barrier Reef Marine Park is jointly managed by the Commonwealth and Queensland governments as a multiple use park, allowing a wide variety of human activities to occur including tourism, commercial fishing, recreation, scientific research and Indigenous traditional use. It is also used extensively as an international waterway for vessels transiting the Reef with eleven ports operating adjacent to the GBR, accounting for some AUS\$ 17 billion of Australia's export trade (AMSA, 2010). The export movement of bulk cargoes and imports of essential fuel and manufacturing inputs are crucial to the economic and social wellbeing of the country. The ports service a population of around 1 million in northern regional Queensland or 27% of Queensland's population (AMSA, 2010).

Recently the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Committee, have raised concerns about the international and national sensitivity and visibility of proposed port developments and associated shipping in and around the Great Barrier Reef World Heritage Area (GBRWHA). Two reports have been prepared to analyse the future risk of shipping and provide port industry vessel forecasts (Braemar Seascope, 2013; PGM

Environment, 2012). The Queensland commodity market is and will continue to be dominated by the coal trades, with coal representing 81.8% of total trade in 2015 in terms of both tonnage and shipping traffic volumes (Braemar Seascope, 2013). It has been estimated that the average annual growth in coal ship traffic between 2011 and 2025 will be approximately 6.31% (Braemar Seascope, 2013) assuming expansion of ports to their full capacity. Despite in excess of 8,000 ship movements each year within the GBR, there has only been a small number of collisions and groundings, with 5 out of 26 'major' oil spills recorded in Australian waters having occurred in the GBR and Torres Strait (PGM Environment, 2012). Cyclones can occur the entire length of the GBR, with the northern sections at greater risk than the southern and as a precaution ships are cleared from anchorages and directed to proceed out to sea when cyclones threaten the GBR. This is typically initiated to allow ships enough time to clear the GBR and to ride out the storm at sea, which is the safest place for them and voids the risk of the ships dragging their anchors. For a further critical review of environmental management and other issues associated with the GBR readers are referred to Brodie and Waterhouse (2012).

1.2 Tropical cyclones

In February 2011, Tropical Cyclone Yasi (roughly the size of Italy), one of the largest cyclones to occur in the region in the last one hundred years, crossed the north Queensland coastline near Mission Beach. Tropical cyclones develop over the warm oceans to Australia's north during the summer months from November to April, and can generate destructive winds, heavy rain and flooding to many coastal areas in

Western Australia, Northern Territory and Queensland. The impact of a cyclone is generally felt over an area of hundreds of square kilometres, over many days with the most destructive winds experienced just outside the eye. These destructive winds can cause extensive property damage and generate windborne debris. The Bureau of Meteorology categorizes cyclones with increasing severity from Category 1 to 5 according to the maximum expected wind speed and minimum central pressure, as shown in Table 1. Cyclone Yasi was categorized as a category 5 in the centre of the study area, crossing the coast near Mission Beach, 138 km south of Cairns, with maximum sustained wind speeds of 205 km/hr and maximum wind gust of 285 km/hr. The lowest central pressure recorded was 292 hPa. Extensive seagrass and coral damage was recorded in a 300 km wide band across the continental shelf, with a reported area of 89,090 km² (15% of the total) of the Marine Park sustaining some coral damage and 6% classified as being severely damaged (GBRMPA, 2011).

Tropical Cyclone Yasi is one of the most powerful cyclones to have affected Queensland since records commenced⁴.

Tropical cyclones are the main coastal hazard for low-lying lands along the Queensland coast. An average of 1.2 cyclones per year occur within 500 kilometres of Brisbane (Harper *et al.*, 2001). The town of Cairns is considered vulnerable to the impacts of cyclones, with some critical infrastructure in low-lying areas including the airport, already vulnerable to the highest tides (Poloczanska *et al.*, 2007) and Cairns Hospital. King tides regularly threaten homes along the Arlington Esplanade

Table 1: Bureau of Meteorology Cyclone Categories.

Cyclone category	Gust wind speed at 10 m height in flat open terrain			Central Pressure
	km/h	knots	m/s	hPa
1	90-125	49-68	25-35	>990
2	125-164	68-89	35-46	970-985
3	165-224	89-121	46-62	950-965
4	225-279	121-151	62-78	930-645
5	>280	>151	>78	>925

³ Deloitte access Economics (2013).

⁴ Source: Bureau of Meteorology - <http://www.bom.gov.au/cyclone/history/yasi.shtml>.

in Clifton Beach, with residents having to sand bag their properties to prevent inundation in some cases (Steneck, 2008). Major cyclone, flood and storm events between 1967 and 1999 (approximately 70 events in total) have cost Queensland almost AUS\$ 8 billion (1998 dollar estimates) (Johnson *et al.*, 2005). In 2006, damage costs from Cyclone Larry were estimated at more than AUS\$ 1 billion (Valentine & Johnson, 2004). Extensive damage to property and infrastructure from Cyclone Yasi has been costed at AUS\$ 800 million.⁵ In particular the Lucinda Sugar Terminal was damaged by Cyclone Yasi to a point that all exports ceased during repairs (Braemar Seascope, 2013). Additionally further impacts were felt as sugar plantations recovered from floods as a result of the cyclone in southern ports such as Mackay and Bundaberg, which also have large exports of bulk sugar.

1.3 Cyclones, storm surges and coastal vegetation systems

Cyclones not only cause significant damage to property and infrastructure, but can also be responsible for the triggering of subsequent storm surges through high wind velocities. Wave effects can increase the water level by the same elevation as the surge itself (Trollope *et al.*, 1972). In a tropical system a storm surge can be 300-700 kilometres across, penetrate far inland and raise water levels for several hours (Feagin *et al.*, 2010). There is general acceptance globally that coastal ecosystems such as mangroves and saltmarsh absorb energy from waves and storm surges making them less damaging and providing regulating ecosystem services such as protection of shores and prevention of erosion (Stolton, Dudley & Randall, 2008; UNEP-WCMC, 2006). Such global acceptance is evident, for example, by the naming of a sacred coastal grove in Southern India, which translates as 'the forest that controls the waves' (UNEP-WCMC 2006). Furthermore, around 90 per cent of fishers interviewed by Walton *et al.* (2006) in the Philippines believed mangroves provided protection from storms and typhoons.

Some literature exists to support the premise that coastal ecosystems can

mitigate storm surges but does not quantify the mitigation potential. However, it is thought that coastal ecosystems mitigate storm surges through attenuating waves as they pass over or through wetlands, marshes and mangroves. The science on short-period wave attenuation may not necessarily be extrapolated to the conclusion that vegetation can reduce the effects of storm surges or tsunamis (Feagin *et al.*, 2010). Wave energy is also lost through frictional drag as the wave passes mangrove or saltmarsh vegetation and through bottom friction in shallow water areas (Shepard, Crain, & Beck, 2011). Additionally, increased bed roughness as a result of vegetation trunks, branches and roots reduces currents and dissipates wave energy (Quartel *et al.*, 2007). As a result, this reduces the strength of a storm surge, and can reduce its peak or delay its arrival inland (Wamsley *et al.*, 2010). Additional benefits of vegetation that have been reported include trapping floating objects such as broken branches.

Trees can also mitigate damage by acting as a debris barrier. This was observed after Cyclone Tracy in Darwin (Cameron *et al.*, 1983), Cyclone Winifred in Innisfail (Oliver & Wilson, 1986) and Cyclone Yasi in Townsville (Greening Australia & Calvert, 2011). Research has shown that there is a clear case for using natural assets in a holistic flood and cyclone hazard management approach and that natural assets will have the most impact on reducing or preventing flood and cyclone damage from events with a lower average return interval. The more extreme events (such as tsunamis) will overwhelm any approach (Kerr & Baird, 2007). The research shows however that natural assets interventions are likely to be more cost-effective in many cases than structural approaches (Department of Environment and Heritage Protection, 2012). They also provide other economic benefits through supporting ecosystem services, biodiversity, fisheries, drinking water treatment, recreation and tourism. A holistic approach should include land use planning, natural assets interventions balancing the needs of the catchment, ecology and community.

In this paper, we present an approach to mapping the value of protected areas and land use for cyclone and coastal

protection, based on a case study of the Tully-Murray catchment, Cassowary Coast Regional Shire in the Wet Tropics and Category 5 Severe Tropical Cyclone Yasi. We believe that our research can serve as a template to assist in identifying areas for protection or 'hotspots' that need to be retained and rehabilitated because of their value in buffering the effects of cyclones, storm surges and associated flooding adjacent to the coast and in the swaths of cyclones.

2. Methodology

2.1 Datasets and analysis

The methodology adopted a spatial analysis approach to both visualize and analyse the six classes of land use in the Tully-Murray catchment/Cassowary Coast Regional Council area affected by Cyclone Yasi. Using ESRI ArcGIS 10.2 software the spatial datasets were assembled and compiled into one geodatabase. All of the spatial datasets were subsequently clipped to the study area boundary.

2.2 Creating cyclone buffers

The 'buffer' command was used to create the wind speed zones around Cyclone Yasi's track using the cyclone's wind speed attribute.

2.3 Natural resources – Regional ecosystems

Regional ecosystems have been defined for Queensland as '...vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil' (Sattler & Williams, 1999). These were clipped to the Cyclone Yasi wind speed shape file and calculations of the amount of hectares for each wind speed class and for each regional ecosystem Biodiversity Status⁶ attribute (i.e. Endangered, Of Concern, and Not of concern) were calculated.

2.4 Land use

The 2009 Queensland Land Use Mapping (QLUMP) shape files were clipped to the buffered cyclone wind speed cover, and area calculations made for each land

⁵ Source: <http://statements.cabinet.qld.gov.au/MMS/StatementDisplaySingle.aspx?id=73637>.

⁶ According to the Environment Protection Agency's degradation criteria, the Biodiversity Status is based on an assessment of the condition of remnant vegetation in addition to the pre-clearing and remnant extent of a regional ecosystem.

use category and wind speed. Using the ALUM classification system – Version 7⁷, we examined the primary and secondary classes, which are related, to land use – the main use of the land, defined by the management objectives of the land manager. The primary and secondary classes of land use can be distinguished in order of generally increasing levels of intervention or potential impact on the natural landscape. A 'union' or topological overlay was performed using the Cyclone Yasi wind speed and land use spatial datasets which enabled us to retain all the features from both datasets and to create a new polygon dataset with all the features and attributes of both layers.

2.5 Terrestrial Protected Area Estates

The terrestrial Protected Area Estate started in Queensland with the proclamation of the *State Forests and National Parks Act 1906*. Over time the Protected Area Estate has grown from 131 hectares to total about 12.2 million hectares⁸. Protected areas were clipped to the buffered cyclone wind speed cover and area calculations made for each IUCN category and wind speed. A 'union' or topological overlay was performed using the Cyclone Yasi wind speed and protected areas spatial datasets.

2.6 Demographic and socio-economic data

The communities in our study area included Hinchinbrook, Cardwell, Tully Heads, Hull Heads, Bingil Bay and the Mission Beach area (North Mission, South Mission, and Wongaling Beach). All of the above communities lie in the jurisdiction of the Cassowary Coast Regional Council (CCRC). Additionally using the digital State Suburbs⁹ and 2011 census data from the Australian Bureau of Statistics (ABS) we created spatial layers to represent human population distribution and density across the region. Other spatial layers created from the ABS 2011 census data

⁷ Australian Land Use and Management Classification (ALUM) Version 7, May 2010 <http://www.daff.gov.au/ABARES/aclump/Pages/land-use/alum-classification-version-7-may-2010/default.aspx>.

⁸ <http://www.wildlife.org.au/conservation/issues/2012/protectedareas.html>.

⁹ For further information on State Suburbs ASGS Non ABS Structures Ed 2011 Digital boundaries see <http://www.abs.gov.au/websitedbs/cens> <http://www.wildlife.org.au/conservation/issues/2012/protectedareas.html>

included: population over 65 years old, indigenous people, sum of population per suburb, age, income, median weekly rent, employment and occupation. As old and dependent people are very vulnerable to natural hazards such as tropical cyclones, two groups were generated; population above 65, and children from the age of 0 to 19 years. The age group for children was chosen to include pre-ambulant children that cannot remove themselves from danger, children of an age not able to read (e.g. warnings) but also adolescent children because of their cognitive immaturity which can lead them to take unreasonable risks (UNEP, 2002). All of these layers were once again clipped to the wind speed and swath area of Cyclone Yasi and merged.

2.7 Freehold property valuation data

Property valuation data were obtained from the Cassowary Coast Regional Council for three time periods: 2010, 2011 and 2012. These data were based on valuations carried out by the Department of Natural Resources and Mines (DNRM) on the 1 October of each year. Data were provided on a locality basis¹⁰ and a 'union' performed using the Cyclone Yasi wind speed and property valuation layers.

3. Results

Although only a relatively small population resides in the Cassowary Coast region, effects from Cyclone Yasi (Australia's second largest cyclone) were felt, particularly in areas where no coastal vegetation remains. Regional ecosystems exposed to the very destructive wind speeds of Cyclone Yasi are summarized in Table 2 and shown spatially in Figure 2. A small percentage (1.9%) of 'Endangered'

regional ecosystems were exposed to 270 km/hr winds in the study area, with a further 16.1% of 'Of concern' regional ecosystems also affected. Hinchinbrook Island, a largely uninhabited island, and National Park, containing both 'Endangered' and 'Of concern' regional ecosystems also experienced 240 km/hr winds before Cyclone Yasi crossed the coast. Protected area estates, primarily National Parks (IUCN Category II) were the most affected by Cyclone Yasi in the Wet Tropics region with over 8 million hectares (97.6%) exposed to wind speeds in the range of 150-270 km/hr (Table 3, Figure 3).

Significant parts of both the Wet Tropics and Great Barrier Reef World Heritage Areas were also exposed to Cyclone Yasi (Figures 3-4). Within Cyclone Yasi's swath 5.47% of the Great Barrier Reef's cays and reefs were exposed to wind speeds between 150-270 km/hr, as well as a further 1.57% of islands (Table 3, Figure 4). Dunk, Bedarra and the Family group of islands were particularly hit hard experiencing 270 km/hr winds (Photos 1-3). Additionally, Hinchinbrook Island (183,272 hectares) and reef (1,207 hectares) also experienced 210-240 km/hr winds.

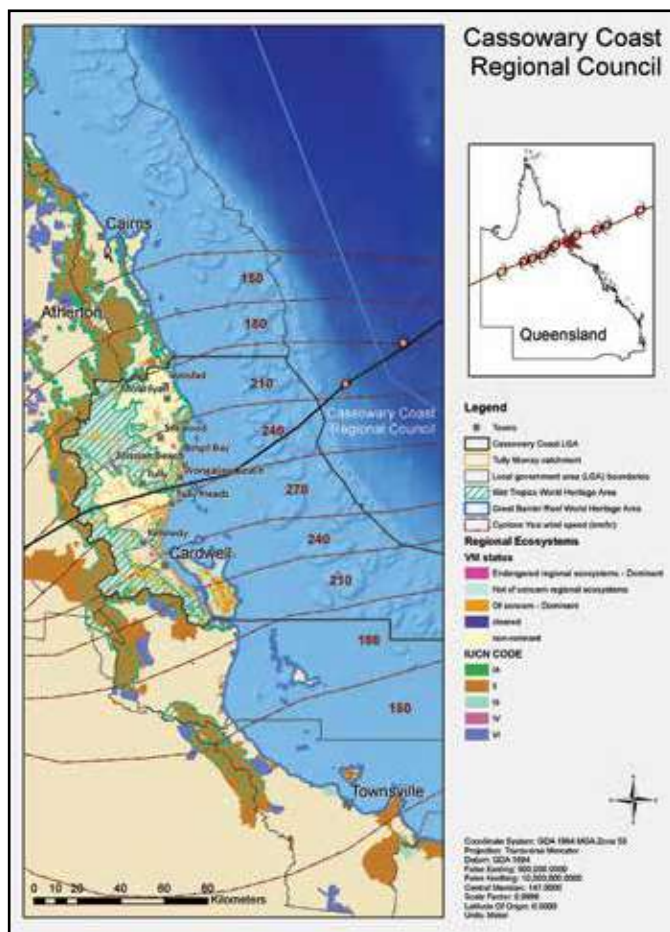
A total exposed area of 77,065 hectares (62.5%), classified as 'Conservation and natural environments' were subjected to Cyclone Yasi's very destructive winds, measured at around 270 km/hr (Table 5). Breaking the land use classes down further (using the secondary classification) reveals 42,605 hectares were affected by 270 km/hr winds, and an overall 53.8% of the entire study area

Table 2: Percentage and area (hectares) of regional ecosystems affected by Cyclone Yasi wind speeds.

Regional ecosystem	Wind speed km/hr					Total	%
	150	180	210	240	270		
Endangered	0	69.8	1,427.1	3,960.3	2,620.2	8,077.5	1.7
Of concern	0	827.1	26,668.4	33,541.2	12,707.9	73,744.6	15.8
Non-remnant	0	1,415.6	50,035.6	76,428.1	17,249.6	145,128.9	31.0
Not of Concern	0	81,249.4	104,220.5	95,124.2	33,687.1	241,181.1	51.5
Cleared	0	0	0	0	0.3	0.3	0.0
	0	10,461.9	182,351.6	209,053.8	66,265.1	468,132.5	100.0

¹⁰ http://www.nrm.qld.gov.au/services_resources/item_details.php?item_id=32736.

Figure 2: Dominant regional ecosystems and IUCN protected areas affected by Cyclone Yasi, 2011.



(Table 6). A further 15% or 9,380 hectares of 'Production dryland agriculture and plantations' were also exposed to the very destructive winds (Table 5, Figure 3). Secondary land use classes affected included: cropping (12.9%), other minimal use (8.8%), and estuary/coastal waters (6.6%). Fortunately, only 1% (15,306 ha) of the total study area classified as residential was affected by Cyclone Yasi, with no residential areas in the 270 km/hr swath.

Although only a small component of the study area is classified as residential, an analysis of the 14,780 freehold property values in the study area (which includes rural residential and rural properties) reveals a substantial number of properties within the cyclone path had a value at the time of over AUS\$ 2,465,515,395 (Table 7). Subsequently since then these property values have decreased in value to AUS\$ 2,147,154,703 in 2011 and AUS\$ 2,014,325,544 in 2012. Overlaying the ABS census statistics (Figures 5-6) also shows a high population density as well as a large Indigenous population, and people aged over 65 years old (Figure 5) that are concentrated along the coast, particularly in the north around the towns of Innisfail, Tully and Cardwell which were directly in the 270 km/hr wind zone area. Along with this residential area there comes a lack of remnant coastal vegetation and associated protected areas and national parks, further increasing the rate of flood and wave velocities leading to damaging flood waters especially along the Cardwell beach front.

Table 3: Percentage and total area (hectares) of protected area estates (IUCN categories) affected by Cyclone Yasi wind speeds in the Wet Tropics region.

IUCN Protected Area	Conservation Park	Forest Reserve	National Park	State Forest	Resources Reserve	Total Area (ha)	%
I	0	0	0	0	0	0	0
II	0	0	273,122.6	0	0	273,122.6	96.2
III	692.5	0	0	0	0	692.5	0.2
IV	0	0	0	0	0	0	0
V	0	0	0	0	0	0	0
VI	0	1,056.1	0	9,042.4	4.8	10,103.2	3.6
Total	692.5	1,056.1	272,8357.5	9,042.4	4.8	283,918.3	100

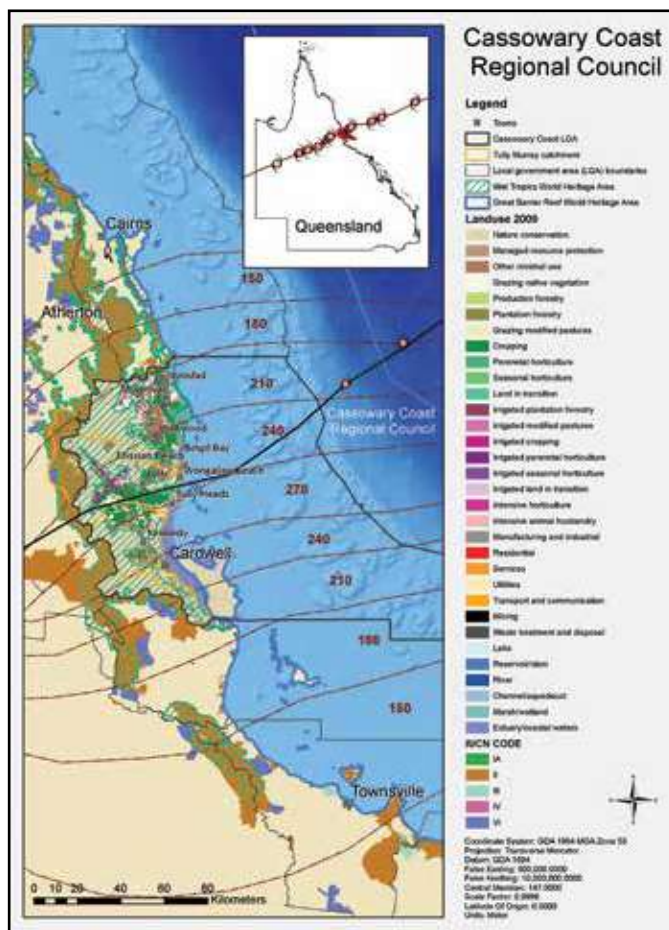
World Heritage Areas	Wind speed km/hr					Total
	150	180	210	240	270	
Wet Tropics	0	8,846.7	92,571.5	87,143.8	36,329.4	224,891.4
Great Barrier Reef	348	22,856.8	66,610.4	64,927.0	28,250.3	182,933.1
Total	348	31,703.5	159,181.9	152,070.8	64,579.7	407,824.5

Table 4: Great Barrier Reef World Heritage Area (GBR WHA) and features exposed to Cyclone Yasi wind speeds within the Cassowary Coast Local Government Area (LGA).

Wind speed km/hr	Area (hectares)	% of GBR WHA within Cassowary Coast LGA	% of total GBR WHA
150	436.44	0.04	0.00
180	160,511.27	13.93	0.46
210	397,844.84	34.52	1.14
240	382,227.53	33.17	1.10
270	211,416.45	18.35	0.61
Total	1,152,436.56	100	3.31

GBR Feature	Wind speed km/hr					Total	%
	150	180	210	240	270		
Cay	0	0	0	15.4	2.7	18.1	0.01
Island	0	0	20,508.4	19,566.9	583.1	40,658.4	22.2
Reef	348.7	22,855.6	46,067.5	45,340.6	27,664.5	142,276.9	77.7
Rock	0	1.2	34.4	4.0	0	39.6	0.03
Total	348.7	22,856.8	66,610.4	64,926.9	28,250.3	182,993.1	100

Figure 3: Secondary land use classes and IUCN protected areas affected by Cyclone Yasi, 2011.



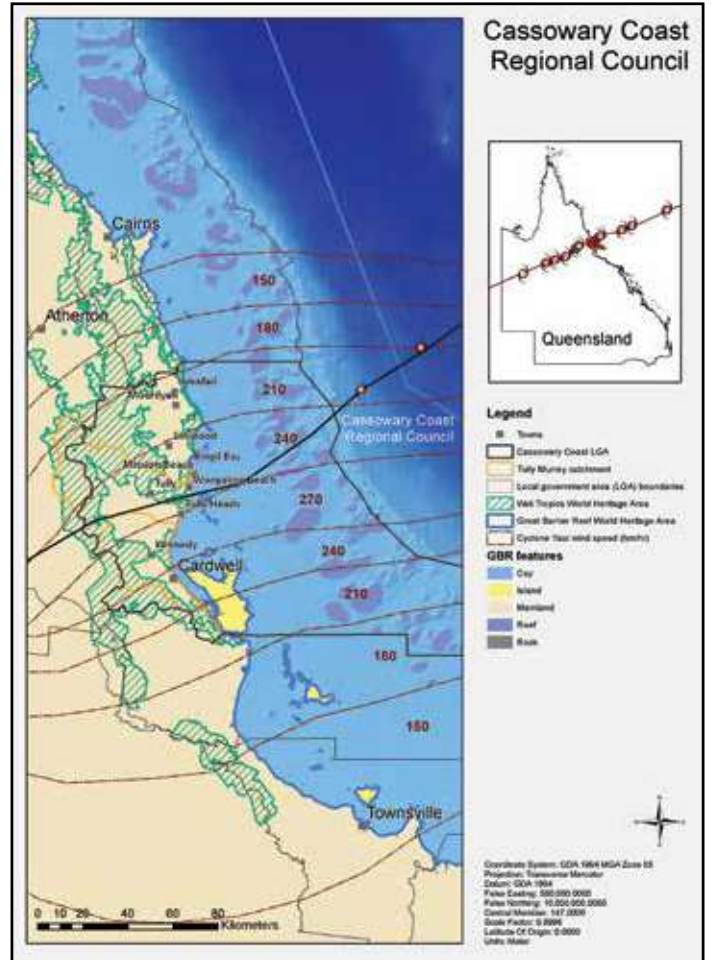
Dunk Island Resort prior to TC Yasi.



Dunk Island Resort following the destructive waves, storm surge and winds caused by TC Yasi.



Figure 4: Great Barrier Reef features affected by Cyclone Yasi, 2011.



Damage and mass sand deposition at Dunk Island Resort caused by several metre storm surge during TC Yasi.



Table 5: Area (hectares) of primary land use affected by Cyclone Yasi at different wind speeds (km/hr).

Primary land use	Wind speed km/hr					Total	%
	150	180	210	240	270		
Conservation and natural environments	0	9,106.1	126,920.4	131,660.9	48,064.5	315,752.2	63.2
Intensive uses	0	234.7	3,006.9	3,699.3	480.3	7,421.2	1.5
Production from dryland agriculture and plantations	0	666.6	18,194.0	44,518.8	9,385.2	72,764.7	14.6
Production from irrigated agriculture and plantations	0	165.1	7,489.9	7,857.5	1,106.4	16,618.9	3.3
Production from relatively natural environments	0	280.9	16,775.9	15,137.5	5,510.8	37,705.2	7.5
Water	0	31.9	15,032.0	21,599.4	12,554.3	49,217.7	9.9
Total area	0	10,485.4	187,419.3	224,473.5	77,101.7	499,479.9	100.0

Table 6: Area (hectares) of secondary land use affected by Cyclone Yasi at different wind speeds (km/hr).

Secondary land use	Wind speed km/hr					Total	%
	150	180	210	240	270		
Cropping	0	17,213.3	63,640.3	40,034.5	6,423.6	64,215.5	12.9
Estuary/coastal waters	0	51.3	32,896.3	0	0	121.1	0.03
Grazing modified pastures	0	147.6	51.3	52.4	35.2	244.7	0.05
Intensive animal production	0	7,342.3	692.0	7,805.1	1,040.8	16,343.8	3.3
Intensive horticulture	0	16,283.8	26.9	12,781.9	3,835.3	33,181.9	6.6
Irrigated cropping	0	7,436.0	235.1	3,912.4	1,214.9	12,576.2	2.5
Irrigated perennial horticulture	0	106,806.6	16,180.9	112,178.5	42,620.7	270,435.9	54.1
Irrigated seasonal horticulture	0	19,103.8	30.4	19,048.8	5,423.8	43,852.4	8.8
Land in transition	0	889.9	145.2	4,366.1	2,961.5	8,270.3	1.7
Livestock grazing	0	2,026.6	32,885.7	2,450.6	449.7	5,159.1	1.0
Managed resource production	0	2,284.7	1,463.4	1,273.8	70.3	3,647.9	0.7
Manufacturing and industrial	0	371.2	318.4	460.1	5.3	839.1	0.2
Marsh/wetland	0	5,302.2	12,556.3	16,356.3	11,256.8	32,915.4	6.6
Mining	0	247.3	169.4	445.1	0	692.4	0.1
Nature conservation	0	18.5	261,484.6	8.4	0	26.9	0.01
Other minimal use	0	36.9	43,555.1	108.4	0	145.3	0.03
Perennial horticulture	0	1,010.0	12.5	433.6	20.3	1,463.9	0.3
Plantation forestry	0	181.5	8,213.6	135.9	1.1	318.6	0.1
Production forestry	0	71.3	4,520.9	98.2	0	169.5	0.04
Reservoir/dam	0	2.7	78.2	9.8	0	12.5	0.01
Residential	0	492.1	4,924.3	2,355.6	1,675.5	4,523.2	0.9
River	0	9.0	3,627.0	56.9	12.2	78.3	0.02
Services	0	85.7	836.1	78.8	24.2	188.7	0.04
Transport and communication	0	4.6	188.6	5.9	0	10.6	0.01
Utilities	0	0	10.6	16.2	0	16.2	0.01
Waste treatment and disposal	0	0	16.2	0	30.4	30.4	0.01
Total area	0	187,419.3	488,759.6	224,473.5	77,101.7	499,479.9	100.0

Table 7: Value of freehold properties within the Cassowary Coast Regional Council area affected by Cyclone Yasi, and after in 2012 and 2013.

Wind speed km/hr	Total area (ha) of localities within wind speed track	Area (ha) that includes property value	Total property value \$AUD of localities
150	0	0	0
180	11,048.79	3,797.83	24,764,288
210	205,543.58	133,079.41	889,545,438
240	285,020.27	242,566.98	1,436,237,660
270	91,558.22	91,558.22	114,968,009
Total	593,170.85	471,002.44	2,465,515,396
2012	593,170.85	471,002.44	2,147,154,703
2013	593,170.85	471,002.44	2,014,325,544

Figure 5: Cassowary Coast Regional Council – demographics showing children (dependents 0-19 years old) and population aged above 65 years affected by Cyclone Yasi, 2011.

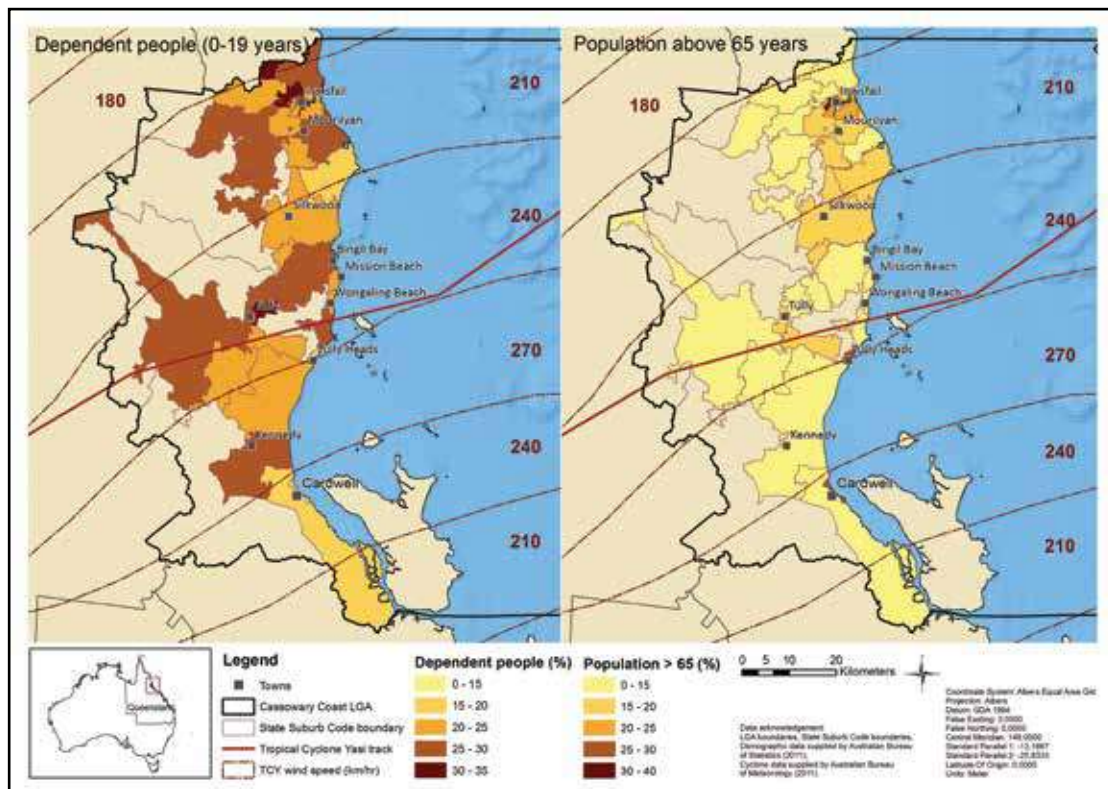
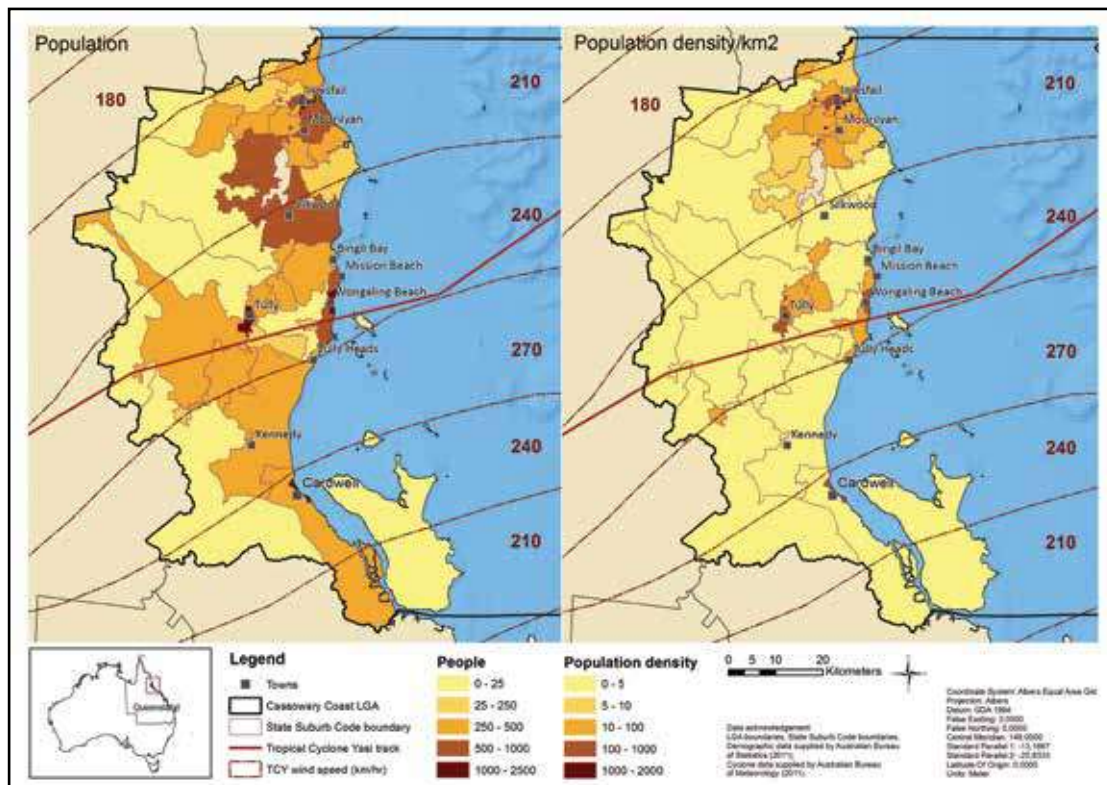


Figure 6: Cassowary Coast Regional Council – demographics showing population density and number of people affected by Cyclone Yasi, 2011.



4. Discussion

During the early development of many Australian coastal regions, a lack of planning and development restrictions, combined with a clear disregard for coastal hazards, has resulted in significant numbers of people and infrastructure placed at risk from hazards such as storm surges and inundations (King *et al.*, 2012) which are often secondary effects from tropical cyclones. With the onset of climate change, coupled with development pressures associated with coastal population growth, levels of vulnerability and risk in storm surge prone areas will only increase. In response to this projected increase, this case study investigated the remaining area of natural coastal features and protected areas in the wake of Australia's second largest cyclone in the Cassowary Coast Local Government Area (LGA) in protecting communities from cyclones and associated storm surge and damage.

Cyclone Yasi made landfall near Mission Beach and continued inland for over 500 kilometres before it weakened near Mt Isa. Serious storm tide inundation was narrowly avoided as tropical Cyclone Yasi crossed 4 hours post high tide. However, it still caused extensive wind/rain damage and resulted in storm tide inundation in several locations along Queensland's tropical coast. The high wave energy generated by Cyclone Yasi resulted in beach erosion between Cairns and Townsville, and damage to infrastructure along the coastline between these two cities. Our analysis interrogates further the effects of Yasi on the natural environment within the Tully-Murray catchment where wind speeds between 200-275 km/hr were recorded by looking at both primary and secondary land uses, regional ecosystems and features of the Great Barrier Reef.

In Australia more than 92% of the population is already concentrated in six State capital cities and additionally unprecedented urban growth is also taking place along the Australian coastline, a phenomenon termed 'sea-change'¹¹

¹¹ Sea-change is a popular Australian expression for what has been termed 'amenity migration' in the United States, Canada and Europe (Esparza & Carruthers, 2000; Marcouiller, Clendenning, & Kedzior, 2002; Moss, 2006).

(Bohnet & Pert, 2010; Burnley & Murphy, 2004). By steering particular land uses away from vulnerable areas and encouraging their development in less hazard-prone locations, a community can reduce the risk to individuals and livelihoods. In the Queensland Coastal Plan (2011) there has been an increased focus on coastal hazard zones, based on a static increase in mean sea level and changes to the intensity of mid latitudinal storms and tropical cyclones¹². Future land use planning and zoning will be imperative to the hazard adaptation process, for instance by reducing development in hazard prone areas. In North Queensland where the probability of severe cyclone-induced storm surges is relatively high in future decades, the strategy encouraged by the Queensland Reconstruction Authority is to build residences better able to withstand severe cyclonic winds and associated storm surges (Queensland Reconstruction Authority, 2011).

Historically, in many communities a 'land use plan' may be nothing more than a common understanding of where particular land uses should occur. Effective land use management systems need to have plans that are supported by policies, that prevent particular land uses from occurring in specific areas and encourage their development in more desirable locations. As shown the property values within the study area have decreased since Cyclone Yasi, and the economic impact has been estimated at close to AUS\$ 3.6 billion dollars (according to forecasting service Tropical Storm Risk (TSR)). Some say its overall damage as measured by insurers puts it as the second worst cyclone to ever hit Australia, after Cyclone Tracy, which struck Darwin in 1974. It has been estimated that Cyclone Yasi destroyed about 15% of all sugar crops in Australia¹³, and 50% of the productive potential in the region. Estimates of close to AUS\$ 504 million dollars¹⁴ in lost sugar cane generated revenue were also described.

¹² see Queensland Coastal Plan, s2.1 – Defining Coastal Hazard Areas

¹³ <http://www.news.com.au/finance/sugar-price-soars-on-us-markets-as-cyclone-yasi-hits-queensland/story-e6frfm1i-1225999207987>

¹⁴ <http://www.reuters.com/article/2011/02/03/us-cyclone-australia-losses-idUSTRE7121K620110203>

When assessing the socio-economic position of the Cassowary Coast Regional area, a few disturbing patterns appear (when compared to other regions in the Wet Tropics), namely: incomes and employment are relatively low, unemployment is relatively high, and more than three quarters of the population have been assessed as falling within the bottom two quintiles of the Australian Bureau of Statistics', Socio-Economic Indexes for Areas (SEIFA)¹⁵ index of socioeconomic disadvantage (Office of Economic and Statistical Research, 2011).

Protected areas have a high capacity to supply regulating ecosystem services (e.g. storm protection, flood control, erosion regulation) due to the low level of human intervention. The larger the protective buffer (especially along the coastline) the greater the damage reduction. In our study, a large area of the coastline has been cleared and was exposed to greater damage. Historically, much of the region was covered by tropical rainforest with local variations in type. Although our study did not look specifically at mangroves, they have been recognized as an important buffer between land and sea, filtering terrestrial discharge, decreasing the sediment loading of coastal waters and maintaining the integrity of coastlines (Lovelock & Ellison, 2007). The role of mangroves as a natural protective belt against cyclone and storm surges is however under threat, at the very time when storm damage is predicted to increase through climate change. The major impact from Tropical Cyclone Yasi occurred to the coast on the southern side of its track (in the vicinity of the radius of maximum winds) for beaches facing an east to south-east direction (e.g. Tully/Hull Heads, Mission Beach, Bingil Bay), which had the greatest exposure to onshore winds. It is suggested that future studies compare areas with and without mangroves along this coast at a more local scale, and investigate and quantify the role of mangroves in ameliorating effects such as wave surges post cyclone. It is recommended that vegetation characteristics such as vegetation density, stiffness, and width be measured, as

¹⁵ <http://www.abs.gov.au/websitedbs/censushome.nsf/home/seifa>

vegetation width and height have been shown to have a positive effect on wave attenuation and shoreline stabilization (Shepard *et al.*, 2011). Furthermore, a recent study of the links between the oceans and human health noted a critical need for epidemiological research to address the public health consequences of coastal flooding and the anticipated amplification of this human health hazard due to climate change (Kite-Powell *et al.*, 2008).

5. Conclusion

Damage from cyclones is caused by high wind velocities and additionally through storm surges inundating coastal areas. Measures to reduce the impact of cyclones in the past have included: using expensive structural and non-structural approaches to attenuate storm surges; the design of buildings and infrastructure to withstand high wind speeds; strengthening

community and ecosystem resilience so that systems recover more quickly; and providing a buffer zone between the coastline and infrastructure.

The insight provided from this study builds on these measures by examining protected areas and natural features as barriers and their cyclone buffering capacity. This study strengthens the view that management of natural areas should be integrated into coastal zone hazard mitigation and climate change adaptation policies. Natural Resource Management (NRM) managers and communities need to be more aware of the value natural ecosystems play in protection of shores from storm surges and waves resulting from cyclones.

In the wake of Tropical Cyclone Yasi, the Cassowary Coast Regional Council, in association with James Cook University

and the Queensland Reconstruction Authority released a set of non-statutory guidelines related specifically to communities affected by Yasi and destructive surges (King *et al.*, 2012). Although the report and guidelines were based on a specific assessment of the Tully/Hull Heads townships, the recommendations included are currently applicable to all low lying coastal communities throughout Queensland. How we choose to respond to coastal hazards from cyclones and sea level rise has further significant implications for sustaining our coastal livelihoods and ecosystems. It is clear that coastal management decisions should consider the dynamics of natural coastal systems previous to human modifications and be cautious about any actions that erode the natural benefits and ecosystem services provided by natural resources and protected areas.

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Chapter 2

Economics of climate adaptation in Barbados – facts for decision making

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Abstract

Climate change could significantly increase the risk of hurricanes and storms in the Caribbean and threaten future development in the region, concludes a study released by the Caribbean Catastrophe Risk Insurance Facility (CCRIF). According to the study's results damage from wind, storm surge and inland flooding already amounts to 4% to 6% of the national Gross Domestic Product (GDP) per year in Barbados and other Caribbean countries. Under a high climate change scenario, annual expected losses could rise by another 1 to 3% of GDP by 2030.

Early investment in climate resilience is more cost-effective than post-disaster recovery. Barbados, for example, could cost-effectively avoid more than a third of expected losses by implementing risk mitigation initiatives such as beach nourishment and reef and mangrove revivals. Protecting mangroves and coral reefs can considerably reduce damage from strong winds and storm surge. Every dollar invested in the Folkestone Marine Park on the west coast of Barbados, for instance, could reduce 20 dollars of hurricane loss.

This is why climate adaptation is a priority for national and local decision makers. In identifying the most relevant strategies, decision makers need to know: What is the potential climate-related loss to the country's economy? How much of the loss can be averted? What investment will they need, and will the benefits outweigh the costs?

The Economics of Climate Adaptation (ECA) compiles the facts to answer the above questions. It offers decision makers a methodology to integrate climate adaptation with economic development and sustainable growth. The Economics of Climate Adaptation methodology is developed by the ECA Working Group, a partnership between the Global Environment Facility, McKinsey & Company, Swiss Re, the Rockefeller Foundation, ClimateWorks Foundation, the European Commission, and Standard Chartered Bank. ECA studies have been carried out in more than 20 different places, including the City of New York, the Caribbean, India, Guyana, the United Republic of Tanzania, Mali and China. They show that up to 65% of loss can be averted using cost-effective adaptation measures, such as risk prevention, risk mitigation and risk transfer.

This paper presents the ECA methodology, provides results from Barbados where it was applied, and discusses the relevance of the methodology as well as the findings in establishing adaptation strategies to climate change.

1. Introduction

The unequivocal warming of the climate system, as reported by the Intergovernmental Panel on Climate Change (IPCC) has already affected the Caribbean. Temperatures in the Caribbean have increased by about 1°C during the last century, while sea level rise has reached about 2-3 mm per year since

1980 (IPCC, 2013). These conditions are compounded by significant changes in precipitation patterns in the region, thereby increasing the economic and social vulnerability of the entire region. Consequently, countries need lasting adaptation strategies that can help to provide security for the livelihood of the citizens and protection against an ever changing climate.

Weather events can threaten cities, regions and entire nations. Losses from natural catastrophes are rising as wealth accumulates in the world's most exposed regions and our climate continues to change (Swiss Re, 2014b). Wind, storm surge and inland flooding can threaten a country's physical infrastructure and housing, tourism, agricultural, industrial and service sectors (Bank for International Settlements, 2012). Local effects of climate change can aggravate the risk. Furthermore, rising sea levels contribute to coastal flood events that might occur more often (IPCC, 2012). Natural hazards already represent a significant risk to inhabitants and economies in Barbados and other Caribbean countries. In Barbados, higher sea surface temperature in the tropical Atlantic and higher specific humidity may provide more energy to future hurricanes, increasing damage potential (IPCC, 2013). Hurricanes cause significant damage through wind and torrential rain, which causes coastal and inland flooding.

Adaptation to climate risks is needed. Adaptation measures, that combine risk prevention, risk mitigation and risk transfer, as part of a comprehensive

adaptation strategy, can make rural and urban communities more resilient to the impacts of climate change. Mangroves and healthy reefs can be an option for risk prevention. Mangroves can considerably reduce damage from strong winds and storm surge through attenuation of wind speeds, dissipating wave energy, and delay erosion (Kunkel *et al.*, 2006). Mangroves thrive in or near river deltas where fresh and salty waters mix. Also living coral reefs can reduce storm surge run-up on land by up to 50% (Kunkel *et al.*, 2006). The diverse coral reef communities provide a very rough surface that exerts drag force on incoming waves. However today, mangroves and especially coral reefs in Barbados are threatened. A wide variety of activities ranging from coastal development and deforestation to climate change, pollution to overfishing have endangered mangroves and coral reefs. Additionally, mangroves further dwindled due to hurricanes that uprooted whole communities and deposited sediment in rivers that reduced the flow to mangroves. Establishment of new protected areas and national parks can effectively protect, stabilize and expand the current mangrove population and coral reefs.

To systematically analyse today's and future climate risks and to assess adaptation measures ranging from risk prevention, risk mitigation and risk transfer measures, the Economics of Climate Adaptation (ECA) Working Group, has developed the ECA methodology (ECA Working Group, 2009). The ECA Working Group is a partnership between the Global Environment Facility, McKinsey & Company, Swiss Re, the Rockefeller Foundation, ClimateWorks Foundation, the European Commission and Standard Chartered Bank. The ECA methodology provides the facts and tools required to develop quantitative adaptation strategies that can be incorporated into national development plans to increase resilience against climate related hazards.

The resulting ECA report, from applying the above methodology (CCRIF, 2010) provides quantitative cost-benefit analysis of risk prevention, risk mitigation and risk transfer measures in the Caribbean. This report can enable countries to actively address the climate change challenges facing the region. The report focuses on

impacts of climate risks and change on a country's physical infrastructure (including housing), but also on tourism, agricultural, industrial and service sectors. It establishes baseline risk scenarios and provides quantitative cost-benefit analysis of risk prevention, risk mitigation and risk transfer measures. It highlights that adaptation measures need to include a wide range of prevention, mitigation and risk transfer measures, starting from behavioural initiatives such as awareness campaign, investments in ecosystem services and green infrastructure (protected areas, mangroves, beach nourishment, wetland restoration and reef revival); including also infrastructure improvements, such as strengthening buildings against storms or constructing reservoirs and wells to combat drought; technological measures, such as the improved use of fertilizers; and last but not least effective disaster relief and emergency response programmes. Moreover, risk transfer or insurance measures also play a key role in addressing rare but severe weather events, such as a once-in-100-year storm surge. Such information is of immense value to both Caribbean policy makers and the business sector, in their efforts to develop, implement and execute sound adaptation strategies.

2. Methodology

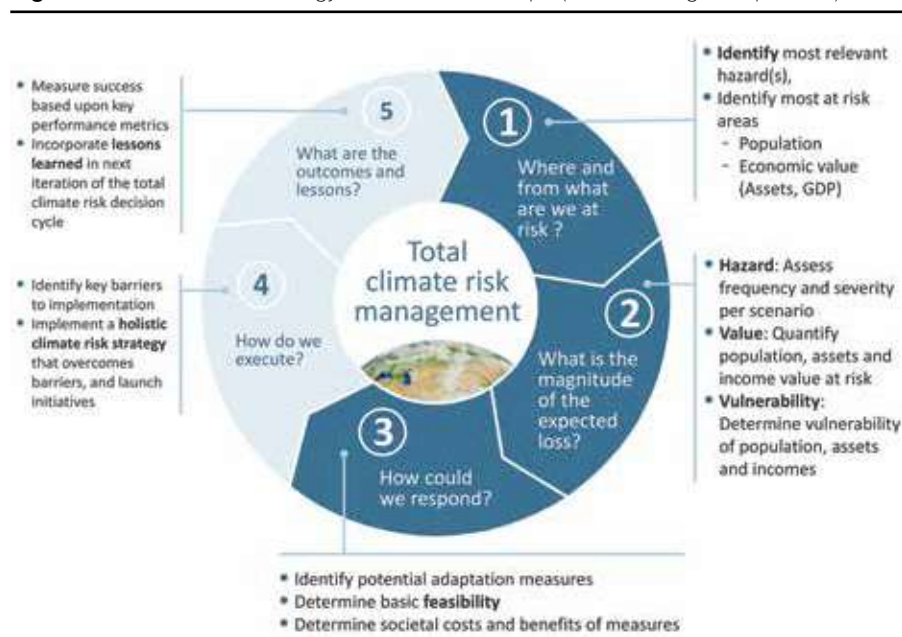
The Economics of Climate Adaptation methodology provides the facts and tools required to develop quantitative adaptation strategies that can be incorporated into national development plans in order to increase resilience against climate hazards.

This includes the assessment of the expected annual loss to the economy from existing climate patterns; a projection of the extent to which future economic growth puts greater value at risk; and finally an assessment of the incremental loss that could occur over a twenty-year period under a range of climate change scenarios based on the latest scientific knowledge. The management of the total climate risk addresses five key questions, each driving a core set of analysis (Figure 1). The ECA methodology¹ answers the first three questions in depth. However steps 4 and 5 need to be tackled by decision makers and practitioners. In the methodology section steps 1 to 3 are explained.

2.1 Where and from what is the country most at risk?

For a given region, population and assets at risk are compiled. This compilation is based on population density and distribution of economic activity in

Figure 1: The ECA methodology consists of five steps (ECA Working Group, 2009).



¹ For a detailed introduction to the economics of climate adaptation please refer to the seminal publication, Shaping climate-resilient development, a framework for decision-making, Swiss Re, 2014a, which includes eight case studies. Specifically see page 122ff (http://media.swissre.com/documents/rethinking_shaping_climate_resilient_development_en.pdf).

a geocoded map. For Barbados, assets such as the country's physical infrastructure (including housing), its tourism, agricultural, industrial and service sectors have been included. Based on the geographical distribution of included assets, the most relevant climate hazards such as wind storms, floods and sea level rise, are identified. Local historical data sets including temperature, precipitation and individual events also need to be compiled for a comprehensive understanding of the situation.

2.2 What is the magnitude of the expected loss?

The methodology follows a rigorous risk management approach to assess local total climate risk, which is the sum of today's climate risk, the economic development paths that might put greater population and value at risk (a projection) and the additional risks presented by climate change (based on impact scenarios). Based on historic events and probabilistic natural catastrophe modelling, the annual expected economic loss today is calculated. The term 'annual expected loss' is used in the sense of risk assessment, where the risk is the probability of something happening multiplied by the resulting cost if it does.

To deal with uncertainty, three climate change scenarios, namely 'no change', 'moderate change' and 'extreme change' are derived for the year 2030. The scenarios are derived from the latest scientific findings available, such as those of the IPCC. For extreme events, such scenarios could depict changes like increased frequency of strong hurricanes (Saffir-Simpson category 4 and 5), increase of storm surge height, sea level rise, prolonged droughts and/or increase in extreme precipitation.

2.3 How could we respond?

A comprehensive inventory of local adaptation measures, many of which span both climate adaptation and economic development, are identified. The adaptation measures were identified through interviews and participatory workshops with external experts, government ministries, private-sector stakeholders, as well as multilateral and local Non-Government Organizations (NGOs). Collaboration with local authorities

is especially crucial for the prioritization and analysis of measures across the development spectrum. Local interviews and experience in implementing public works are critical in developing a shortlist of measures. The full range of available measures to avert or transfer the loss – spanning infrastructural, technological, behavioural and financial solutions – is evaluated, and their costs and benefits calculated. For Barbados, 20 adaptation measures from a longer list were selected based on their appropriateness and feasibility. For the cost-benefit analysis, the benefit is calculated as the averted loss and any additional revenues if applicable. The costs include capital and investment costs and operating expenses as well as any potential operating savings derived from the measures. The stream of costs is discounted back to today's dollars using local discount rates. One way to summarize the facts is the adaptation cost curve (see Figure 2 and Figure 5 for Barbados). The curve shows the damage reduction potential as well as the cost-benefit ratio of each adaptation measure. Each adaptation measure is plotted on the adaptation cost curve, ranging from the most cost-efficient on the left of the curve to the least cost-efficient measures on the right. The horizontal axis depicts the total climate risk and indicates the extent of the loss averted by each measure. The cost-benefit ratio of 1 represents the same

amount of damage costs and benefits (i.e. reduced loss through preventive measures). To account for uncertainties involved in the assessment of costs and benefits, measures with a cost-benefit ratio below 1.5 were examined more precisely. Based on the cost-benefit analysis, a portfolio of cost-effective adaptation measures was compiled for each country.

3. Results

The analysis has shown that annual expected losses from weather events amount to approximately US\$ 139 million or 4% of GDP in Barbados (Figure 3, CCRIF, 2010). The majority of the loss is due to strong winds. Meanwhile, inland and coastal flooding account for roughly a quarter of the losses.

In other Caribbean countries studied, annual expected losses were highest in Jamaica, accounting for 6% of GDP, and lowest in Antigua and Barbuda with 1% of GDP (Figure 4, CCRIF, 2010). Such differences between countries are driven by a diverse set of factors, including topography/exposure to coastal hazards, economic significance of particularly vulnerable sectors (e.g. residential assets, which are typically less well protected against climate hazards) and location (e.g. in 'Hurricane Alley'). Already today, the economic damage is high and is in the range of the impact of a serious economic recession.

Figure 2: The adaptation cost curve compiles the damage reduction potential as well as the cost-benefit ratio of each adaptation measure (ECA Working Group, 2009).

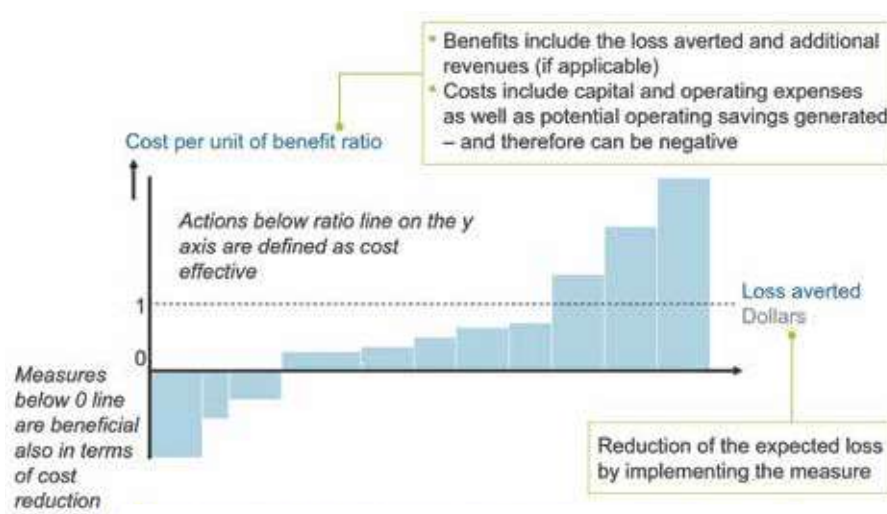
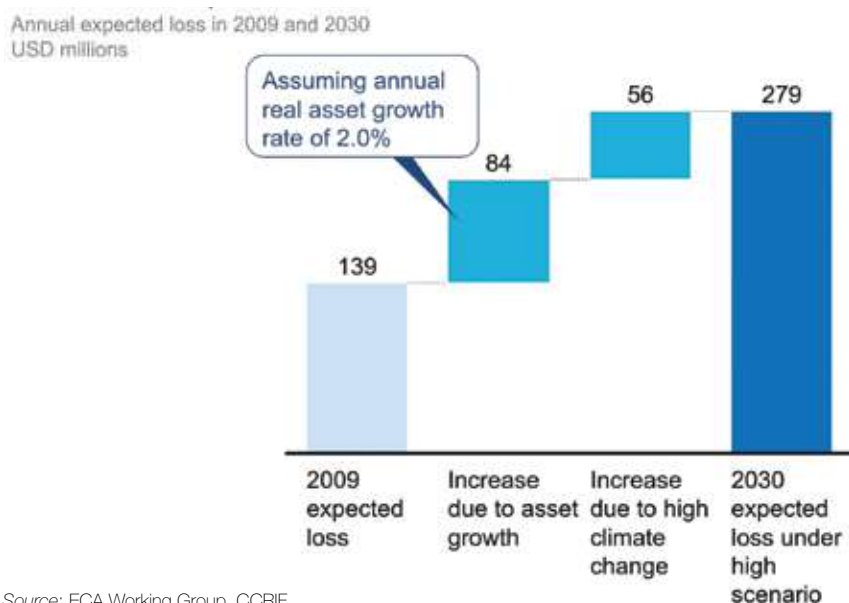


Figure 3: Today's risk, economic development and climate change contribute to the total climate risk in Barbados in 2030.



Source: ECA Working Group, CCRIF.

The total climate risk however, is the sum of today's risk, increase due to asset growth until 2030 and climate change. Adaptation measures are not yet taken into account. The economic loss potential in Barbados may rise to US\$ 279 million per annum by 2030, taking into account an estimated additional US\$ 84 million in potential average yearly loss generated by the increase in asset accumulation as a result of economic development during that period (Figure 3, CCRIF, 2010). Additionally, a high climate change scenario featuring rising sea levels, more severe hurricanes and land subsidence adds another US\$ 56 million for a total amount of US\$ 279 million expected annual losses by 2030. Overall, expected loss as a proportion of GDP could rise to between 2% and 9% in the high climate change scenario by 2030 (Figure 4, CCRIF, 2010). In absolute terms, expected loss may triple between now and 2030, with wind remaining the single largest contributor. Economic growth is typically the greatest driver of the rise in expected loss, accounting for some 60% of the increase in all countries, with the exception of Jamaica, where it accounts for around 40%.

On a local scale, climate change can severely modify the risk profile of a country by impacting local sea levels, hurricane intensity, precipitation patterns and

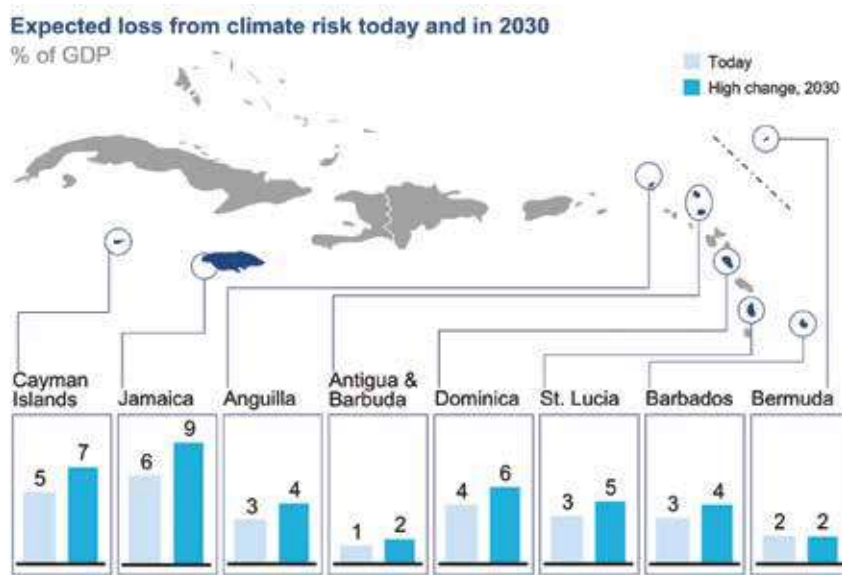
temperature patterns. In the high climate change scenario, sea levels may rise by up to 15 mm/year (excluding local geological effects such as uplift/subsidence), and wind speeds may increase by around 5% as a consequence of the expected rise in sea surface temperature in the hurricane genesis region. It is important to note that even small local changes may have large effects due to the non-linear correlations between climate and hazards. A 200-year

event in Bermuda, for instance, might become a once-in-a-lifetime (75-year) event as a result of these seemingly small changes.

The third step in the risk management cycle looks at how to respond and manage the risks pro-actively. Cost-efficient adaptation measures can avert up to 35% of future losses in Barbados (CCRIF, 2010). Numerous measures are available to decision makers to respond to the potentially increasing threat of climate change. These responses can be clustered into two main groups:

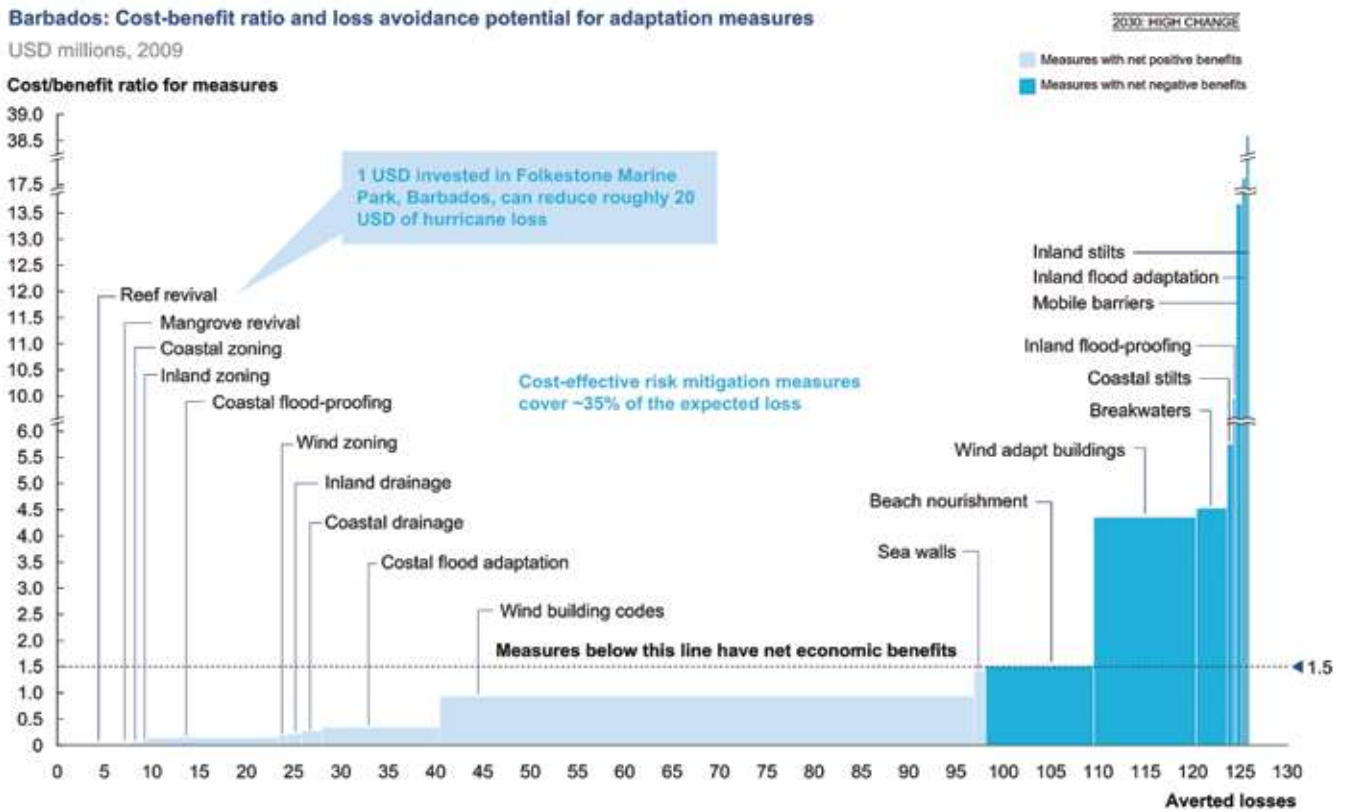
- **Risk Mitigation:** Risk mitigation responses are adaptation measures aimed at reducing the damage. They include asset-based responses (e.g. dykes, retrofitting buildings) and behavioral measures (e.g. enforcing building codes).
- **Risk Transfer:** Risk transfer solutions, such as catastrophic risk insurance, are adaptation measures aimed at limiting the financial impact for people affected by distributing the risk to other players in the market. Risk transfer solutions are particularly effective in the case of low-frequency and high-severity events. Risk transfer mechanisms are based on transferring part of the risk to a third party (e.g. an insurance/reinsurance company or the capital market), and include both

Figure 4: Expected loss from climate risk today and in 2030 in eight Caribbean countries.



Source: ECA Working Group, CCRIF.

Figure 5: Adaptation cost curve for Barbados: Cost-benefit-ratio and loss avoidance potential for adaptation measures.



Source: ECA Working Group, CCRIF.

traditional insurance products and alternative risk transfer instruments (e.g. NatCat (natural catastrophes) bonds).

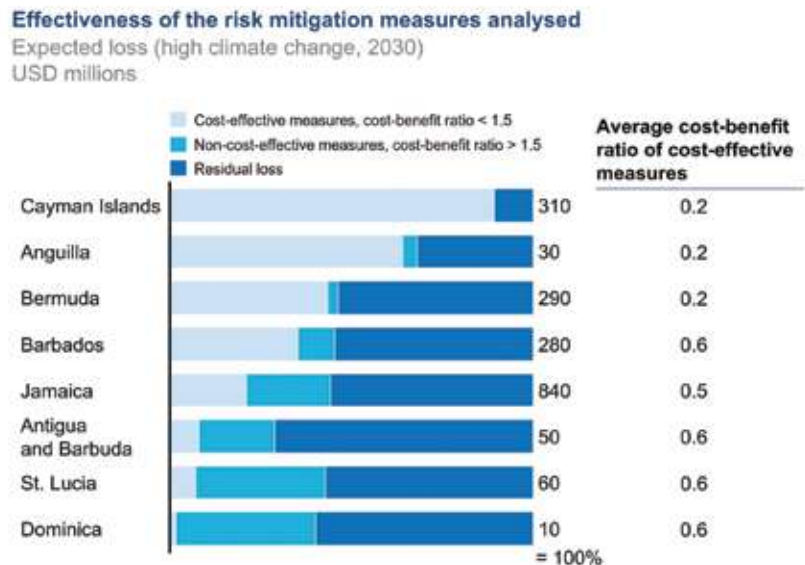
The cost-benefit ratio is the loss reduction compared to the mitigation costs, including capital and operating expenses. A cost-efficient measure will prevent more losses than the mitigation costs. The reduced losses per US dollar invested are shown in the adaptation cost curve (see Figure 5). The study shows that a number of cost-efficient adaptation measures are available and that together these could lower damages in Barbados by 35% (CCRIF, 2010). Among the most attractive adaptation measures are reef and mangrove revivals, strengthened zoning laws, increased drainage capacity and wind specific building codes. For instance, protecting the Folkestone Marine Park on the west coast of Barbados and ensuring reef and mangrove revivals can lower losses by US\$ 20 million annually for an annual cost of only US\$ 1 million (CCRIF, 2010). Other measures assessed range from retrofitting existing buildings with wind-proofing measures, installing windbreaks to

protect crops, beach nourishment, building sea walls, elevating new buildings, and managing vegetation to minimize debris.

As displayed in Figure 6, in the other Caribbean countries studied, up to 90%

of the expected loss in 2030 under the high climate change scenario can be averted cost-effectively using risk mitigation initiatives (CCRIF, 2010).

Figure 6: Effectiveness of risk mitigation measures analysed.



Source: ECA Working Group, CCRIF.

4. Discussion

Among the hazards considered, hurricane-induced wind damage has the largest damage potential, accounting for up to 90% of the overall damage in the Caribbean. The contribution of coastal flooding/storm surge to total damage is higher in low-lying countries. In the Cayman Islands coastal flooding/storm surge accounts for about 45% of total damage potential (CCRIF, 2010). There is also a considerable difference between the risk profile for smaller and larger countries. Larger countries are more likely to be hit by a strong hurricane by virtue of the area they cover, although hurricanes have a lower relative impact. Smaller countries are hit more rarely on average, but with more devastating effects ('hit or miss').

Preserving Folkestone Marine Park by protecting and expanding the coastal mangrove stands can reduce considerable damage from storm surge by dissipating wave energy on the coastline. A hundred metres of mangrove forest can achieve up to 90% reduction in storm wave energy for waves up to 6 m (Barbier *et al.*, 2008). Additional benefits are natural restoration and habitat rebuilding, together with ecotourism attractions. In addition, mangrove forests trap sediment therefore reducing erosion and may withstand waves of 5 to 7 m or higher (Brinkman *et al.*, 1997, Mazda *et al.*, 2006, Alongi, 2008). Mangroves may also migrate inland to accommodate sea level rise and consequently it can significantly increase the lifetime of seawalls (by up to a factor of 10, Gillman *et al.*, 2006). However adaptation does not come for free. Mangrove revival in Folkestone Marine Park not only requires financial resources, but also a cultural shift – mangroves are currently viewed as a nuisance because they are mosquito breeding grounds, have an unpleasant smell, and cause blockage of sea access. Early cultivation efforts may be wiped out in storms until communities become established. Finally the full effectiveness of damage reduction through mangroves requires mature mangrove forest.

In the case of the Caribbean, seven additional steps are required to put the final results of the ECA study into action. These steps span from understanding the results at a highly granular level to

designing a cost-effective portfolio of adaptation measures, accessing funding by submitting fact-based requests, and accelerating implementation.

Not all possible measures were assessed due to data and time limitations. Despite a full application of the framework, real-world constraints of time and resources would force some type of prioritization of the measures to be assessed through the methodology. Importantly, the prioritization of adaptation measures will also be driven by local policy goals, constraints and considerations which may be quite different from minimizing financial costs and maximizing economic benefits. Cost-benefit analysis provides a powerful tool to identify the most attractive adaptation measures based on an economic assessment. However, as discussed above, this approach has some limitations and provides just one input into a multicriteria decision-making process. One of the most significant limitations of cost-benefit analysis is its assumption that decision makers are risk-neutral and make choices based primarily on economics – and would therefore tend to prefer measures for which economic benefits outweigh the costs of implementing the measure. As we emphasize throughout this report, decision making is based on many other factors, including qualitative impacts and policy targets. Furthermore, to make practical use of these insights, additional work will be required from actors such as policy makers, engineers, agricultural specialists, geographers and geologists, economists, climate change scientists, and development specialists, among others.

Nevertheless, the ECA methodology shows that adaptation measures are available to manage the total climate risk and to reduce a significant part of today's and future losses. In the 20 ECA case studies conducted so far, up to 65% of future losses can be averted using cost-effective adaptation measures. The study illustrates the importance of a balanced portfolio of measures in each country. It is important to underline that the findings discussed above are based purely on economic considerations. However, decision makers have to consider further important elements, such as safeguarding life, and reducing human misery. Our findings suggest that the focus of an

adaptation strategy in countries where only a small share of the damage can be averted cost-effectively (e.g. Dominica and St. Lucia) should rely on using suitable risk mitigation initiatives to protect human lives and build on risk transfer solutions to protect economic assets.

5. Conclusion

The Economics of Climate Adaptation report on the Caribbean can enable us to actively address the climate change challenges facing the Caribbean. The report establishes baseline risk scenarios and provides quantitative cost-benefit analysis of risk prevention, risk mitigation and risk transfer measures. Early investment in climate resilience is more cost-effective than post-disaster relief. Barbados can cost-effectively avoid more than a third of expected losses by implementing risk mitigation initiatives such as beach nourishment and reef and mangrove revivals. Every dollar invested in the Folkestone Marine Park on the west coast of Barbados, for instance, could reduce 20 dollars of hurricane loss. Such information is of immense value to both Caribbean policy makers and the business sector, in their efforts to develop, implement and execute sound adaptation strategies. The Caribbean Hazard Mitigation Capacity Building Programme of CARICOM is helping Barbados and other Caribbean countries to create national hazard vulnerability reduction policies; and the United Insurance Company of Barbados is giving financial incentives for homeowners to put preventive measures in place. The Caribbean Catastrophic Risk Insurance Facility (CCRIF) has set up a scheme for small Caribbean States to buy parametric insurance coverage against natural disaster risk. A number of Caribbean countries have already started working on their National Adaptation Programmes of Action (NAPAs). The fact base provided by this study can augment the development and review of these national adaptation strategies. For example, the study prioritizes areas and sectors at risk and provides clear inputs for building an economically viable portfolio of adaptation initiatives designed to increase each country's resilience. Additionally, the results of this study can be used by countries' governments in multilateral and bilateral funding discussions for adaptation initiatives. Given the economic and political

climate, the availability of such funds will not necessarily be permanent. Access to adaptation funding may therefore hinge on each country's ability to support effective business cases with sound quantitative data in a timely manner. This study

provides a relevant toolkit to aid with this.

The ECA case studies highlight economic development and climate change as the key drivers for future climate-related losses. The analysis presents a strong case for

immediate action. Implementing adaptation measures, including risk transfer, can help build global resilience to climate change. It is also less expensive than doing nothing and dealing with the rising costs only after they are incurred.

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Chapter 3

Reducing disaster risks to mangrove forest livelihoods through watershed-based protected area management

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Abstract

Mangrove ecosystems provide invaluable protection from climate change impacts and create environments in which communities can build coastal resilience. They are situated at the interface of saltwater and freshwater sources, where the stable flow of sediment and freshwater allows mangrove forests and associated livelihoods to thrive. One of the largest mangrove forests in Southeast Asia is located in Peam Krasaop Wildlife Sanctuary of Koh Kong Province in Cambodia. It is supported by a 4 km

protective coastal barrier beach and four rivers that are its lifelines. However, as the barrier beach retreats landwards, fishing villages are becoming increasingly vulnerable to coastal hazards. River sand mining and sea level rise are likely responsible. Forest conservation, initiated by IUCN, would improve the consistent flow of freshwater and sediments from the upstream rivers to the ocean, thereby reducing barrier beach migration and coastal disaster risks. This case study highlights the importance of protected area management that accounts

for hydrological connectivity from the upstream watershed to the coast, and it provides further recommendations to protect mangrove-dependent livelihoods from coastal hazards.

This research proposes river management strategies that will reduce barrier beach migration and build coastal resilience. It establishes priority zones for rehabilitation on the barrier beach, based on barrier beach migration rates. Coastal features, including spits and un-vegetated beaches within these priority zones are targeted

The community of Koh Kapik relies on surrounding mangroves for protection from coastal hazards.



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for intervention. Re-vegetation with local plant species will prevent further landward migration of the barrier beach and protect livelihoods. During a provincial workshop and meeting with national government representatives the use of these strategies was discussed. This improved understanding of the highly connected sediment dynamics, coupled with rehabilitation and erosion prevention strategies, offers a pathway to build greater coastal resilience in Peam Krasaop Wildlife Sanctuary. Similar socio-ecological systems exist throughout the tropics, and lessons learnt from this case study can therefore be examined for application to other mangrove-dependent communities.

1. Introduction

Livelihoods of the Peam Krasaop Wildlife Sanctuary (PKWS), of Koh Kong Province, Cambodia are heavily dependent on ecosystem health that supports fish habitats, coastal hazard protection, fresh drinking water and ecotourism (Figure 1). The PKWS and conservation zoning within its boundaries were established in order to protect the largest mangrove forest in Cambodia and provide habitat to a variety

Figure 1: Satellite image of the broad study area, including impacted rivers, mangrove forests and focused coastal study area (Terralook Landsat image taken 10 January 2002).



Figure 2: Fallen mangrove trees stranded on the ocean side of the beach, following barrier beach migration.



of fish, crustacean and shellfish species, on which many settlements are dependent (Nong, 2002, p.1). Before the sanctuary was established in 1998 (Rann, 2012), virtually no mangrove trees remained as a result of unregulated deforestation for charcoal production.

Since that time, landward migration of a protective barrier beach towards the mangroves was accelerated at an unprecedented rate, causing the loss of vast areas of mangrove forest yearly (Figure 2). Although barrier beaches are highly dynamic geomorphic features, relative stability is critical for the protection of large mangrove areas because mangroves are found between the mainland and the

ocean (c.f. Schaeffer-Novelli, *et al.*, 1990), where wave energy is high.

This study investigates rapid environmental degradation, associated with beach migration that is a result of changes in sediment transport dynamics. Immediately landwards of this beach, locals are reliant upon the stable ecosystem as the source of food. Their homes lie at sea level and are protected from coastal hazards only by the barrier beach. Livelihoods are threatened by:

- i) Coastal mangrove forest devastation (Figure 2)
- ii) Severe landward barrier beach migration (Figures 3 and 4)
- iii) River bank erosion
- iv) Koh Kapik channel infilling

These occurrences are linked due to the drift of sand, silt and clay down-river and along coastal currents. There are numerous causes of the ecosystem disruption in the area. Sea level rise is shown to cause drastic landward migration of the barrier beach. Sand mining alters the volume and grain size of river-sourced sand that reaches the barrier beach. Dam construction also reduces barrier beach replenishment of sand. Changes in storm intensity under climate change cause sudden beach migration.

This study therefore identifies which anthropogenic variables, such as sand mining and development, are causing the rapid barrier beach migration. Rehabilitation and adaptation recommendations are made. Lessons learnt from this case study can be applied to other barrier beach environments to act as a manual for barrier beach and mangrove forest management elsewhere.

Figure 3: Aerial photograph of trees stranded in the ocean water on the southern portion of the barrier beach, following barrier beach migration and erosion.



Figure 4: Aerial photograph of barrier beach captured 12 November 2012 by helicopter. The orange line represents the barrier beach location in 1994, during which time the beach was continuous without the current gap.



Koh Kapik, a commune of 2,900 residents (Sar, 2012) located 12 km south of Koh Kong, both contributes to and is harmed by the impacts of altered sediment transport dynamics. Sedimentation of silt over time in the Koh Kapik channel has resulted in substantial infilling, which impairs the ability of the community to use boats to support their fishing livelihoods, access drinking water, and escape coastal hazards under recognizable climate change impacts. These problems can be resolved, but only temporarily by dredging. The source of the problem – increased volumes of clay released from upstream – must be addressed, in order to provide protection and escape coastal hazards. Sedimentation in the channel will otherwise continue following initial dredging.

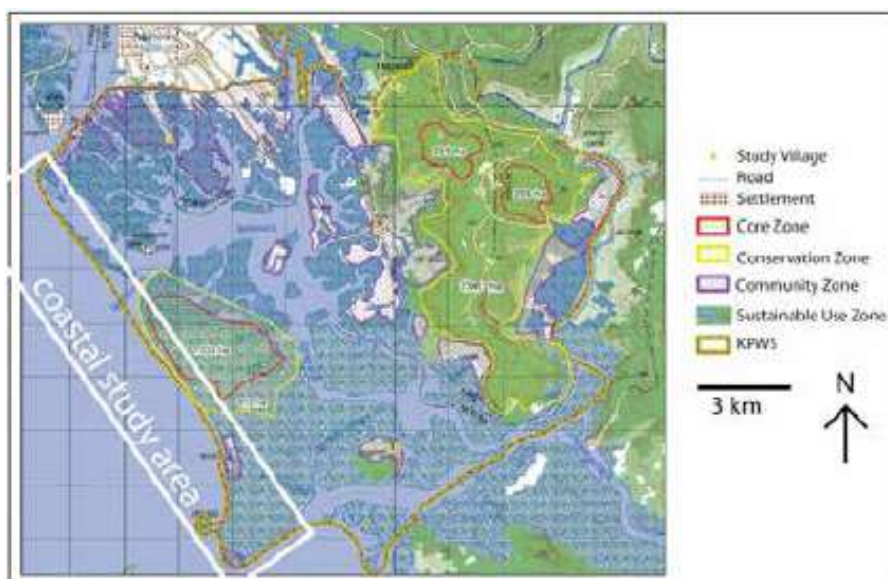
It is clear that significant resources and human capital have been invested in the development of PKWS (Figure 5) and conservation zoning. Challenges in zoning, however, exist in highly dynamic environments, such as coastlines where impacts in protected areas may originate from locations beyond the zoned areas. Ecosystem stability for livelihood prosperity in PKWS is threatened by the changes in sediment flow along the path from

the upstream river sediment source to the coast. Future zoning improvements would therefore need to consider the high connectivity of the ecosystem where critical areas upstream are protected from sediment extraction and erosion in order to prevent downstream and down-current environmental degradation.

2. Methodology

This study was designed to identify the causes of lost mangrove forest in Peam Krasaop Wildlife Sanctuary. These mangroves have provided a basis for disaster risk management for local livelihoods. The impacts of i) upstream

Figure 5: Schematic map of PKWS and conservation zoning (adapted from Kimsreng Kong and Kong Sun).



sand mining in rivers, and ii) sea level rise are investigated in order to develop strategies with which villages can improve resilience to coastal hazards, especially since these hazards have increased in frequency and magnitude.

Study methodologies were interview-based, field-based and computer-based with ground-truth comparisons. A team of three, including a translator, conducted interviews using standardized questions, all of which could be confirmed. Beach migration was quantified through satellite image analyses, using Terraspec Landsat satellite images from as far back as the year 1973. These images demonstrate changes in shape, length, width, continuity and migration of the barrier beach (Figure 6). Images were overlain to compare barrier beach locations amongst all years available. Ground truthing complemented this work through sedimentary sequence analyses and helicopter surveys (courtesy of Wildlife Alliance). Sand mining and dam impacts were studied through water and soil

analyses, sedimentary component analyses, and community member interviews.

Priority locations for intervention on the barrier beach were selected based on the rate of migration (from satellite images and vegetation density (from field observations). Under these criteria, a rapidly migrating beach with no vegetation is of the highest priority.

Barrier beach features in the study area were also ranked according to impact and rehabilitation potential, for which features with high ranking for both categories should be targeted. High impact indicates that rehabilitation or lack of intervention will have great consequences for barrier beach migration. High rehabilitation potential indicates that intervention is likely to be successful.

3. Results

3.1 Study of barrier beach migration

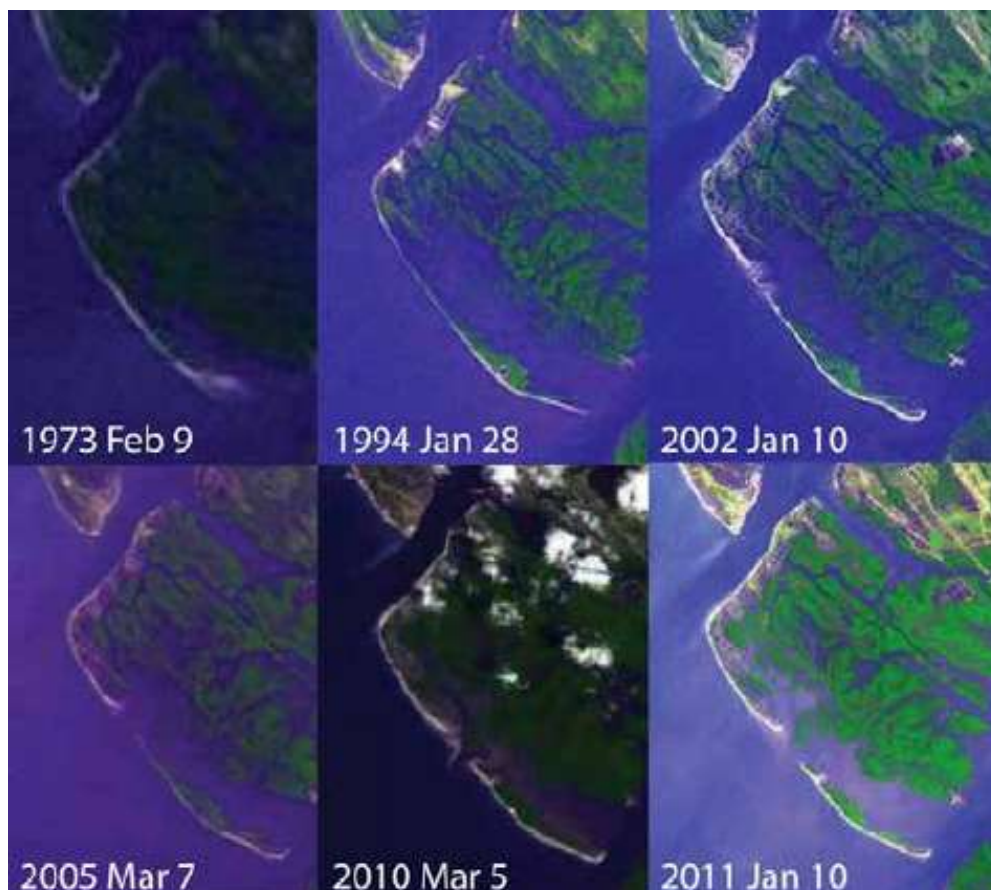
Barrier beach migration results demonstrate the severity of changes in

sediment transport dynamics caused by upstream, anthropogenic activity and marine-based sea level rise. Intervention and restoration activities, based on the principles of sedimentology and watershed hydrology, indicate opportunities to reduce expected spatial and temporal trends under baseline conditions.

3.2 Interviews

Moderate storms during the wet season of 2011 were associated with the migration of the barrier beach (Figure 1). The storms were not thought to have been particularly strong, yet the distance of consequent beach migration was greater than in the past. Strips of mangrove trees 1.2 km long with a width up to 40 m have been killed, due to the waves, suffocation by sand, and excessive salinity levels. The barrier beach was breached and concerns were raised that the exposure of the mangroves to high wave energy and mobilization of sand caused destruction of the protected mangroves.

Figure 6: Satellite images (Terraspec Landsat) demonstrating barrier beach changes in morphology, length, width, continuity and migration. Fluctuations in mangrove coverage are also evident.



New evidence from interviews with local environmental professionals and community members suggests that the barrier beach has been migrating for at least the past 10 years. The remains of a concrete foundation for a shrimp farm, once on the landward side of the barrier beach, are now submerged by ocean water 20 m from the beach. Estimates indicate that the beach has migrated a minimum of 100 m. Local fishermen also explain that mangroves once surrounded by only mud are now covered by over one metre of sand.

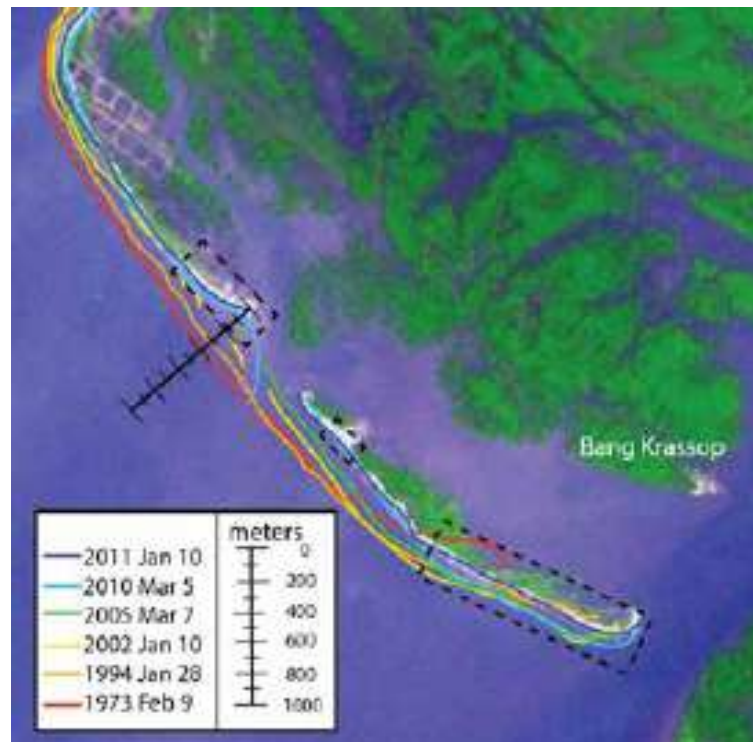
3.3 Satellite image analysis

Most notably the barrier beach has been divided into multiple sections through breaching events since 2002, while there is no evidence for this prior to 2002. A temporal trend in the increase in sand volume is recognized in the southeasterly direction. Seasonal variability can be excluded as an explanation for differences because all images were captured during the dry season when little geomorphic changes take place.

Barrier beach lengthening in the southeasterly direction provides evidence that longshore drift (the current parallel to the shore transporting sediment) is southeasterly. The direction was confirmed during two field visits when floating objects placed 5 metres from the shoreline floated south. Additionally, it was observed that waves break from north to south. Knowledge of dominant longshore drift direction will prove useful in understanding the source of sediment. Figure 7 confirms landward migration of the barrier beach over the period for which the satellite images are available.

This analysis demonstrates that the barrier beach migration reached a maximum of 390 m from 1973 to 2011, at an average rate of 10.3 m per year (Figure 8). Mangrove forest loss due to barrier beach migration is 0.60 km², considering northerly mangrove forest loss and southerly forest gained since 1973. The central part of the barrier has migrated most dramatically. The northern 3 km of the barrier has only migrated landwards at an average of 240 m from 1973 to 2011, with an average rate of 6.3 m per year. The southern 1 km of the barrier has undergone two phases of migration: i) a seaward migration prior to 2005, ii) a

Figure 7: Barrier beach fronts from all available years are indicated in various colours. The visible satellite image is the most recent from 10 January 2011. Between that date and 9 February 1973 migration reached a maximum of 390 m. Dashed boxes represent priority zones for beach stabilization where landward migration is most rapid and vegetation is sparse.



landward migration after 2005. Recent landward migration is most rapid in the southern 1 km, reaching 90 m per year. The southern tip of the barrier beach eroded from 2010 to 2011 (Figure 9). Areas with little or no vegetation are migrating most rapidly.

Priority zones for intervention

- i) Southern Priority zone shows the most rapid migration and the very southern tip has only a thin strip of vegetation
- ii) Central Priority zone has low vegetation density and shows sand dispersal
- iii) Northern Priority zone has experienced massive sand relocation between 2010 and 2011 and holds only sparse vegetation

suffocating the mangroves behind the barrier

The fishing village of Bang Krassop is currently protected by the barrier beach. However, continued erosion, recognized between 2010 and 2011 by local residents, will expose the village to coastal hazards, including large waves during storms.

Figure 8: Migration rates have progressively increased during 4 of 5 periods. The most recent period has the most rapid rate. Distances are sourced from the measurement bar of Figure 7.

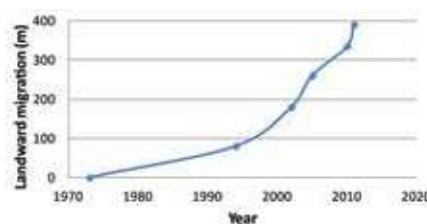
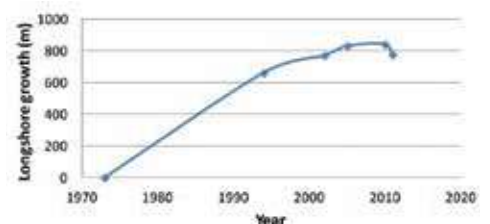


Figure 9: Growth distances southward.

Longshore growth rates have generally decreased over time, except in the southern part. The most recent period shows net erosion of the southern extension of the barrier beach.



Priority barrier beach features for intervention

Some barrier beach features are more susceptible to experiencing overflow, breaching and migration. For example, the beach in the Northern Priority zone without vegetation (Figure 10) is not able to build up high elevation to prevent overflow. The down-current, growing edge of the barrier beach (known as a spit) faces more intense wave energy and therefore migrates more rapidly than other locations. The breached barrier beach has the largest impact on mangroves because the sand has easily been washed landward, suffocating mangrove tree roots. Supporting stable barrier beaches with vegetation will prevent these vulnerable features from forming.

Features in the study area should be targeted according to a balance between i) negative potential impact on mangroves and settlements, and ii) rehabilitation potential. For example, the southern tip of the barrier beach, while most susceptible to migration, is also most difficult to control through re-vegetation or other rehabilitation techniques.

High impact indicates that rehabilitation or lack of intervention will have great consequences for barrier beach migration. High rehabilitation potential indicates that intervention is likely to be successful. Each score is the sum of impact potential and rehabilitation potential (Table 1).

3.4 Assessment of sand mining and dam construction impacts

It was found that the onset of river sand mining correlates, in time, with increased beach migration and mangrove devastation, which is consistent with satellite analysis findings. Since sand mining began, there has been a

Figure 10: Aerial photograph of the Northern Priority zones in 2001, demonstrating the impacts of barrier beach migration and breaching (Google Earth Pro).



Note: the cloudy colour of the sand suffocating mangroves.

reduction in fish catches by 70-90% and displacement of many families as shorelines have retreated by 100 m, according to interviewees. Upstream dam construction has increased water turbidity over a 40 km stretch in the short term. The dam will decrease sand replenishment in the river and beaches in the long term, causing further river bank collapses and barrier beach migration.

Sand mining in the Tatai and Koh Por Rivers, within PKWS (Figure 1), began in 2008 and has continued since then, generally increasing in extraction volumes over time. Winton Enterprises, a Hong Kong-registered group, was sub-contracted to export the sand to Singapore for land reclamation (Yoong, 2011). However, no payments have been made to

compensate local communities for losses, nor do the communities gather any benefits from mining. Peam Krasaop Director, Oul Rann, has monitored the dredging and describes the changes in intensity of sand mining in Tatai River as follows, according to the quantity of sand he saw exported:

- 2008: Onset of sand mining in southern Tatai River with constant increase in intensity
- 2009: Operations increased and moved upstream northward
- 2010: Decreased but continued
- 2011: Increased
- 2012: Reached peak, then the largest sand mining vessels were substituted by smaller vessels

Virtually the entire length of the river has been mined of sediment. Rann believes that at least 100 container ships (Figure 11), equivalent to 48,000 m³ of sand, have been removed from the Tatai River.

A similar volume is estimated for Koh Por River by Rann and the estuary at Koh Kong city, and the timing of sand mining is approximately the same as for the Tatai River. Thus, a minimum estimate of 100,000 m³ has been established. However, sand can be mined at a rate of 800 m³ per hour, according to a local boat driver. Sand mining intensity has dramatically decreased for Koh Por in

Table 1: Rankings of barrier beach features in the study area according to impact and rehabilitation potential – features with high ranking for both categories should be targeted (None - Very high [0 - 5]).

Feature	Impact Potential	Rehabilitation Potential	Score
Un-vegetated beach	Moderate	High	7
Spit	High	Moderate	7
Breached barrier beach	Very high	Very low	6
Vegetated beach	Very low	High	5

2012 and there are only seldom reports of sand mining vessels passing through September – October 2012.

The Director also explains that the onset of sand mining corresponded with more intense landward barrier beach migration in the study area.

Dam construction

Construction of the 246 megawatt dam, located 25 km upstream of PKWS began on 29 March 2010 and has caused significant increases in river water turbidity since then (*Phnom Penh Post*, 2010). The rapid dam construction loosened large volumes of sediment that has become entrained in the river current, giving waters a dark brown colour and destroying fish habitat. Despite the 40 km distance to the beaches south of Koh Kapik in this study, sediment at these beaches is largely sourced from upstream of this dam. The dam therefore acts to block sediment that usually replenishes beaches protecting the mangrove forests.

3.5 Ecological and social impacts

The Tatai commune residents have a comprehensive understanding of the environmental degradation caused by sand mining and dam construction. The onset of local sand mining and dam construction correlates with the timing of observed

Figure 11: Photograph of sand mining vessel (top) and mining operations (bottom) 3 km south and 0.5 km south of Tatai commune, respectively.



environmental and livelihood degradation, including:

Constant river bank erosion along the length of both rivers has reached up to 100 m of river widening (Figure 12).

River bank erosion caused the loss of hundreds of trees and loss of homes.

The small boat of a fisherman was even reportedly crushed by a sand mining vessel during a fatal accident in the night. Due to the loss of fish habitat, fish catches have been reduced by 70-90%.

Priority areas for intervention

River banks exposed to high flow velocity are most likely to erode due to sand mining. The outside of river bends naturally experience high velocity, and channel deepening from mining will further increase this flow velocity.

Figure 12: Estuary erosion (top) left power lines in the water 2 km west of Koh Kong city. River bank collapses 1 km north of PKWS in the sand mining region (bottom).



River bars and islands that are nourished by excess sediment will experience erosion because they are reliant on a critical amount of sediment in flowing waters to build these river features.

3.6 Future projections

Sand mining and dam construction cause variability in downstream impacts over time. In the short term, sand mining causes an uneven and rough river bed that entrains sediment, making river water cloudy. The impacts on the coast are rapid because silt and fine sand flows quickly in suspension downstream. In the long term, downstream areas will show similar impacts from sand starvation because the combined removal of sand from mining and the halting of sediment flow from the dam will prevent sediment that

is generated far upstream from reaching downstream areas. The coast, which is nourished and supplied with sand from the rivers (Figure 13), will experience erosion.

Sand mining on the Koh Por River has taken place 4-12 km upstream from the barrier beach of this study, while sand mining on the Tatai River has taken place 8-20 km upstream of the beach south of Koh Kapik. The barrier beach will therefore recognize erosion and landward migration before the southern beach. For the beaches of PKWS the lag time is expected to be 15-25 years, due to the low gradient of the rivers.

In the short term (over approximately the next 10 years) local erosion upstream and localized river bank collapse is anticipated to cause further river widening. Sedimentation downstream and along the coast is predicted, including river bar growth and beach widening.

In the long term (years 2020-2030), widespread erosion upstream is anticipated as sediment in the river moves downstream to compensate for sediment-starved areas in the river. Bank erosion will also be experienced further. River bar and island erosion downstream is also predicted. These features form in low-velocity river flow zones when sediment supply is high, and the features will therefore degrade with a lower sediment supply. Beaches will experience sediment shortages, eroding in beach height and length because they are fed by sediment that is sourced upstream of dam construction and sand mining areas. This will ultimately expose mangrove forests to greater wave energy and cause further landward barrier beach migration.

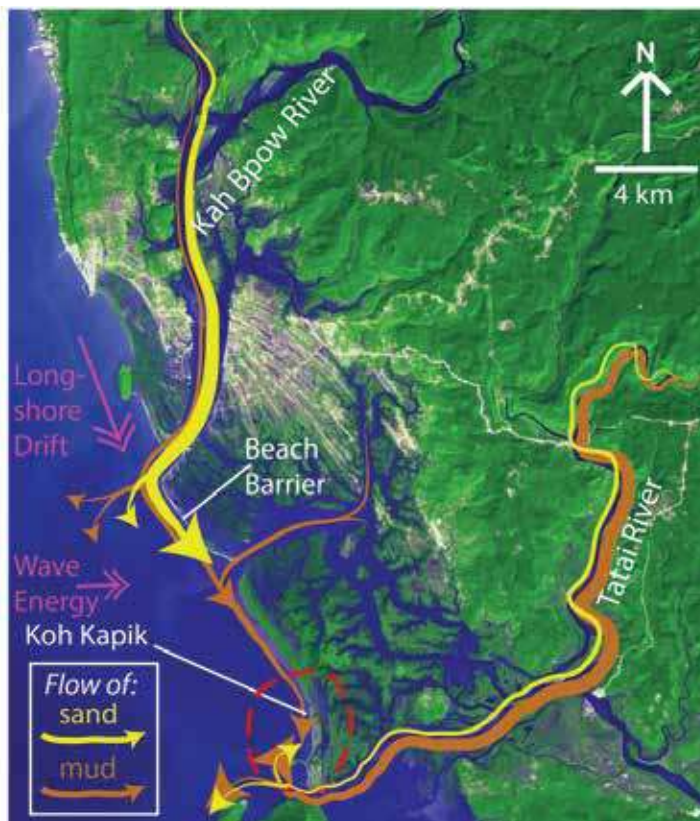
3.7 Recommended solutions for livelihood protection and disaster risk preparedness

Proactive measures can be taken to stabilize sediment dynamics, including the following remedial actions:

Barrier beach rehabilitation and river protection

Vegetative rehabilitation strategies are more strongly recommended than structurally engineered designs, because mangroves, rivers and beaches are strongly connected by the flow of water and sediment. Rapidly trapping sediment on one beach or river

Figure 13: The sediment movement from rivers to coastlines, then following longshore drift. The red circled area indicates a beach south of Koh Kapik, where sediment supplies meet, causing magnified coastal erosion/sedimentation variability from sand mining and dam construction. (enhanced Terralook Landsat image taken 10 January 2002)



bank location would starve the area down-current of sediment, thus transferring erosion to another location. Rehabilitation to a more natural state will instead offer benefits to down-current areas.

Barrier beach rehabilitation

It is critical to promote vertical and longshore growth of the barrier beach in order to prevent further mangrove loss and exposure of Bang Krassop to coastal hazards. It will, however, be a challenge because a reduced sand supply and landward migration will instead be the tendency under climate change, dam and sand mining impacts.

Allowing the barrier beach to grow vertically will prevent further barrier beach breaches during storms. The barrier beach will additionally develop more mass this way, adding strength against landward push during storms. Vegetation traps sand on higher beach elevations when large waves and wind push sand landwards (Figure 14). Engineered structures on the coast would, in this way, be counterproductive because

they would prevent this critical sediment movement and beach development. Such structures would also prevent the natural longshore transport of sediment, which the coastal geomorphic features and ecosystem are reliant upon.

Structurally engineered techniques may, however, be appropriate in the future if a future cost-benefit analysis favours a structure. For example, if barrier beach migration threatens the Bang Krassop commune, bamboo breakwater structures can be used to reduce wave energy and trap sediment for land growth (Albers & von Lieberman, 2010).

Human traffic reduction

Un-vegetated and sparsely vegetated areas of the priority zones require the closest attention to human traffic because they have the potential to increase beach stability if vegetation density increases. Due to the scarcity of soil, it is difficult for plants to thrive here. Sparse vegetation is therefore vulnerable to disturbances that can be caused by tourist groups and local

Figure 14: Vegetation on the barrier beach (the Beach Morning Glory *Ipomoea pes-caprae*, *Ipomoea biloba*), secures and traps sand, building up the height of the barrier beach (right).



fishers, and must be protected in order to increase vegetation density. Regulating activity in the priority zones and designating sparsely vegetated areas as off-limits will accelerate the growth of beach-stabilizing vegetation, thereby reducing the rate of beach erosion and landward migration.

4. Discussion

Integrated community-based efforts and external policy improvements have an opportunity to improve coastal watershed management, which will mitigate the river and coastal hazards that threaten coastal livelihoods in PKWS. Local knowledge indicates that the re-planting of key tree species will reduce river bank erosion. The sediment transport results of this study indicate that alternative sand mining practices may be more sustainable than current techniques. Implementation of these future strategies may offer further protection against river and coastal hazards by addressing the source of the problem, which is the disruption of sediment transport dynamics caused by upstream activities.

4.1 River rehabilitation

Water coconut trees

The communes on the Tatai River recognize the value of riparian water coconut trees (Figure 15) in the prevention of river bank erosion. These trees grow naturally and the communities also plant the trees in target locations to protect their river banks. They do not appear to be invasive, and are particularly effective for protecting river banks where the water level is relatively shallow.

Bamboo trees

The community finds that these trees are better suited to protect river banks where a steep drop exists between the bank and the river bed. Residents generally feel that the trees are an advantage to protecting their land from giving way to the river. The only recognized drawback is that the plants may block river access.

Further use of water coconut and bamboo trees will provide resilience against imminent sand mining impacts.

Revised sand mining strategies

Alternative mining techniques can reduce ecosystem and livelihood impacts while increasing the economic viability of the industry. Local residents have explained that the sand quality has been inadequate for export standards at times during the last two years. The grain size of the sediment has not been sufficiently uniform. This is often caused by the incorporation of river bank sediment, which consists of fine grains, during bank collapses. Thus reducing the frequency of river bank erosion will both protect the environment as well as the quality of exported sand. This can be done using the following strategies:

- Mining away from river banks will prevent some bank collapses because mining creates pockets without sediment. As sand moves downstream the voids migrate short distances to areas adjacent to fragile river banks, which might cause bank collapses. Mining near the centre of the river provides more space for sand

Figure 15: Water coconut trees (*Nypa fruticans*, fringing the Tatai River) have been planted by locals to buffer river banks from erosion and bank collapse.



levels on the river bed to even out, thereby maintaining sand next to river banks that supports the banks.

- Mining away from the outside of river bends will further prevent bank collapses because the outside of river bends are naturally prone to erosion, even without sand mining. In fact, rivers naturally migrate towards the outside of river bends because the velocity of river flow is highest there. Mining in this location accelerates that process unsustainably.
- Reducing the frequency of mining in a single location will allow sediment supplies to regenerate to levels that can quickly fill in pockets lacking sediment, which would otherwise also cause bank collapses.

IUCN Cambodia conducted a half-day workshop on local ecosystem protection to prevent adverse changes in local beach and river erosion/sedimentation (Figure 16). This allowed communities in PKWS to gain an understanding of the interconnectedness of the rivers and beach, namely the importance of stabilizing sediment transport dynamics. Thirteen participants from agencies of the line departments, local authorities, and Peam Krasaop Wildlife Sanctuary discussed community-based solutions to support livelihoods. Local knowledge was shared on native plant species that can be used in particular environments for rehabilitation. Plans are now being made to apply the lessons learnt during the workshop in order to improve the health of the mangrove ecosystem and protect local livelihoods from coastal hazards associated with climate change in the Koh Kong Province. With this, they recognize that ecosystem rehabilitation strategies must be coupled with erosion prevention strategies:

4.2 Rehabilitation:

Communities living on eroding river banks had already used the bank-stabilizing characteristics of water coconut and bamboo species. Stakeholders whose livelihoods are based near the barrier beach are now looking into planting native vegetation to slow the rate of beach migration and erosion. Future work should further investigate case studies of the usage of plant species described in this study to control erosion and beach migration. Replanting should then take

Figure 16: Participants of the workshop titled *PKWS Ecosystem Protection: Current Issues and Solutions to Support Livelihoods*.



place in the priority zones outlined in this study.

4.3 Prevention:

During the provincial workshop, a provincial leader from the Ministry of Industry, Mines and Energy improved his awareness of the mutual benefit of preventing river erosion for both communities and for the quality of sand to be exported. Strategies as simple as mining away from the outside of river bends will prevent river widening. In this way, further educating those involved in the mining industry will protect the livelihoods of PKWS communities.

5. Conclusion

Local activities in PKWS have pronounced impacts on sediment flow dynamics that stabilize the rivers and protective beaches of the mangrove ecosystem. Climate change further exacerbates these effects, namely the expansive loss of coastal mangroves as the barrier beach migrates landward. In the short term, river bank erosion near sand mining operations will present challenges to those living near the river. In the long term, the reduction in sand volume flowing downstream may accelerate barrier beach migration. However, communities have knowledge about rehabilitation strategies that can be used to build resilience to these impacts.

Specific native flora species can be planted in priority zones of the barrier beach to increase beach height, which will slow the migration rate. Support should also be provided to families who would like to prevent the loss of land next to

rivers, where sand mining has caused river bank collapses and the displacement of families. Controlling this erosion upstream will improve not only beach health, but also reduce the rate of sedimentation in Koh Kapik channel, which may otherwise soon require dredging again. Using the recommended channel excavation strategies will additionally stabilize mangrove sediment and reduce down-current impacts.

Rehabilitative and preventative approaches are economically beneficial for all stakeholders. The use of more sustainable mining techniques will protect the land and even improve the quality of exported sand. Concerted efforts are required. Community-based resilience against the impacts of dam construction, sand mining and climate change can be improved by strengthening collaborations to protect the rivers, beaches, mangrove ecosystem, and ultimately protect livelihoods within PKWS from these coastal hazards that are caused by poor watershed management and climate change.

This case study highlights the importance of managing upstream rivers and forests as an integral part of mangrove forest protection for the reduction of disaster risks to coastal communities. In Cambodia and throughout the tropics mangrove forests are not only impacted by rising sea levels, but they are also destabilized by interruptions in steady flows of freshwater and sediment. Barrier beaches are dynamic features that are particularly susceptible to the impacts of

local stressors, such as sand mining, and global changes, such as sea level rise. However, an understanding of watershed

connectivity, preventative upstream solutions and targeted beach rehabilitation will protect downstream mangrove forests.

In this way, concerted community efforts can reduce coastal disaster risks and strengthen local livelihoods globally.

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Chapter 4

Coastal ecosystems in Kouchibouguac National Park of Canada: adaptation possibilities for protecting traditional knowledge of a local community

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Abstract

Over the past 50 years, the coastal ecosystem of Kouchibouguac National Park of Canada has become increasingly exposed to climate related events such as sea level rise and storm surges. Salt marshes are an important component of this ecosystem as they contain many traditional medicinal plants for the nearby First Nations. This case study examines the potential challenges facing these plants and the community that relies on them, as well as the possible adaptation solutions, including restoration, monitoring and translocation. The study included field surveys along the coastal marshes of the park, integration of the data with a digital elevation model and climate change scenarios, and talking circles with community members to discuss the implications of the data. The results of the field survey showed that most of the populations of sweetgrass (*Hierochloa odorata*) and other traditional medicinal species are under threat when storm surges occur. Under the projected scenarios of sea level rise coupled with storm surges, many of these sites would probably not be able to recover, leading to loss of populations. Some of the proposed measures that may also be useful for disaster risk reduction include linking weather forecasting (for storms) with harvest and monitoring periods in order to avoid risks to people, as well as relocation of some populations.

1. Introduction

Salt marshes are lands characterized by particular drainage patterns because of different soil types and elevation, and are submerged periodically by tidal flow. They are unique, fragile ecosystems, which are very sensitive to human exploitation. Salinity, sedimentation, tidal flushing and other environmental factors influence the diversity and the productivity of marshes and species distribution (Cowardin *et al.*, 1979; Morris *et al.*, 2002). They are especially dependent upon tidal flushing since minor alterations of the shape and the drainage of salt marshes can disrupt the equilibrium and the survival of several species. Salt marshes are highly diverse, but are also constantly changing due to human and natural influences (Redfield, 1972). North American marshes are very productive and have been the subject of many studies (Nicol, 1936; Redfield, 1972; Jacobson & Jacobson Jr., 1989; Bertness, 1992). There are however very few natural and undisturbed marshes remaining in North America due to human exploitation, invasive species, and different types of degradation, including pollution (Zedler *et al.*, 2004; Bromberg Gedan *et al.*, 2009).

In Atlantic Canada, where most of the communities and their activities are located along the coast, there is a need to better understand how climate change will impact on economic development. This coastal ecosystem has been shown to be under high sensitivity to sea-level rise and other phenomena such as storm surges under scenarios of climate change (overview published by the Geological Survey of Canada in Shaw, 1998; Vasseur

& Catto, 2008). Areas of the eastern New Brunswick coast are amongst the most severely threatened coastal areas of the Atlantic. In this region, sea level is already rising with demonstrable impacts (Vasseur & Catto, 2008). Threats in this area come primarily from impacts of coastal flooding and erosion, and damage due to forced sea ice movement caused by storm surges in winter. Parts of this area are highly exposed to wave action during storms in the ice-free season, as demonstrated by shoreline and infrastructure damages experienced during two storms in 2000. Similar yet less intense events occurred again in 2002, 2004 and 2010 with higher frequencies. The 2010 storms (as several came over a period of a couple of weeks between December 2010 and January 2011) had significant impacts on local coastal communities of the region (Plante *et al.*, submitted).

For the First Nations, and especially the Mi'kmaq communities of the New Brunswick eastern coast, climate change is an issue that they know they will have to deal with for the sustainability of the traditions and the use of natural resources. This is especially important for the traditional food and medicines found in salt marshes. Sweetgrass (*Hierochloa odorata*), for example, is a very important plant for First Nations communities (Shebitz & Kimmerer, 2004) and is mainly found in these marshes. It is used for various purposes, including in ceremonies as incense, to weave baskets, as ornaments and in teas (Knockwood, 1992; Shebitz & Kimmerer, 2005).

Kouchibouguac National Park of Canada (KNPC) is one of the main sites where the Mi'kmaq community of Elsipogtog harvests sweetgrass and several other medicinal plants. Mi'kmaq are recognized as the first known inhabitants in the region as no archaeological evidence has confirmed other occupation. They spent winter inland and during summer, moved closer to the shores in lagoons, estuaries and river mouths where fishing and seafood harvesting provided plenty of food (DeGrâce, 1984).

KNPC was established in 1969 through the expropriation of several families who lived mostly from agricultural activities including animal pasture, hay fields and cultivating crops such as potatoes. Covering an area of 238.8 km² (Figure 1), it is part of New Brunswick's Lowlands. It was created to protect representative ecosystems of the Maritime Plains including the Acadian forest. Soil texture and drainage vary greatly in the park due to original land use, geology and its relatively flat topography (slope being less than 5 m/km with altitudes between 0 and

30 m) (Desloges, 1980). The climate is humid continental with important maritime influences near the shore (Graillon *et al.*, 2000). The average annual temperature is 4.8 °C, average freeze-free period is 177 days and annual precipitation averages 979 mm (Desloges, 1980).

The park has as mandate to maintain the ecological integrity and cultural heritage of the area. In order to do so, a better understanding of the ecosystem and the pressures it faces is required. In addition, the park is considered as a cultural site with several artefacts (including burial grounds) related to the Mi'kmaq communities, it has signed agreements in the past to work together with Elsipogtog to protect this cultural heritage.

KNPC's natural coastal ecosystems are facing the direct impacts of climate change, mainly sea level rise and flooding due to storm surges. These storms come from the southern Atlantic in the form of hurricanes or tropical depressions in the summer. In the winter, with increased ocean temperatures, surface ice along

the coast does not become solid as in the past. Under severe winds and storms ice build-up scratches low coastal land and causes damage to the ecosystem. This project was initiated through this agreement and the expressed concerns from the park and the community that disasters – in this case, mainly related to storm surges, tropical storms and hurricanes – could significantly affect the park's capacity to protect this cultural heritage including traditional plants. In this context, both the park and the community engaged in a dialogue and this study to look at ecosystem-based adaptation (EbA) strategies and at the same time, disaster risk reduction (DRR) to be better prepared to face the changes. The following section describes the methods and approaches that were used to enhance the understanding of the area in this context.

2. Methodology

A field survey of traditional plants was completed, in collaboration with the Elsipogtog community in order to understand the potential impacts of climate change on their traditional resources. The field data were analysed as geographical and projection models, using the Geographical Information System (GIS). Several flooding scenarios integrating hypothetical sea level rise and terrestrial subsidence projections (e.g. Carrera *et al.*, 1988) were developed to evaluate the potential impacts of sea level rise on the existing populations of sweetgrass and other medicinal plants that are located in salt marshes. The modelling was an extension and consequently a new regional application of the methodology reported in Thompson *et al.* (2001). It was based on the reconstruction of the model of the storm surge events of 21 January 2000 (declared a disaster by the federal government). Using the results, discussions were held with the Elsipogtog community to define potential adaptation strategies that included further strengthening of KNPC's role in preserving the traditional species used by the communities.

2.1 Field surveys and interviews / focus groups

An inventory of medicinal plants from the salt marshes of Kouchibouguac was completed during the summer of 2004 with the help of elders and officers of

Figure 1: Map of the Kouchibouguac National Park of Canada. From north to south in red, salt marshes that were surveyed, including Marais de l'Embouchure de la Rivière St-Louis (Anse à Simon à Michel), Marais de la Grande Anse and Marais des Étroites to the Pointe des Allains. In purple, only sweetgrass was surveyed, including North Richibuctou Dune.



Elsipogtog. It covered the species that are considered to have medicinal and food values for Mi'kmaq. In the first marsh, from the Marais des Étroites to the Pointe des Allains, 65 quadrats were established within 13 transects. For the second marsh, Marais de la Grande Anse, 9 transects with 30 quadrats were established. For the third marsh, Marais de l'Embouchure de la Rivière St-Louis (Anse à Simon à Michel), 23 quadrats were established within 5 transects. The distributions of the species were recorded and geo-referenced. Once the vegetation inventory was completed in the salt marshes, precise maps were created using Geographical Information Systems software (GIS) (Arc/GIS version 8.0) (Figure 2) and then integrated into the digital elevation model (DEM) to run the different flooding scenarios (see below).

In addition, historical and sociocultural information was recorded and integrated to better understand the historical trends and intensity of use. The socio-economic impacts of the decline of such species have also been assessed, which can be used in the development and economic evaluation of possible adaptive strategies under various climate change scenarios. Using the semi-directed interview approach (Daunais, 1984), interviews were conducted between July and September 2005 (with approval from the research

ethics board of the Université de Moncton). Interviews were informal and conducted in the home of the respondents. All interviews were conducted in English and respondents were guided but no specific questions were asked. Discussions revolved around climate change, traditional plants and sites in their community and its surroundings (including Kouchibouguac). In respect of the community's traditions, respondents were not recorded and notes were written following the interviews. Following this, a trip report of the interviews was verified with the community. This was done to make sure that respondents were cited properly and that the community was satisfied that no comments were taken out of context or misinterpreted.

2.2 Integration of the data for impact modelling

In order to understand how sea level rise and flooding resulting from storm surges could affect the traditional plant species found in the salt marshes several flooding scenarios were developed using very precise digital elevation models (DEM) that were integrated into a GIS. These scenarios had to consider climate change related sea level rise and the fact that Atlantic Canada is still changing in terrestrial elevation due to past glaciation (e.g. Carrera *et al.*, 1988). The scenarios were based on historical tide-gauge

records, new water level data (from existing and new gauges), GPS measurements of vertical crustal motion (to measure how much the land is sinking), other evidence of vertical motion (from releveling, gravity data and model outputs e.g. ICE-5G). They were also based on the geological and palaeoecological evidence for past sea-level changes on the floor of Northumberland Strait and from marsh deposits along the coast (component of the project developed by Environment Canada and Dalhousie University). The resulting data on relative sea level trends and best estimates of vertical motion were combined with the latest available predictions of global and regional mean sea level to estimate the probable rise in relative sea level in the study area over the coming century. Following this the data were used for flood risk modelling and to ascertain future coastal erosion rates.

Storm surges are known to affect the salt marshes and in general, the coastal ecosystem. In this study, they were integrated into the DEM and climate change scenarios for sea level rise, based on the reconstruction of the model of the storm surge events of 21 January 2000 and 29 October 2000. In addition, the impact of ice on sea level in the coastal zone of salt marshes can be assessed by running case studies using a coupled atmospheric-ice-ocean modelling system for the Gulf of St. Lawrence (Pellerin *et al.*, 2002) with and without ice.

Figure 2: Locations of sweetgrass plants and populations in the studied marshes of Kouchibouguac National Park of Canada.



2.3 Talking circle

Results from data analyses were presented to the Elsipogtog community and strategies were discussed in a talking circle. A talking circle is a traditional round table discussion approach used by the Mi'kmaq communities when they desire to talk about an issue in which each person must wait their turn to talk. During these meetings, results were presented and discussed. This process, which was iterative, lasted for a few months in order to leave time to the community to discuss among themselves.

3. Results

3.1 Description of marshes

A total of 41 species were identified in these marshes. Plant species such as *Glaux maritima* and *Limonium carolinianum* were found in all three marshes. Of

these, three species were considered to be of concern (being rare either provincially or federally) and two species were considered to be of importance for traditional use by the First Nations. Sweetgrass, our key plant, was found among several other common plants such as New York aster (*Symphyotrichum novi-belgii*), grass-leaved orache (*Atriplex littoralis*), chaffy sedge (*Carex paleacea*), Baltic rush (*Juncus arcticus*), marsh pea (*Lathyrus palustris*), saltmeadow grass (*Spartina patens*), freshwater cordgrass (*Spartina pectinata*), and seablite (*Suaeda maritima*). Out of respect for the community, the location of several traditional plants cannot be published, except for the map of sweetgrass.

3.2 Integration of climate change scenarios with the plant community survey

The three traditional marsh zones are modelled to simulate flooding using three scenarios of storm surges which integrate sea level rise over the next century, resulting in increases in sea levels of 2.55 m (by 2020), 3.05 m (by 2050) and 3.25 m (by 2080) (Daigle *et al.*, 2006). GIS data were only available for one of the three marshes studied, but data can easily be extrapolated to the other two marshes considering they were all in the same area of the park. The results provided by the models showed that the three traditional marsh zones are flooded under the three scenarios used for this project. Even under the most optimistic scenario, the flood line reached the forest and consequently the entire marsh area showed flooding. Therefore, under the current projection of

subsidence and sea level rise, most of the sweetgrass populations would be under water by 2080 especially under storm surges (Figure 3).

3.3 Impacts on the plant communities and their traditional use

The interviews and the focus groups provided the following information regarding the traditional species. Sweetgrass is a very important plant for First Nations. According to their belief, it is the first plant put on Earth by the Creator. It is therefore a very sacred plant. Other plants of importance for the people of Elsipogtog are tobacco (*Lobelia inflata*), cedar (*Thuja occidentalis*), Canada yew (*Taxus canadensis*), calamus or muskrat root (*Acorus calamus*), sea milkwort and sage (*Salvia* sp.). Sweetgrass is becoming scarce because of over harvesting. The usual locations used by the elders are not secret anymore so they are accessible by anyone. Another threat to sweetgrass is residential expansion, as demonstrated by one of the sites near the town of Richibucto, which is being threatened by urban development. Other reasons described for the scarcity of medicine plants besides coastal urban development, are the establishment of trails and the absence of regulations for the protection of these plant species. Elders are now getting sweetgrass from other locations because of high levels of toxins from coastal pollution and eutrophication in the area, which eliminate all the benefits of the plants and may even cause harm to users. Many other medicinal plants are threatened by over-picking throughout Canada. The protection of the Mi'kmaq traditional

knowledge is becoming an important way for them to protect their culture. Other important plants living in salt marshes include sea milkwort which is used for tea, calamus or muskrat root (not found in this study) which is used for incense, and *Taraxacum officinale*, which has many uses for the First Nations even though it is not an official marsh plant (however found in salt marshes in 2004) (Hinds, 2000).

All of these traditions will therefore be affected by sea-level rise. The elders of Elsipogtog were concerned as it was not possible to predict the precise impacts that sea-level rise will have on plant communities, but studies have shown that only a few plant species can cope with both flooding and the higher than usual salinity (Allison, 1996; Baldwin & Mendelssohn, 1998; Craft *et al.*, 2009; Sharpe & Baldwin, 2012). There are also many factors like freshwater supply, duration of flooding and frequency of events that affect plant succession and therefore marsh stability (Allison, 1996; Bertness & Ewanchuk, 2002).

3.4 Discussion on potential adaptations and actions

For Elsipogtog, it is important to protect the plants and their habitats since the species will have to adapt to harsher environmental conditions like saltwater, wave action, erosion, longer periods of inundation, etc. In discussion with the community, the following strategies were suggested as possible ways to adapt and sustain the traditional use of resources, as well as in some cases reduce risks:

- Status quo, let everything stay as it is and nature will take its course (this was mainly suggested for the populations that are in KNPC);
- Move existing infrastructure on the reserve near marshes that is not absolutely necessary (e.g. sheds, old roads, etc.) to reduce pressure on the plants;
- Move all structures that are near marshes (e.g. houses, roads, other buildings, etc.); this was suggested over the longer term to ensure the survival of native populations. However this might not be feasible since the territory of the community is very narrow;

Figure 3: Digital elevation model with the locations of some of the sweetgrass populations (red dots) in the Anse à Simon à Michel Salt Marsh and the lines of flooding under a scenario of a storm surge of 2.55 m (black line), 3.05 m (yellow line), and 3.25 m (red line).



- Protect safer zones for the future: rehabilitate marshes that were destroyed, act now to protect remnants of marshes and consider relocation of the traditional species to better protected marshes. This strategy was implemented almost immediately as the elders and the chief already knew a few places where this could be done;
- Plant sweetgrass in areas that are suitable for growth such as a nursery. This solution was felt to be a last resort as it would mean distancing themselves from the natural ecosystem; and,
- Involve the community in all these actions including education on storms and sea level rise and the risks that they bring in the harvesting season.

4. Discussion

For Elsipogtog, the protection of the natural ecosystem of KNPC is essential to maintain their cultural heritage and traditions. It was clear that some of the solutions were considered important as EbA strategies while others were considered as DRR. In their case, they did not see much difference between both types of actions as they believed that through EbA, the ecosystem would be stronger to deal with extreme events and therefore reduce the risks for their own community (infrastructure and preservation of their traditions). This perception is frequent as stated by Spalding *et al.* (2013, p.2): 'there is recognition that healthy coastal ecosystems play an important role in coastal protection, and in reducing the vulnerability of coastal communities to climate change and coastal hazards'. In this discussion we first examine the implications in terms of EbA and then focus on DRR, noting the interdependence of the community with the park's ecosystem.

Ecosystem-based adaptation for KNPC and Elsipogtog aims mainly at protecting the coastal ecosystems and especially the salt marshes that serve as buffer during the storms and also where traditional plants are found. Soft approaches of EbA by protecting the ecosystem from development and additional stress from human activities can be very effective as it leaves time for the ecosystem to adapt to gradual changes such as sea level rise.

While protection walls, dykes and such infrastructures are considered effective in the short term, they are very costly and often exacerbate the problem of erosion (Brown *et al.*, 2011). As the main goal for Elsipogtog is to be able to preserve traditional species which are crucial in their medicinal and cultural heritage, protecting salt marshes is the first step. For them, KNPC has to be protected without any infrastructure along the coast in order for the species to be able to move. They did not believe that they could necessarily do something about it.

The surveys highlighted the importance of these species, their location in salt marshes, and the potential impacts of sea level rise and storm surges over time on not only their existence but also on the traditional and cultural cohesion of the community. Sweetgrass is found from mid-to-upper zones of salt marshes and is highly affected by tides. Given this, even a small rise in sea level would affect sweetgrass populations. The future of the plant (as representative of other traditional plant species) in the region lies on how the salt marsh ecosystem will react to higher salinity, flooding and to an unpredictable future regarding extreme weather events.

Elsipogtog discussed the various scenarios in terms of changes in plant locations with sea level rise. The community and KNPC agreed that monitoring of salt marsh plant populations should be and is now integrated into the EbA strategies as it can help better understand the health of the populations and the ecosystem. Factors such as increase in salinity may affect plants differently. Gradual and slow changes in sea level may help some freshwater marsh plant species to survive. However rapid flooding as shown with the models and storm surge scenarios suggest that most plant species may have to adapt to harsher environmental conditions like saltwater, wave action, erosion, longer periods of inundation, etc.

Hard approaches to EbA have been considered but as last resorts. For example, moving structures from the coasts was seen as important for the plants to be able to migrate but also to protect the people living in those houses. The possibility of translocation (assisting migration) of traditional plants was considered as an option if the conditions

were becoming too severe. However, if nurseries were to be developed, some of the plants would most likely come from KNPC.

From the park's perspective, giving the First Nations access to the park for their traditional plant species is part of the adaptation strategies as the rest of the coastline is under development pressure and encroachment. It is important to note that the elders of Elsipogtog have come, and continue coming, to the park to harvest sweetgrass under a Memorandum of Understanding (MOU) between the First Nation of Elsipogtog and Kouchibouguac National Park of Canada. This first MOU was signed in 2000 in order to allow them to have this option with the impacts of climate and environmental changes along the coast limiting access to traditional plants. This agreement was renewed in 2009 especially to ensure that traditional and cultural heritage can be maintained for Elsipogtog, despite these changes and pressures on coastal ecosystems (Parks Canada, 2010).

The current park management plan protects the coastal zone by avoiding its development. Trails and other types of infrastructure are kept to a minimum and avoid salt marshes. This type of management will in the long term help to protect the current populations. Adjacent higher land is also developed to a minimum, if not at all, to ensure possible transition over time. Future trail or campground development will have to continuously consider the issues of sea level rise and storm surges which can threaten the coastal ecosystems and the safety of tourists.

DRR strategies focus mainly on storm surges that can lead to flooding, coastal erosion and damage to infrastructure. The threats are not only due to spring to autumn storms, but also from ice formation on the coastline during winter which can have severe impacts in the following spring. In spring, large pieces of ice tear plants out of the ground, leaving areas bare and unstable (Redfield, 1972; Niering & Warren, 1980; Bertness & Ellison, 1987).

Coastal ecosystems can be unpredictable and with populations possibly getting too close to unstable grounds may increase the risks to harvesters. Using a

participatory process for risk identification and monitoring can help communities better understand the risks posed by storms (Kafle, 2012).

The early warning system for storm surges remains a main component for both the park, which has to notify visitors, and for Elsipogtog with harvesters out in the marshes. Although there is a greater access to the Internet and people frequently use the radio to be informed, a recent survey in the coastal communities of New Brunswick showed that these media were not always effective in notifying the communities about disasters, most people relying on word of mouth (Vasseur *et al.*, submitted). Therefore education and increased awareness must be continuously maintained as DRR actions. Education was felt important as a DRR measure to ensure that people were more aware of the importance of extreme event forecasting at harvesting times. This would reduce the risk of needing to rescue people threatened by storms. With a large proportion of the community being young, education in schools about preparedness for storms is a focus.

During the discussions, the relocation of species could also be considered DRR when the sites are better protected thus reducing possible risks to people during harvest. Another suggestion brought up by one of the elders was to not cut trees along the shore for protection against erosion. In fact it was suggested that more trees, such as willows, should be planted in the buffer zones to reduce the risks from storms.

Policies can help in DRR if they are effectively implemented. Currently, the province does not have any regulation to protect coastal zones. It has a coastal policy which as of today is still not enforced. Such a policy could prevent new buildings and infrastructures being constructed near the shore. These actions would reduce the risks to people and their infrastructures.

The people from Elsipogtog are aware of the limitations they face in terms of EbA and DRR. For example, it was mentioned that the size of the reserve (territory where the community can develop) is too small to accommodate its population. Because

residential development is a priority for this growing population and there is a lack of space along the coast in the reserve, unfortunately salt marshes become a place of choice for housing development, even if the risks are greater for these people. Therefore conflict exists between the capacity to allow the ecosystem to adapt to changes and the need for the population to extend its territory due to population growth. As a compromise, Elsipogtog has embarked on a process of finding and buying lands outside its reserve. But with such pressures, there is a motivation to maintain their alliance with KNPC where they know the species might be able to survive in the longer term more than on their land.

For any park having to balance ecological and cultural heritage, it is important to examine the potential impacts of climate change as well as EbA strategies and DRR measures. It is very clear that compromises have to be made and this includes for example the avoidance of any physical structure that may stop the migration of the salt marshes and the traditional medicinal plants. Having the opportunity to have open discussion between the park's managers and First Nations also helps to promote the protection of these ecosystems by reducing illegal harvesting to avoid further stress on the ecosystem.

5. Conclusion

Salt marshes contain plant species that are of great importance to the traditions and culture of the First Nations of Canada. Unfortunately, due to sea level rise in KNPC and surrounding areas as well as increased frequency of storm surges leading to flooding and coastal erosion, such species are at risk. The study showed that the salt marshes were inundated entirely, even at the lowest levels of flooding. This is a significant threat to the loss of plant species such as sweetgrass. Traditional plants will have to be monitored continuously in order to determine how they react to changing conditions in their habitat, and when threats are too serious and therefore require urgent action. The community of Elsipogtog already has some ideas for the adaptation actions that would need to be carried out in the case of threats. However, in their eyes, unless threatened, plant populations in KNPC should not be touched.

Elsipogtog community members felt empowered but needed more tools to act upon the adaptive measures mentioned. The links between KNPC and Elsipogtog have been strong for a long time due to the importance of protecting KNPC salt marshes for safeguarding the First Nation's cultural heritage. Traditional plant species are part of their livelihoods. Re-signing the collaboration agreement between KNPC and Elsipogtog demonstrates the will that both have to continue protecting salt marshes not only from impacts of tourism and other local human activities but also from climate change, especially storm surges. Analysis of different adaptation and risk reduction measures compatible with local problems and the generation of research questions led to sharing of knowledge and new ideas on how to proceed. While few 'hard' (e.g. engineered) adaptation or risk reduction measures were immediately initiated, planning and education (especially regarding extreme events) remained one of their focuses. Developing two plans, EbA and disaster-preparedness, should continue for this First Nations community and for the park in order to develop priorities.

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Chapter 5

Thinking outside the protected area boundaries for flood risk management: the Monterrico Multiple Use Natural Reserve in Guatemala

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Abstract

A novel approach to protected area management is being implemented in the Monterrico Multiple Use Natural Reserve (MMUNR), which is located on the Pacific coast of Guatemala. The integration of processes occurring beyond the reserve's boundaries into the management planning of the Reserve enables a holistic perspective on social and ecological links and can serve as an example for other sites in the region and beyond.

The Reserve is highly influenced by three main watersheds which make it susceptible to floods, not only as natural events but made worse by processes and activities outside the protected area; additionally, floods are perceived as the most relevant environmental issue by the MMUNR's inhabitants. Moreover, protected area management is often only focused on actions implemented inside the boundaries, which may overlook interconnections between a protected area and its surroundings, affecting its long-term integrity. In this sense, to overcome the negative impacts caused by these flooding events, that are expected to increase in the future, it is necessary for the Reserve's management to change its current scope.

To do this, the Centre for Conservation Studies (CECON) began a process to update the Reserve's management plan to include people's concern about floods. This process involves the following steps: creation of a Conceptual Ecological Model (CEM) for Monterrico Reserve that shows its links and relationships with its surroundings; establishment of a permanent stakeholder engagement process; and to bring together the insights gained from these steps into a new Reserve management proposal.

During this process, intermediate results have been achieved for the management of the Reserve: a) new scale of management actions; b) broader governance arrangements; and c) wider scope of management.

The analysis of this case study highlights some lessons that have been learnt and by taking them into account in the new management plan are expected to improve its management: a) the Reserve by itself will not be able to control the risk of floods inside its territory; b) an integrated water management approach should be taken in managing the Reserve; c) conservation and watershed restoration actions outside the Reserve's limits should be established.

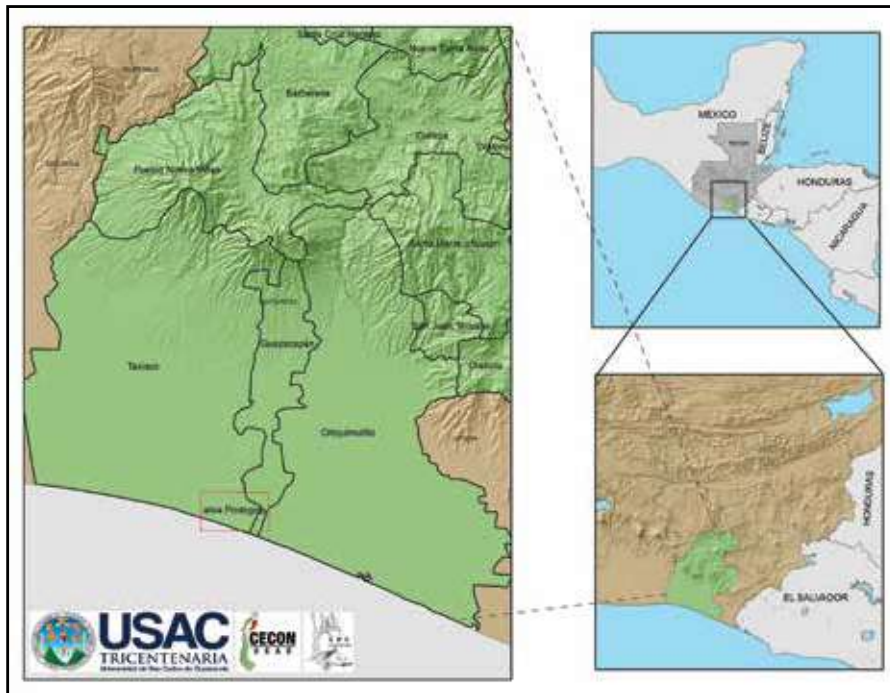
1. Introduction

This case study has been analysed and documented with the support of the **Blue Solutions**¹ initiative.

Monterrico Multiple Use Natural Reserve (MMUNR), located on the Pacific coast of Guatemala (Figure 1), comprises about 2,800 hectares and a 22 km perimeter of estuarine and coastal-marine ecosystems. It is managed by the University of San Carlos of Guatemala through the Centre for Conservation Studies (CECON), and it is one of the last remaining coastal marine protection areas in the country. The Reserve is one of the 322 protected areas legally recognized by the Guatemalan System of Protected Areas established by the National Council of Protected Areas (CONAP), the public institution that is in charge of protected areas and biodiversity in the country. MMUNR was first declared as a Protection Reserve in 1977 to provide special protection for fauna, flora and the ecosystem. This management category is very strict in terms of natural resource utilization, equivalent to IUCN

¹ Blue Solutions aims to assemble and share best practice and innovative approaches in marine and coastal resource management and governance; it also aims to promote their replication and inform decision making. It is implemented in partnership between GLZ, IUCN, UNEP and GRID-Arendal.

Figure 1: Location of Monterrico Multiple Use Natural Reserve.



Source: Centre for Conservation Studies.

Protected Area Category 'Ia – Strict Natural Reserve' (Dudley, 2008). However, the fact that people had been living inside the Reserve prior to its establishment has subsequently been recognized, and it was re-categorized by the Guatemalan Law of Protected Areas in 1989 as a Multiple Use Natural Reserve, in which human presence and usage of natural resources is allowed. This is equivalent to IUCN Category 'VI – Protected area with sustainable use of natural resources' (Dudley, 2008).

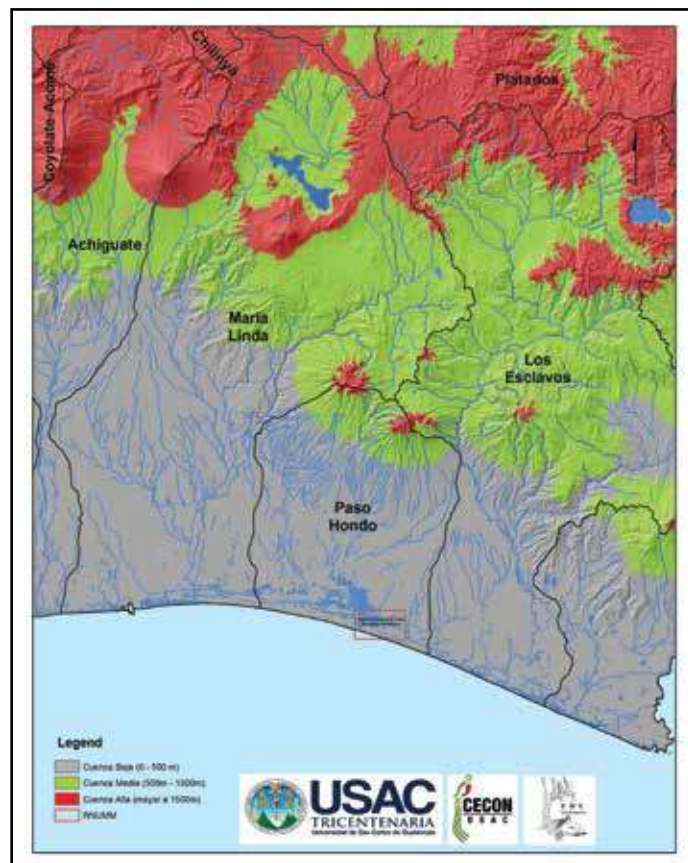
The protected area is part of an estuary system known as Chiquimullilla Channel (García-Fuentes, *et al.*, 2013) which runs parallel to the shore of the Pacific coast, at a distance of about 120 km from La Gomera to Moyuta municipalities (Martínez Rojas, 2006). This estuarine ecosystem is of great importance for the surrounding communities and for the entire country, because it is a source of food, tourism revenue, wood, medicinal plants and transportation (Cano, 2008). Estuarine and coastal-marine ecosystems with an important ecological value can be found inside the Reserve (García-Fuentes, *et al.*, 2013). In the estuary zone, mangrove forest is the dominant vegetation and is associated with rivers and lagoons of constantly changing water salinity

(Cano, 2008). Furthermore, 65% of the Reserve's territory is covered by water bodies (García-Fuentes, *et al.*, 2013) and all its ecosystems are directly or indirectly related to the aquatic system; however, the entire area of the Reserve only represents about 0.5% of the total extension of the three major watersheds that affect it (Paso Hondo River, María Linda River and Los Esclavos River).

In addition, its aquatic vegetation depends on a seasonal climate cycle, driven by changing levels in salinity that are caused by the patterns of tidal influence and freshwater inflows. This allows plants with different salinity tolerance to dominate during different times of the year, with only the mangrove forest remaining at times of high salinity levels (Cano, 2008).

There are five villages inside the Reserve (Monterrico, El Pumpeo, La Curvina, La Avellana and Agua Dulce), with a combined population of about 8,000 inhabitants who pursue activities related to fishing, ecotourism services (hotels, restaurants, tour guides), and agriculture

Figure 2: Watersheds affecting MMUNR.



Source: Conservation Data Centre (CDC) of CECON.

such as cultivation of sesame, corn and, on a smaller scale, watermelon, cantaloupe and artisanal salt production (CECON and CONAP, 1999). MMUNR is annually affected by floods and is considered to be an extremely vulnerable territory (CECON and CONAP, 1999) (Barrios, 2013) (García-Fuentes, *et al.*, 2013) (Pérez Folgar, 2013). Although there are reports about the effects of floods at a national scale² (CEPAL, 2004) (CEPAL/SEGEPLAN, 2005) (CONRED/SEGEPLAN, 2010), there are no comprehensive reports that document and evaluate the effects of such flooding on the MMUNR and its inhabitants. However, two internal reports for the Reserve found that a total of 2,996 families were affected by floods inside the Reserve due to the Tropical Depression 12E (2010) and the Tropical Storm Agatha (2011).

Although floods have always been common inside the Reserve, it is perceived by its inhabitants that their frequency and adverse effects on important habitats, agricultural lands and infrastructure have increased during recent years (Pérez Folgar, 2013). It has also become evident that managing the Reserve alone is not enough to control such floods as often these floods are fuelled by activities outside the Reserve, including changes in drainage patterns, deforestation of riparian forests and water canalization works. In particular, the extension of sugarcane cultivation around the Reserve has led to strong modifications of the environment and especially of the watershed (Barrios, 2013) (Pérez Folgar, 2013). This has resulted in harmful impacts on the Reserve's *Typha* grasslands, an important nesting habitat for waterbirds. The grasslands are not able to recover between floods due to the increased frequency of flooding. Due to these factors, CECON has engaged in an effort to develop an integrated management approach by incorporating activities that happen outside the Reserve but affect its integrity, into the management planning.

² Extreme flooding events have had severe effects on the country's economy; it has been reported that the effects of Hurricane Mitch (1998) and Tropical Storm Stan (2005) alone have cost US\$ 1,030.83 million to the country (CEPAL, 2004) (CEPAL/SEGEPLAN, 2005), and Storm Agatha (2010) cost another US\$ 982 million (CONRED/SEGEPLAN, 2010).

Local fishers



Floods in MMUNR



2. Methodology

This case study has been documented as part of the Blue Solutions initiative, which aims to identify and share proven, replicable approaches in marine development and conservation. The case of the Monterrico Reserve is being highlighted as a 'solution', because it exemplifies protected area management that takes an ecosystem perspective, and showcases processes for integrating a protected area into broader coastal zone management.

Blue Solutions are believed to comprise distinct components or 'building blocks', which can potentially be replicated. Building blocks may be adapted and recombined with others to address specific challenges in other sociocultural, ecological, political or economic contexts, sectors or geographies. The following steps have been identified as *building blocks*, as they are essential components of the process, and are relatively independent of unique contextual circumstances:

- 1) creating a Conceptual Ecological Model for Monterrico Reserve;
- 2) establishing a permanent stakeholder engagement process;
- 3) updating the Reserve's Master Plan.

The following section describes each of these building blocks in detail and provides information on how they were applied to the Reserve.

2.1 Conceptual Ecological Model

Conceptual Ecological Models (CEMs) are non-quantitative planning tools which have been used for understanding and communicating important ecosystem components, linkages, spatial and temporal scales, and major drivers and stressors on ecosystems in protected areas, watersheds, wetlands, amongst others (Briggs, *et al.*, 2013) (Mazzotti, *et al.*, 2005) (Tian, *et al.*, 2010) (Browder, *et al.*, 2005) (Davis, *et al.*, 2005). Additionally, CEMs have been used for supporting management actions such as landscape monitoring (Miller, *et al.*, 2010) and ecosystems restoration (Ogden, *et al.*, 2005). The Reserve's CEM was created through a participatory approach aiming to understand the interactions between the Reserve and its surroundings, specifically the processes that link ecosystems, species and conservation values inside the Reserve, and to recognize the conditions under which those processes could change and affect conservation values inside the Reserve (Barrios, 2013).

Workshops were used to conduct a threats analysis, identify underlying causes of such threats and map responsible stakeholders, as well as ecosystems and conservation values affected. For constructing this CEM, two different scales were analysed: a) landscape and watershed scale; and b) Chiquimulla Channel scale (Barrios, 2013). These workshops were led by researchers from CECON and the School of Biology; and representatives from the Reserve, local communities, CONAP's local office and the Municipality of Taxisco took part in them.

2.2 Permanent stakeholder engagement process

During the initial phase of the planning process, a permanent stakeholder engagement process was established which included representatives from within and outside the Reserve. In this regard, a

series of meetings and field trips was held, involving Reserve inhabitants, sugarcane mills employees, governmental institutions and CECON employees to understand the ecological interdependencies between the Reserve and its surroundings (Barrios, 2013).

Furthermore, workshops and meetings on the issue of floods were organized jointly with the Climate Change Research Private Institute³ to: a) understand the issues arising from lack of management in the upper part of the watersheds and people's perceptions about the problem; b) learn about the steps taken by sugarcane mills to deal with floods; c) realize the impacts of river flow deviation in the area; and, d) understand the effects of containment works against floods that were carried out in the coastal area (Barrios, 2013).

Further workshops and meetings are still planned because the planning process is still ongoing. In addition, once the master plan has been approved by the national authority (CONAP), more participative workshops and meetings will be held to create awareness of the new plan and to eventually assess its implementation. Therefore, the stakeholder engagement process is considered to be long term.

2.3 Updating the Reserve's Master Plan

The triggering factor that started the updating process of the Reserve's master plan, which was originally developed in 1999 (CECON and CONAP, 1999), were the inhabitants' concerns about floods affecting them. In response to this, CECON is leading a process through its Conservation Data Centre (CDC) and Protected Areas units to conduct the following:

- 1) Gathering, updating and analysing information about the Reserve to propose management actions and strategies to be included in the updated master plan. This phase included three master theses carried out jointly with the Master Programme of Environmental Planning and Design of the Faculty of Architecture of the University of San Carlos of Guatemala (USAC) to analyse biophysical (Barrios, 2013), social (Cante, 2013) and urban aspects (Del Cid Borja, 2013) of the Reserve. In addition, a fourth master thesis related to the Reserve's vulnerability in relation to climate change (Pérez Folgar, 2013) was carried out with the support of the Centre for Safe Development and Disasters Studies of USAC, and a

Stakeholders' engagement during updating process.



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³ The Climate Change Research Private Institute (ICC) is a private research centre financially supported by sugarcane mills of Guatemala.

proposal of Environmental Education Strategy carried out with the support of the Guatemalan office of the Japanese International Cooperation Agency (JICA) (Velázquez Jofre, 2012).

- 2) Creation of a discussion draft from insights of the analysis phase.

Additionally, final discussions with stakeholders and elaboration of the final version of the updated master plan to be presented and approved by CONAP are ongoing.

3. Results

Often, protected areas management is focused on actions implemented inside the boundaries only, which may overlook links between a protected area and its surroundings, resulting in shortcomings in assuring its long-term integrity. The innovative solution discussed in this paper will break the prevailing paradigm of protected area management by considering what happens in the entire watershed area, not only inside the Reserve. It will build on lessons learnt after the last floods and allow for watershed restoration outside the Reserve's limits for controlling risk of future floods. This new management paradigm includes insights from this process which are considered as intermediate results: a) new scale of actions; b) broader governance arrangements; and c) wider scope of management. These results are explained below.

3.1 New scale of actions

Knowledge exchange and discussions through workshops, meetings and field trips strongly established the Reserve's interconnections at landscape, watershed and Chiquimulilla channel scale amongst the stakeholders. In addition, it was evident that the current scale of actions taking place inside the Reserve was not enough to address flood issues in the area.

Therefore, a new scale of actions has been included in the Reserve's management planning process, taking into account the improved understanding of ecological, social and economic links between the Reserve and its surroundings. This new scale includes three subscales:

- a) Watershed level: this level includes actions to be taken in any of the three watersheds influencing the Reserve;

- b) Chiquimulilla channel: includes the area comprised by this channel;
- c) Reserve level: actions taking place inside the legal limits of the protected area.

3.2 A new set of governance arrangements

Because of the bigger scale of actions, stakeholders who are currently not involved in the Reserve's management need to be included and hence additional stakeholders and a wider governance arrangement are needed. Amongst the additional stakeholders are the sugarcane industry actors, municipalities inside the watersheds and other governmental institutions related to watersheds and disaster management. In this regard, municipalities are key stakeholders at watershed level due to their responsibility in spatial planning and concomitant regulations inside their territories. Sugarcane industry actors are also important stakeholders because a considerable part of the middle and lower parts of the watersheds influencing the Reserve includes sugarcane plantations, which require substantial amounts of water during the dry season but release it during the rainy season. In addition, governmental institutions such as the Ministry of Environment and the General Secretariat for Planning should be included because of their national jurisdiction that is needed to coordinate actions at the Reserve's watershed level.

Therefore, the possibility of creating a council in which decisions are taken amongst all stakeholders is currently under discussion. This discussion is taking into account legal and organizational limitations, given that the administration of the Reserve cannot be given to external stakeholders. However, they can be integrated into the management process.

3.3 New management scope

This new approach proposed is based on: a) processes rather than isolated management actions, and b) better coordination and synergy amongst different research centres within the University of San Carlos of Guatemala.

Since the establishment of the USAC's protected areas, CECON has had the sole responsibility of their management. However, the Reserve's management has become more complex over time,

which requires a different set of skills that go beyond CECON's capabilities. In this regard, synergies amongst different research centres and schools within the University of San Carlos of Guatemala will be a key factor for establishing a scientific and multidisciplinary management for the Reserve. Some of these synergies are: a) School of Biology to continue improving the Ecological Conceptual Model and to generate ecological information; b) Centre for Marine and Aquaculture Studies regarding limnology and hydrological studies; c) Centre for Safe Development and Disasters Studies, to include the risk management concept into the Reserve's master plan based on the tailor-made vulnerability assessment (Pérez Folgar, 2013) conducted for the area. This vulnerability assessment was based on people's perceptions about risks and vulnerability and indicated the following: a) floods, extreme rainfalls and storm surges are the most relevant natural hazards for people living inside the Reserve; b) inhabitants are aware of impacts of climate change, and recognize that local governments are not including this topic in their planning; c) there is no monitoring system related to natural hazards nor a risk management plan that takes climate change effects into account.

In addition, this assessment pointed out that the main climate change threats to the Reserve are at economic, social and ecological level; therefore, a holistic approach based on the coordination of actions with all stakeholders is needed. In this sense, the following actions were proposed: a) elaboration of a disaster risk management plan taking into account effects of climate change; b) monitoring natural and anthropogenic threats and vulnerable zones; c) implementation of an early warning system; and, d) strengthening municipal planning and management emphasizing local capacity building and including the concerns, experiences and knowledge of people in the Reserve.

Regarding disaster risk reduction, this newly introduced approach is proposing, amongst others, the following actions: a) establishing the ecological baseline of each ecosystem to be restored inside and outside the Reserve; b) promoting the relevance of ecological restoration

to stakeholders; c) developing and implementing an integral monitoring system of the watershed that includes climatic, ecological and socio-economic aspects. Furthermore, documentation of changes in microrelief and vegetation to assess the vulnerable areas and ecosystems at a precise scale is also planned.

4. Discussion

Globally, an increase in climate variability is expected, causing more recurrent extreme events like floods and droughts (Aggarwal & Singh, 2010); for Guatemala, high inter-annual and seasonal rainfall variability with a decrease in the number of rainy days and an intensification of the hydrological cycle has been predicted (IARNA-URL, 2011).

This expected intensification of the hydrological cycle along with changes in land use, and changes in the watershed flow regimes⁴ in the upper and middle parts of the influencing watersheds caused amongst others factors by sugarcane mills (Barrios, 2013) (Pérez Folgar, 2013), are expected to exacerbate floods inside the Reserve. In this sense, there is an increased urgency to integrate the Reserve into the broader landscape due to the synergies and negative feedback loops between habitat fragmentation and climate change, as pointed out by Ervin, *et al.* (2010).

In addition, given that the entire Reserve area only represents about 0.5% of the total extension of the three watersheds that affect it, and that 65% of the Reserve territory is formed by water bodies, the Reserve is highly influenced by what happens in the entire catchment area, particularly floods, and not only by processes inside the protected area.

Therefore, managing this protected area based on actions taking place only within its boundaries may not be sufficient to deal with flood issues; additionally, a more integrated approach that includes watershed management in protected areas (González, *et al.*, 2013) should be incorporated into the Reserve's management.

For this, the Reserve needs to shift to a new management paradigm which will require a new scale of actions going beyond the Reserve's boundaries, wider and integrated scope of management and broader governance arrangements coherent with new stakeholders and the new scale and scope of management. Additionally, a more comprehensive and effective governance scheme is not only needed for the Reserve's broad management, but specifically for risk reduction and disaster management, as suggested by Ahrens and Rudolph (2006).

With the new management proposal, the Reserve's management is migrating from a 'classical model' of protected area management to a 'modern model' by recognizing the Reserve as part of a comprehensive ecological network and integrating it with the surrounding landscape, and even to an 'emerging model' by including elements of disaster mitigation (Ervin, *et al.*, 2010).

The establishment of this new management scheme implies new opportunities and challenges. As opportunities for the Reserve, the following have been identified: a more participatory conservation process which is expected to generate positive conservation outcomes; better understanding by stakeholders of the Reserve's functioning and ecosystem services provided, and hence increased support for its management; and the possibility to reach agreements with private sector (mainly sugarcane mills). For the involvement of the sugarcane mills, the fact that the Climate Change Research Private Institute (ICC) was initiated by them resulted in increased recognition of potential climate change impacts and therefore greater willingness to participate in disaster risk management in general, and related to the Reserve more particularly. In this sense, the inclusion of the private sector in disaster risk governance and management will also help to establish a new paradigm (UNISDR, 2013) in disaster risk management for the Reserve.

In addition, it is important to mention that a generally high awareness and acceptance of the importance and values of the protected area by its inhabitants has helped the discussions, and that water,

as the element that connects the Reserve and its surroundings, has clearly shown the links between conservation and welfare of the human population. Therefore, the risk of flooding in the area makes people receptive to suggestions for reducing and adapting to this risk, and this can also be considered as an opportunity to implement this new approach.

Amongst the challenges it is possible to identify the following: implementation of an effective governance scheme and willingness of key stakeholders to be involved; stakeholders' reluctance to take actions implying financial costs when they are not affected directly by the Reserve's conservation status; availability of resources to implement this new approach; and to achieve an effective coordination amongst organizations with jurisdiction inside the new management scale. Regarding disaster risk management, it is worth mentioning that coordination of actions with governmental civil protection agencies represents a considerable challenge, taking into account that at national level disaster risk reduction and environmental conservation in general terms are seen as not related issues. Another relevant issue to point out is that at national level, responses are given as reactions to disasters rather than prevention.

The analysis of this case study highlights some lessons that have been learnt: a) the Reserve by itself will not be able to control the risk of floods inside its territory; b) an integrated water management approach should be taken in managing the Reserve; c) conservation and watershed restoration actions outside the Reserve's limits should be established.

Finally, the inclusion of the lessons learnt into the Reserve's master plan updating process is an important first step to achieve this new management paradigm. Currently, this is being included in the first draft of the revised Master Plan, which will be shared and discussed with stakeholders and approved by CONAP; it is expected that this new management scheme will officially come into force during 2015; however, its implementation by CECON has already started through the development of the Reserve's Ecological Conceptual Model at ecosystem scale.

⁴ Barrios (2013) and Pérez-Folgar (2013) reported that during the dry season sugarcane mills have deviated watercourses to irrigate their crops causing droughts downstream; and during the rainy season the excess water is drained into watercourses exacerbating floods inside the Reserve.

5. Conclusion

The experience in Monterrico Reserve has suggested that protected areas management based on actions taken only inside their boundaries may not be enough to deal with flood issues; especially when a protected area is located in the lower part of an interlinked watershed system. Therefore, interventions beyond the limits of such areas to manage the risk of floods are needed. This experience has also shown that updating a management plan to include 'external' actions is the foundation for connecting the protected area to its surroundings. In

addition, updating a management plan is not just a specific event in time, but a powerful process to establish permanent stakeholder engagement.

The MMUNR experience also shows that connecting a protected area to its surroundings implies an increase in the scale of actions, the inclusion of new stakeholders and new governance arrangements which need to be considered during the master plan updating process. In addition, this new management paradigm also implies new challenges, such as stakeholders'

reluctance to avoid actions adversely affecting the Reserve, especially when this has financial implications for them, and when the negative impacts of these actions do not affect them directly; implementation of an effective governance scheme and willingness of key stakeholders to be involved; and new funding sources that will be needed to properly implement such an ambitious approach. This process gave rise to new opportunities to engage with the private sector (mainly sugarcane mills) to manage flood issues inside the Reserve.

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About Blue Solutions

Blue Solutions are demonstrated, scalable approaches that inspire and facilitate action towards healthy and productive marine and coastal ecosystems.

In order to identify such solutions, a framework has been developed. We believe that 'blue solutions' comprise distinct building blocks that determine its success. Such building blocks may be adapted and recombined with others to address specific challenges in other sociocultural and ecological contexts, sectors or geographies. This framework has been developed together with the Resilience Exchange for scaling solutions for social change.

The Blue Solutions initiative provides a global platform to collate, share and generate knowledge and capacity for sustainable management and equitable governance of our blue planet. It is implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), in direct partnership with GRID-Arendal, the International Union for Conservation of Nature (IUCN) and the United Nations Environment Programme (UNEP).

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Chapter 6

Mangrove forests enhance rice cropland resilience to tropical cyclones: evidence from the Bhitarkanika Conservation Area

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Abstract

According to theory, mangrove forests act as a buffer to protect inland areas from tropical cyclone damage. This case-study tests the theory by analysing impacts of the presence of the Bhitarkanika Conservation Area mangrove forests on rice croplands in coastal Odisha, India. This region was struck by an intense cyclone on 29 October, 1999. The normalized difference vegetation index (NDVI), a remote sensing derived measure of vegetation greenness and an indicator of rice crop productivity, was used to monitor the impact of the cyclone on rice croplands with and without protection offered by the Bhitarkanika mangroves. Rice croplands with an extensive mangrove buffer had a greater capacity to resist the impact of the cyclone compared to croplands with no mangrove buffer. Where there was mangrove protection croplands suffered a less dramatic loss in productivity. Additionally, the productivity of rice croplands with a low-density or extensive mangrove buffer recovered at a quicker rate compared to croplands with no mangrove buffer. Preliminary investigation suggested that it took three years for the productivity in rice croplands with no mangrove buffer to reach the same levels as croplands which had a low-density mangrove buffer at the time of cyclone impact. Communities in this region are often poor and reliant upon rice crop production for their livelihoods and food security. Therefore, preserving the Bhitarkanika Conservation Area, or expanding its mangrove coverage, may enhance the livelihood resilience of local communities to tropical cyclones.

1. Introduction

The Bhitarkanika Conservation Area (BCA) is located in coastal Odisha, India (Figure 1) and covers a 3,000 km² area in Kendrapara district. It includes the mangrove forests of the Bhitarkanika National Park as well as the Bhitarkanika Wildlife Sanctuary and the Gahirmatha Marine Sanctuary. The total mangrove coverage within the BCA is 145 km². The Gahirmatha Marine Sanctuary is a nesting ground for the 'vulnerable' olive ridley sea turtle and the mangrove habitat supports a diverse range of flora and fauna, including one of the last three populations of the estuarine crocodile (*Crocodylus porosus*), the largest populations of king cobras (*Ophiophagus Hannah*) and water monitor lizards (*Varanus salvator*) in India, 263 bird species, including migratory waterfowls, and 31 mammal species including the

Irrawady river dolphin (*Orcaella brevirostris*). The mangrove forests also provide other ecosystem services, such as fisheries and fuel wood, and the BCA is comprised of a mixed landscape of natural habitats, settlements and agricultural lands, namely paddy fields (Badola & Hussain, 2003).

The densely populated coastline surrounding the BCA is frequently struck by intense tropical cyclones which can wreak havoc on the livelihoods of the poor rural population (Chittibabu *et al.*, 2004; Shepherd *et al.*, 2013). Coastal Odisha has been identified as one of the world's disaster-poverty hotspots, where exposure and sensitivity to natural hazards further entrench the impoverishment of coastal communities and hamper the current low levels of socio-economic development (Chhotray *et al.*, 2013), (Shepherd *et al.*,

Figure 1: Mangrove forests of the Bhitarkanika Conservation Area (March 2014).



2013). Rice cropping forms the main livelihood activity, and is crucial to food security in this region (DES, 2013). Rice crops are particularly vulnerable to cyclone impacts; especially as crop-critical development stages (August-October) and harvest (October-November) coincide with meteorological conditions favouring tropical cyclone formation. Thus, cyclones have devastating impacts on both rice crop development, food security and economic growth for an already poor population (Chhotray & Few, 2012; Chhotray *et al.*, 2013; Revenue and Disaster Management Department, 2013). Furthermore, the BCA mangroves can be considered as a microcosm for the entire Bay of Bengal. The Bay of Bengal also hosts the world's largest population concentration of severe and extreme poverty and these communities are frequently impacted by intense cyclones (such as cyclone Nargis in 2008). They are also reliant upon rice cropping with varying coverage of mangrove forests; often mangroves have been deforested to create room for rice cropland expansion (e.g. the Sundarbans in India and Bangladesh and the Irrawaddy Delta in Myanmar) (Webster, 2008; Das & Vincent, 2009; Shepherd *et al.*, 2013; Webb *et al.*, 2014). This case-study explores the role of mangrove forests in supporting resilient livelihoods in rice-dominant areas, by comparing rice crop productivity with relation to protection or no protection by mangroves, following a cyclone event.

It is suggested that degradation of natural ecosystems, including mangroves, reduces the resilience of coastal regions to natural hazards (Adger *et al.*, 2005; Gunderson, 2012). Mangroves have been shown to act as a buffer to the destructive forces of coastal hazards such as tsunamis, storm surges and cyclonic winds and they also provide a range of resources to help communities recover livelihoods after disasters (Adger, 2000; Adger *et al.*, 2005; Das, 2012; Das & Crépin, 2013). The Hyogo Framework for Action (HFA)¹, Priority for Action number four stresses the importance of reducing the underlying risk factors, including through sustainable

management of ecosystems and natural resources alongside integrated, disaster sensitive land-use planning to reduce disaster risk (UNISDR, 2007). In Odisha, previous research has highlighted that community resilience to cyclone impacts varies across the landscape; coverage of mangrove forests are one explanatory factor for observed variation in resilience to cyclone induced disasters (Das, 2012; Chhotray *et al.*, 2013; Das & Crépin, 2013). Mangrove forests of the BCA have been recognized as an important buffer against cyclone-force winds and a means of taking the energy out of potentially damaging storm surges before they hit communities (Das & Vincent, 2009; Das, 2012; Das & Crépin, 2013). Research on the 1999 super-cyclone, which resulted in 10,000 fatalities (Chittibabu *et al.*, 2004), has shown that villages in the leeward side of the BCA mangroves suffered reduced fatalities due to storm surges and reduced structural damage due to intense winds (Das & Vincent, 2009; Das, 2012; Das & Crépin, 2013). The economic value of the BCA mangroves has been estimated at US\$ 177 per hectare (1999 prices) reflecting their short-term damage reducing benefits (Das & Crépin, 2013). However, little work has been done to identify the longer-term benefits of the BCA mangroves in enabling a more rapid recovery of rice cropping (one of the major sources of livelihoods in this region) after cyclone impacts.

In this study, we use remote sensing imagery to capture the longer term livelihood *resilience* benefits that the BCA mangroves provide to rice crop production across the entire landscape, using the 1999 super-cyclone as a case-study. *Resilience* to natural hazards refers to the capacity of a system to absorb or recover from a shock of a given magnitude (e.g. a cyclone) without a negative influence on its structure, functioning and service provision (DFID, 2011; Eakin *et al.*, 2012; Gunderson, 2012). In the case-study site in Odisha, rice-cropping is the system, the shock is the super-cyclone and resilience is measured by the capacity of the system to maintain levels of rice crop production or the rate of recovery of rice crop production. Here, the presence of mangroves is assessed for two resilience components:

1. Resistance and buffering capacity: To what extent does the presence of mangroves reduce the impact of the cyclone on the rice-dominant socio-ecological system and associated levels of rice crop production? Akter & Mallick, (2013) define resistance within a resilient system as the capacity to withstand physical, structural and economic damage and Gunderson (2012) suggests coastal forests play a buffering role within coastal socio-ecological systems moderating the impact of cyclone induced storm surges.
2. Recovery: How does the presence of mangroves influence the capacity, and rate, of recovery of rice crop production? A resilient system is able to recover to a pre-cyclone steady-state, that is pre-cyclone levels of socio-ecological system functioning and service provision. The UK Aid/Department for International Development (DFID) measure resilience in terms of whether a system 'bounces back better', 'bounces back', 'recovers but in a worse state than before' or 'collapses' after exposure to a perturbation (DFID, 2011).

2. Methodology

Remote sensing data was used to identify the total rice cropping area and mangrove forest coverage. The size of the mangrove buffer was measured using the Geographical Information System (GIS). Resistance, buffering and recovery were estimated from levels of cropland greenness (a surrogate measure for crop productivity), again using remote sensing imagery.

2.1 Rice cropland and mangrove forest discrimination

The extent of rice croplands and the mangrove forests were identified using satellite imagery. The analysis was restricted to croplands within 10 km of the coast in order to limit the role that distance from the coast plays in reducing cyclone impacts on rice crop production and to isolate the mangrove-resilience signal. Cyclone intensity and impact on infrastructure decreases with distance inland (Das, 2012; Das & Crépin, 2013). Also, the study area was limited to a 33 km stretch of coastline so as to minimize variability in climate and the timing of rice

¹ The Hyogo Framework for Action is the United Nations Office for Disaster Risk Reduction 10 year plan to build the resilience of nations and communities to disasters (2005-2015).

crop development, which would also influence productivity in a field.

Croplands and mangrove forests were identified by applying land-cover classification techniques to remote sensing data obtained from NASA's Landsat Enhanced Thematic Mapper (ETM+) imagery from October to December^{2,3}, 2000. Imagery from the October 2000 rice growing season was used to discriminate croplands and mangroves rather than from the 1999 growing season in order to minimize the impact of visible short-term cyclone effects on the landscape influencing the land-cover classification. Indeed, the 1999 image (dated 6 November 1999) was taken immediately after cyclone landfall and inundation had not fully receded. Fields cropped in 2000 were assumed to be cropped in 1999; this assumption was based on the fact that there was no large scale shifts in land-cover before and after the cyclone (i.e. large scale deforestation for croplands) and the area planted for *khariif* rice crops in Kendrapara district decreased slightly from 167,000 ha to 132,970 ha between 1999 and 2000 (DES, 2013). These fields were used to monitor the productivity of the rice crop under a range of mangrove buffer widths.

The width of the mangrove buffer was measured using GIS and the mangrove-cropland landscape was split into three zones: cropland with no mangrove buffer, cropland with a low-density mangrove buffer and cropland with an extensive mangrove buffer. The characteristics of these zones are presented in Table 1.

The productivity of rice cropping in each of the mangrove buffer zones was measured using a satellite derived measure of vegetation greenness (the Normalized Difference Vegetation Index (NDVI)). The NDVI is a widely used measure

² The October Landsat ETM+ image was taken on the 23/10/2000 and the December Landsat ETM+ image was taken on 10/12/2000.

³ All remote sensing imagery used in this research was subjected to atmospheric correction using the FLAASH module in ENVI. A hybrid unsupervised-supervised classification technique was performed to classify rice croplands, mangroves and other land-use/land-cover types. An accuracy assessment suggested this classification had an overall classification of 89% with errors of commission and omission for mangrove and cropland classes less than 4%.

Table 1: The characteristics of the three mangrove buffer zones.

Mangrove Buffer Zone	Mean Mangrove Buffer Width (m)	Minimum Mangrove Buffer Width (m)	Maximum Mangrove Buffer Width (m)
No mangrove buffer	0	0	0
Low-density Mangrove buffer	2,055	127	4,064
Extensive mangrove buffer	6,050	4,104	7,072

that provides surrogate information on photosynthetic activity and, in turn, vegetation biomass. The NDVI has a strong correlation with cereal crop production including rice crops (Pinter *et al.*, 1981; Pettorelli *et al.*, 2005; Huang *et al.*, 2013). The NDVI has a range of -1 to 1 with values closer to 1 corresponding to green vegetation with full canopy cover, values below 0.2 typically correspond to bare ground and soil and values <0 indicate the presence of water. The difference in magnitude and variation of NDVI values over rice croplands with differing widths of mangrove buffer was used to indicate the extent to which the BCA mangroves enhance the resilience of rice cropping to cyclones.

2.2 Assessing the 'buffering' and 'resistance' benefits of mangroves

To assess whether the presence of mangrove buffers enable the rice croplands to moderate and resist cyclone impacts on rice crop production, the mean NDVI (measure of rice crop productivity) and standard deviation in NDVI (measure of variability in rice crop productivity) were computed within each of the mangrove buffer zones. This analysis was undertaken for the 1999 *khariif* rice growing season using Landsat ETM+ satellite imagery taken on the 6 November 1999, eight days after the cyclone made landfall. Imagery from the growing season of cyclone impact captures how variation in the presence of mangrove buffers influences the resistance properties of rice-dominant socio-ecological systems.

2.3 Assessing the 'recovery' benefits of mangroves

The mean NDVI and standard deviation in NDVI for each mangrove buffer zone were computed from Landsat ETM+ and thematic mapper (TM)⁴ imagery for the

⁴ Landsat ETM and Landsat TM refer to different Landsat sensors on board different satellites. The Landsat ETM is a more recent sensor but both sensors measure reflectance in the same wavelengths, thus, enabling comparison.

23 October 2000, 26 October 2001, 29 October 2002 and 24 October 2009. This captures the post-cyclone recovery trajectories and time-taken for the recovery of the productivity of rice croplands amongst the three mangrove buffer zones, as well as variability in productivity within the different mangrove buffer zones. The basic assumption is that an increase in NDVI post-cyclone, or decrease in variation in NDVI, indicates recovery of the rice croplands. The small inter-annual variation in the date of imagery mitigates the influence of crop conditions and spectral signature detected in remote sensing imagery varying over a growing season^{5,6}.

3. Results

3.1 The 'buffering' and 'resistance' benefits of mangroves

Areas with an extensive mangrove buffer had a high level of greenness (NDVI > 0.6) following the cyclone when compared to other buffer zones. Assuming the rice crops in this zone are of the same variety and with a similar harvest time (November), it can be inferred from Figure 2 that rice croplands with an extensive mangrove buffer were more resistant to cyclone impacts than croplands with low-density or no mangrove buffer zones (Figures 2 and 3a). It should be noted that a low-density mangrove buffer enables croplands to resist cyclone impacts more than no mangrove buffer (Figures 2 and 3a). Mean NDVI for rice croplands with an extensive mangrove buffer 8 days after

⁵ Any cropland area with an NDVI value less than 0.49 was removed from the analysis for that year. An NDVI value of 0.49 was the minimum NDVI value for cropland pixels in the training data used in the supervised classification (section 3.1); therefore, we assume pixels with an NDVI value less than 0.49 were likely already harvested or left fallow in that year.

⁶ Landsat TM imagery was available for late November 2005 and 2006; however, these images were discounted from the analysis as most of the cropland had been harvested by this point reducing the sample size of productive crops in fields within each zone.

cyclone impact was 0.67 whereas it was only 0.58 for croplands with a low-density mangrove buffer and 0.47 for croplands with no mangrove buffer (Figure 3a). There was also less intra-cropland variability in rice crop productivity in croplands with an extensive mangrove buffer compared to croplands with a low-density mangrove buffer or no mangrove buffer (Figure 3b).

3.2 The 'recovery' benefits of mangroves

The measure of greenness and in turn the productivity of rice croplands was greater in the years following a cyclone compared to the year of cyclone impact in all mangrove buffer zones (Figure 4a). The measure of greenness was higher in rice croplands with an extensive mangrove buffer in all years compared to the other mangrove buffer zones (Figure 4a). However, the difference between the measure of greenness in croplands with no mangrove buffer and a low-density mangrove buffer

Figure 2: Satellite measure of vegetation greenness (NDVI) in rice croplands with differing extents of mangrove buffers eight days after the landfall of the super-cyclone in 1999. Blue pixels correspond to higher greenness values and, thus, more productive croplands, red areas correspond to lower greenness values and, thus, less productive croplands.

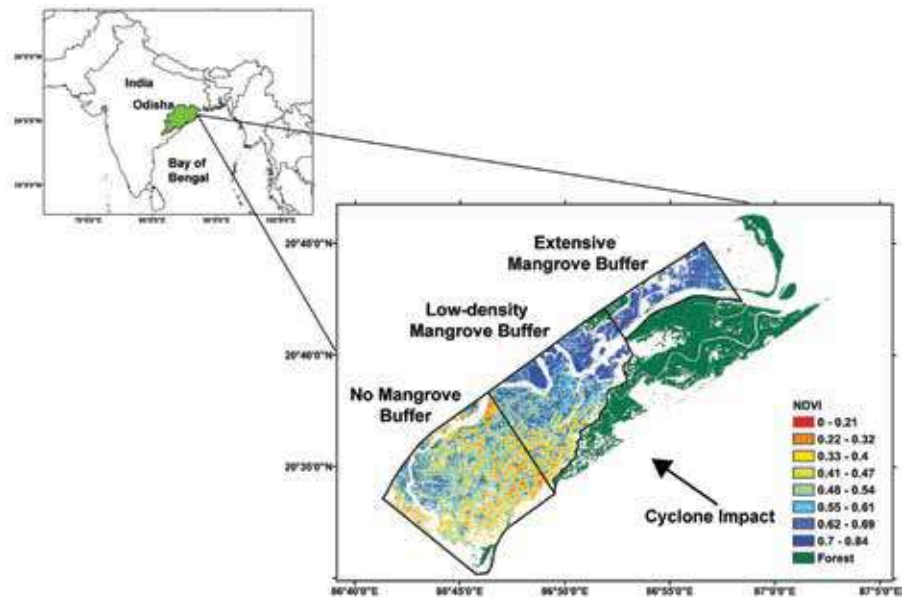


Figure 3: a) mean NDVI in rice croplands within the three mangrove buffer zones on the 6 November 1999 and, b) standard deviation in NDVI in rice croplands within the three mangrove buffer zones on the 6 November 1999.

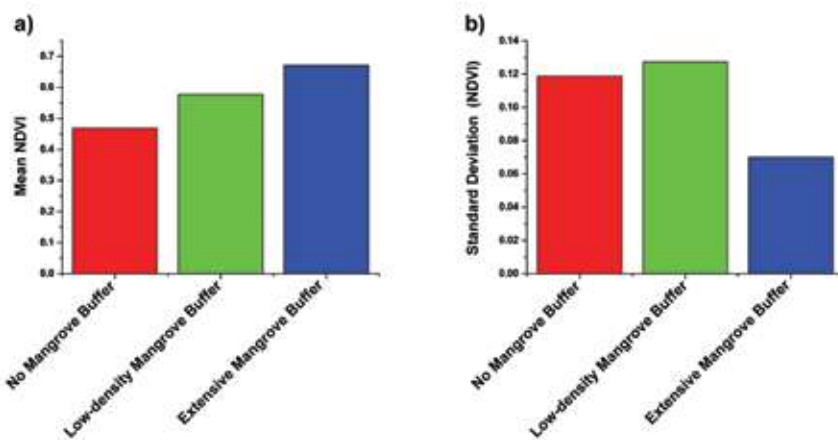
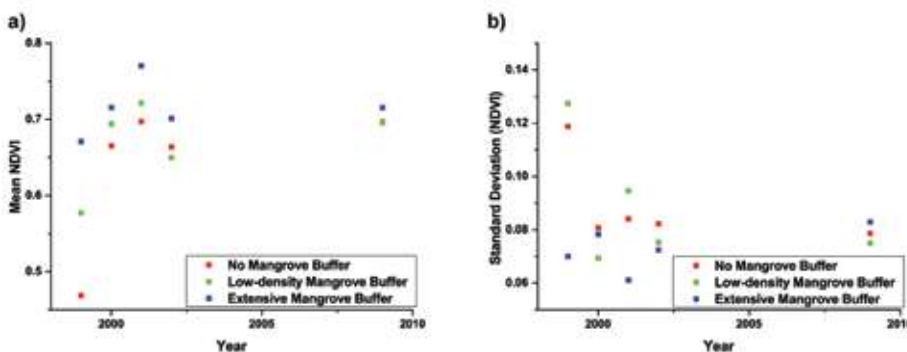


Figure 4: a) mean satellite measure greenness (NDVI) in rice croplands within the three mangrove buffer zones for the 1999, 2000, 2001, 2002 and 2009 kharif growing seasons and, b) standard deviation in satellite measure greenness (NDVI) in rice croplands within the three mangrove buffer zones for the 1999, 2000, 2001, 2002 and 2009 kharif growing seasons.



shrank with successive growing seasons post-cyclone, and by 2009 there was little difference between the three zones (Figure 4a). Levels of productivity in croplands with a low-density mangrove buffer initially (one year after the cyclone) recovered to levels of productivity just below what was experienced in croplands with an extensive mangrove buffer (Figure 4a). This suggests that a low-density mangrove buffer enables a quicker rate of recovery of rice cropland productivity compared to when no mangrove buffer was present. By 2002 productivity in rice croplands with no mangrove buffer was comparable to productivity in croplands with a low-density mangrove buffer (Figure 4a). The ability of rice croplands with no mangrove buffer to recover to productivity levels similar to croplands with a low-density mangrove buffer after 3 years corresponds to observations of rice cropland recovery in West Bengal, India, following cyclone Alia in 2009 (Bhattacharya & Guleria, 2011). Bhattacharya and Guleria (2011) suggest it will take three monsoon seasons to wash away the increased salinity in rice croplands as a result of the storm surge from cyclone Alia. Post-cyclone trajectories in the variability in rice crop

productivity within each of the mangrove buffer zones followed a similar pattern to recovery trajectories in average productivity (Figure 4b). Intra-zone variability in rice crop productivity was lowest for croplands with an extensive mangrove buffer (Figure 4b). Intra-cropland variability in productivity for croplands with a low-density mangrove buffer reduced at a quicker rate than for croplands with no mangrove buffer (Figure 4b).

4. Discussion

Given the close links between rice crop production and food security in coastal Odisha, and that 39% of the rural population is below the poverty line, a key goal for disaster management is to ensure that cyclone impacts do not turn into long-term disasters which exacerbate the existing high levels of poverty and marginalization (DES, 2012; Shepherd *et al.*, 2013). This research suggests that preserving the extent of the BCA mangroves, and expanding current mangrove coverage, will enhance the resilience of rice cropping to cyclone impacts. In turn, this will enhance the resilience of communities in the region. Despite considerable uncertainty in models and observations, it is likely that the intensity of cyclones will increase in the coming century due to climate change (Knutson *et al.*, 2010). Also, climate change induced sea level rise in the Bay of Bengal coinciding with low elevation will increase the frequency of high magnitude storm surges (Woodruff *et al.*, 2013). This provides added impetus to the need to ensure that mangrove forests are protected or expanded, to increase the resilience of rice cropping, and therefore of people, to climate change impacts. This is pertinent as it is increasingly recognized that unless livelihoods become more resilient to disasters, poverty alleviation and socio-economic development goals will not be met (DFID, 2011; Shepherd *et al.*, 2013). However, *in situ* research in coastal communities adjacent to the BCA suggest that reforestation schemes are hampered by the limited functioning of local level forest committees and the relative power of on-the-ground forest management officials (Chhotray *et al.*, 2013). A priority for effective schemes targeting protection, expansion or restoration of the mangroves is to enhance the capacity of local level forest management.

The BCA mangroves were deforested during the 20th century due to the expansion of rice croplands and prawn gheris⁷ (Das & Vincent, 2009; Chhotray *et al.*, 2013). Likewise, any further expansion of the mangroves will have to compete with alternate land-uses, such as prawn gheris, which are often backed by absentee businessmen and yield inconsistent returns to local communities (Chhotray & Few, 2012; Chhotray *et al.*, 2013). This highlights a trade-off between preserving the existing extent of the BCA mangroves and providing space for expansion whilst also meeting the food demand and supporting livelihoods for a growing population; this is particularly pertinent in Odisha given high levels of food insecurity and rural impoverishment (Pritchard *et al.*, 2013). Also, communities within the BCA use the mangrove forest as a source of fuel for cooking, further contributing to its depletion (Hussain & Badola, 2010). Management of the BCA mangroves should not be to the detriment of the food and energy security of local communities; these are non-negotiable rights and crucial for livelihoods development (Hoff, 2011). However, local communities are aware of the 'buffering' benefits of the mangroves, and are in favour of expanding mangrove plantations and integrating development and conservation projects (Badola *et al.*, 2012). The BCA mangroves can provide several ecological services which can support livelihoods (e.g. fishing, honey) (Badola & Hussain, 2003; Hussain & Badola, 2010). This suggests a holistic, integrated approach to management of the mangroves can provide space for protection and expansion of the forests to enhance disaster resilience, preserve biodiversity and contribute to wider development goals simultaneously. Specific plans and detail in current disaster management policy in Odisha has a strong focus on 'saving lives', maintaining community-level and institutional preparedness and providing short-term relief payments (e.g. *State Disaster Management Plan – 2013; Odisha Relief Code; Disaster Management Plan for Odisha (Agriculture Sector) – 2013*). There is comparatively less emphasis in policy on ecosystem based adaptations, including mangrove reforestation, and

there is limited delegation of responsibility regarding protection of mangroves from a disaster management perspective. Therefore, there is a need to institutionalize protection, and expansion, of mangrove forests in the coastal belt as a disaster risk reduction strategy with specific goals and enforced mandates in policy at both state and local levels. A first stage to institutionalizing holistic, integrated management of mangroves as part of disaster management policy in Odisha will be enhanced communication of the benefits mangrove forests provide to a range of stakeholders including local communities, local government officials and state government officials.

Specific pathways to capture synergies between mangrove reforestation and expansion and socio-economic development planning should be identified. One avenue worth exploring would be how mangrove reforestation could be incorporated into existing welfare schemes (e.g. Mahatma Gandhi National Rural Employment Guarantee Act (MNREGS)); other potential avenues for these endeavours include strengthening market support for mangrove products and payment for ecosystem service schemes. Utilizing the mangroves as a tool for local development will likely provide local impetus for their protection and expansion; this will have secondary disaster risk reduction and conservation benefits. Degraded prawn gheris are becoming more apparent across the coastal landscape adjacent to the BCA. Figure 5 is an example of an abandoned prawn gheri in Erasama block, Jagatsinghpur District, south of the BCA. This is often a result of local communities engaging in prawn cultivation without the knowledge or resources to ensure sustainable returns (Chhotray & Few, 2012; Chhotray *et al.*, 2013). These could be priority areas to target for mangrove reforestation and expansion as the salinity of the land prevents conversion to rice cropping or other forms of agriculture. A further remote sensing study could be performed by disaster management planners and forest or agricultural management departments to identify degraded coastal lands, such as disused prawn gheris, where mangrove reforestation could be targeted.

⁷ Prawn gheris are lands used for prawn cultivation.

Figure 5: Abandoned prawn gheris in Erasama Block, Jagatsinghpur District, on land that was once mangroves (April 2014).



5. Conclusion

The results of this research show that extensive mangrove buffers can enhance the resilience of rice crop production to cyclones. The presence of mangrove buffers, even at low-densities, enabled rice cropping systems to resist cyclone impacts on rice crop productivity to a greater extent than when a mangrove buffer was not present. Likewise the presence of mangrove buffers enhances the recovery trajectory of rice cropland productivity in years following a cyclone impact; it took three years for croplands with no mangrove buffer to recover to levels of productivity

similar to croplands with a low-density mangrove buffer. This case study provides evidence that preservation or restoration of mangrove forests around the Bay of Bengal could increase the resilience of rice croplands. Preservation or expansion of mangrove buffers offers a pathway to reduce the impact of cyclones on rice crop productivity, a key asset for livelihoods and food security for a large proportion of the world's poorest population. This would minimize the impact of disasters on long-term livelihoods development whilst simultaneously presenting opportunities for conservation benefits, enhancement

of ecological services, livelihoods diversity and increased resilience to climate change.

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Chapter 7

Traditional knowledge, ecosystem services and disaster risk reduction in Manas World Heritage Site and Biosphere Reserve, India

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Abstract

Protected Areas play a crucial role towards providing essential ecosystem services and for reducing risks from hazards such as floods and erosion in lower catchments. Manas Biosphere Reserve in Assam, northeast India is a biodiversity hotspot, parts of which are also designated as IUCN Category II National Park, a Tiger Reserve and a UNESCO World Heritage Site for its unique biodiversity, eco-cultural representation and natural beauty. It is also a part of the largest trans-boundary tiger conservation landscape in the world. In one location of which, the indigenous tribes have successfully demonstrated the use of century old traditional knowledge for channelling seasonal Himalayan Rivers which ensures the availability of irrigation and drinking water in an otherwise water-deficient (*Bhabhar*) geological region. Popularly known as the Dong Bundh system of Subankhata forests (DBSSF henceforth), these community-constructed micro-dams help in reducing soil erosion and floods. This significantly contributes towards disaster risk reduction (DRR) in the downstream agricultural areas. There are a total of 13 DBSSFs that control

over 112 sq km of the river catchment and are almost entirely managed and run by the indigenous village communities. This paper documents the systematic century-old system and its impact on conservation of natural resources and communities' livelihood. Questionnaire-based surveys and physical verification of the DBSSF construction were attempted for the first time. Identification, recognition and acknowledgement of such traditional systems as incentive-based mechanisms (IBMs) are not only essential for strengthening the management of protected areas but also for the overall conservation of biodiversity and disaster risk reduction strategies.

1. Introduction

Manas Biosphere Reserve spans across 2,837 sq km of forest area within the Assam province of India. The Biosphere Reserve also has several overlapping national and international designations of conservation significance such as IUCN category II National Park, a Tiger Reserve, an Elephant Reserve and an Important Bird Area.

Geographically, to the north, it is separated from the Royal Manas National Park of Bhutan by the River Manas; while to the west, it is separated from the Buxa Tiger Reserve of West Bengal province by the River Sankosh (Figure 1). Although the Parks and Reserves may be managed differently by various stakeholders due to their geo-political location, they share a common biological diversity and sociocultural affinity to some extent.

The core area of Manas Biosphere Reserve has been designated as a UNESCO World Heritage Site for being a repository of outstanding natural beauty, ongoing ecological processes and several rare, endemic and endangered species such as the Pygmy Hog (*Caprolagus hispidus*), Golden Langur (*Trachypithecus geei*), Hispid hare (*Caprolagus hispidus*), Bengal Florican (*Houbaropsis bengalensis*) besides having a significant population of Tigers (*Panthera tigris*), Elephants (*Elephas maximus*) and the Great One horned Rhinoceros (*Rhinoceros unicornis*). Historically this area is the entry point of tigers into India and combined with Buxa-Nameri-Pakke-Namdapha Tiger Reserves and Protected areas in Bhutan and

Myanmar, it also forms the single largest tiger conservation landscape for Bengal tigers (*Panthera tigris tigris*) in the world (Ghosh, 2013).

Geologically, Assam province is located in an earthquake prone zone (zone V) of the Indian subcontinent. This is due to the geographic location where it sits on the edge of the tectonic plate of India, which is in constant collision with the tectonic plate of Asia (Bilham, 2004). Here earthquakes of up to maximum intensity IX on the Richter scale can be expected. It is also a region with heavy rainfall (> 3000 mm) and the undulating terrain and loose lateritic soils make it prone to land sliding floods and massive erosion in the downstream areas of major rivers such as the Brahmaputra.

Subankhata Reserved Forests (which includes 13 DBSSFs) are located on the eastern edge of Manas Biosphere Reserve (Latitude: E 26° 48' 14.8"; Longitude N 91° 24' 32.2"; Figure 2). Subankhata falls under the *Bhabhar* region that is characterized by rocky terrain, boulders as well as course-changing, seasonal Himalayan Rivers, and where the water table becomes very low and almost inaccessible during the dry season (October to April). The *Bhabhar* region runs across the Himalayan foothills and spans several thousand kilometres across north and northeast India. The entire region is water-deficient and local governments have struggled to fully exploit the water potential or to use modern technology, such as check-dams, that can help in preserving water for irrigation and drinking purposes (Mishra & Satapathy, 2003).

The main source of water within the Subankhata landscape is the Pagladiya River which is known to change its course almost every year. The total catchment area is approximately 160 sq km which is entirely managed by local communities belonging to at least seven indigenous tribes. The people are poor and entirely dependent on rain-fed agriculture which is also their primary occupation. The remoteness of the region, as well as limited accessibility to the basic amenities like piped water supply, communication, and transportation has limited the improvement of their living standards.

Figure 1: Location map of Manas Biosphere Reserve and DBSSFs in Assam, India

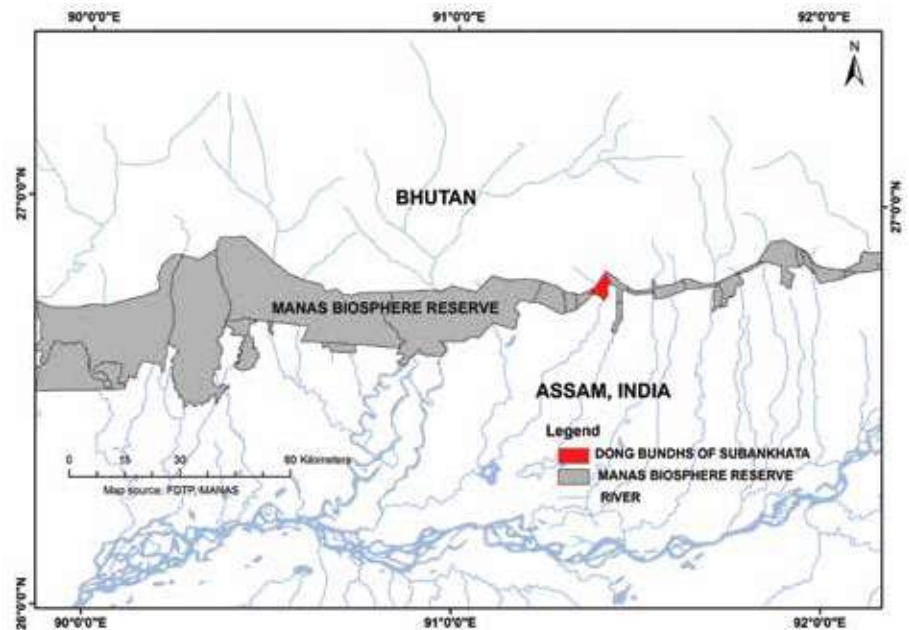
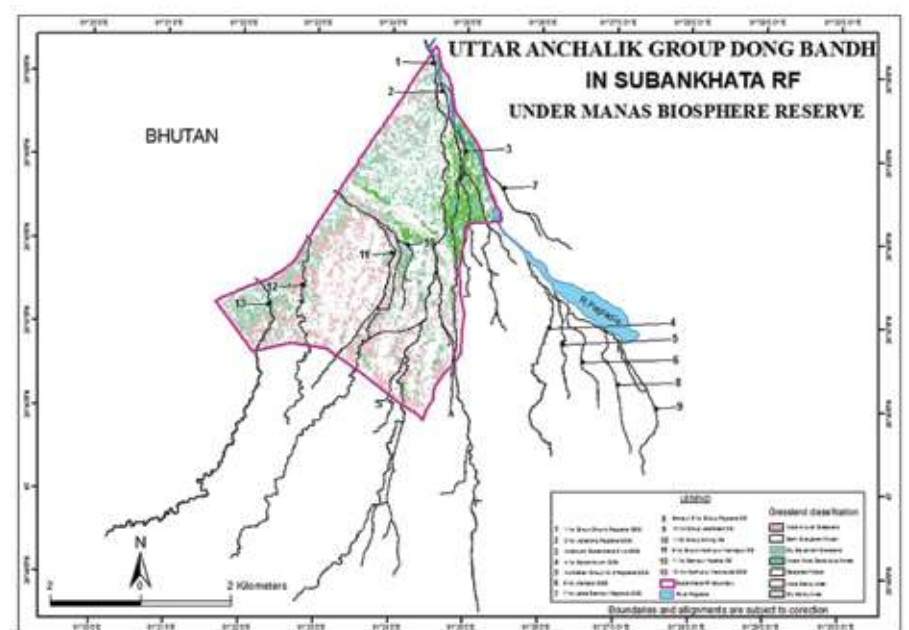


Figure 2: Location map of DBSSFs for Subankhata Reserved Forests in Manas Biosphere Reserve.



Source: (Das, 2014).

1.1 Climate, geographical and ecological significance

Manas Biosphere Reserve is located in the sub-tropical climate zone of the country and is one of the most pristine habitat representatives of the Indian subcontinent. This includes Sub-Himalayan high alluvial semi-evergreen forests, eastern *Bhabhar* *Sal* type forest, East Himalayan moist mixed deciduous forests, eastern wet alluvial grassland, low alluvial savannah

woodlands, riparian fringing forest and *Khair-Sisoo* forests. The vegetation comprises *Sal* (*Shorea robusta*), scrub forests, old plantations (in buffer areas), and semi-evergreen and mixed deciduous forests, interspersed with grasslands and riparian vegetation in certain patches.

The rich assemblage is due to its unique bio-geographical location which is at the confluence of Indo-Malayan, Indo-Chinese

and Australasian pathways making it an important refuge for several endemic and charismatic wildlife species. It also provides an ideal habitat for wildlife, ranging from high altitude Himalayan dense canopied forests to the sub-tropical woodlands, alluvial floodplain grassland and riverine ecosystems in the lower elevations.

In comparison to Manas National Park (that forms the core of Manas Biosphere Reserve), the biodiversity values of adjoining Subankhata Reserve Forests are inadequately documented. The forest types include Sub-Himalayan semi-evergreen, east Himalayan moist mixed deciduous and low alluvial Savannah woodland areas. There have been recent reports of the presence of endangered species such as tigers, elephants and Himalayan black bears which are perhaps using the area as a corridor between the core area (Manas National Park) and the adjoining forest areas in Bhutan (Bipul Das, unpublished data).

1.2 Disaster risk and vulnerability of the study area

DBSSF is located in a zone highly vulnerable to natural hazards, especially earthquakes and floods. The main fault line of the Indian tectonic plate that joins with the Eurasian plate passes through Manas Biosphere Reserve. As a result, earthquakes are frequent in the area. The major earthquake of 1950 had a significant impact on the north-eastern region of India, and since then several minor earthquakes have been recorded in the area as well. These events seem to have induced a shift in the Manas river system, as revealed in the sequential Landsat satellite imageries between 1989 and 2010 (Sarma *et al.*, 2008).

The region also experiences heavy rainfall (> 2818 mm as compared to the national average of 1150 mm annually) and consequent excessive runoff, which results in devastating floods (Mishra & Satapathy, 2003). In 2005, heavy rainfall combined with the release of upstream water holding in the hydroelectric projects in Bhutan led to major devastation for the downstream 'Indian' Manas, including flash flooding, landslides, loss of prime agricultural lands and forced displacement of people (UNESCO, 2008). This may have had a cascading effect on the Brahmaputra river system in Bangladesh, though this has not

been documented yet. The DBSSF area in particular, is prone to annual flooding. It also results in siltation of agricultural lands in the lower catchment.

1.3 Historical and cultural context

Although no written records could be found, it was learnt from the local communities that DBSSF was entirely initiated by the local indigenous inhabitants during the pre-Independence era. During this time, Assam was undergoing rapid forestry and agricultural expansion (Saikia, 2011) and new areas were being explored and settled by the colonial rulers. Due to water scarcity *Bhabhar* tract remained largely unsettled for a long time. In the early 1930s, some inhabitants from Bodo-Madahi tribe who were settled near Subankhata Reserve Forest constructed *Dong Bundhs* (small canals) on the Pagladiya River using locally available material such as timber, bamboo and boulders. It may be assumed that the experiment by local people was critical for surviving in an otherwise water-deficient area. By 1935, the *Dong Bundh* system was a success and Pagladiya River (literally means 'a river that cannot be tamed') and its numerous tributaries were channelized to provide drinking and irrigation water to the villagers downstream. Gradually more settlements were established and the river treaties expanded to cover a significant portion of the catchment area. At present, there are 13 DBSSFs with inhabitants from more than 95 villages managing the irrigation system.

2. Methodology

The main aim of this study was to document the process and understand the ecological significance of traditional water conservation methods such as the DBSSFs under Manas Biosphere Reserve. The main study objectives are:

- To undertake a systematic study and documentation of the DBSSFs.
- To acknowledge Protected Areas and community initiatives for water conservation and disaster risk reduction due to large scale floods and downstream erosion in Manas Biosphere Reserve.

The DBSSF is controlled, regulated and maintained by a registered society called 'The Uttar Anchalik General Pagladiya *Dong Bundh* Committee, Subankhata' which was officially recognized during the

year 1954. It is also registered as a Society under the prevailing laws. Under this committee, there are 13 different DBSSF sub-committees that are described in the table below. A questionnaire-based survey was undertaken to assess the mechanism by which the DBSSF committees have been functioning. Members from the 13 committees were interviewed using a semi-structured interview style (Table 1).

As summarized in Table 1 next page, a total of 95 villages, comprising 6,115 households, constitute the 13 committees actively involved in providing protection to a catchment area of more than 120 sq km. Each committee is composed of a cluster of villages and has an elected president, secretary and treasurer. Some of the committees also have a bank account in which the annual membership fee is deposited. The annual membership fee varies from around US\$ 2-3 annually from each household. All committees have a constitution that includes rules and regulations. The Santipur Kaladia DBSSF sub-committee has a rule stating that every household must designate one member in charge of construction and repair works on the micro-dams. Similarly, the water distribution will also be dependent on the number of bullocks and cultivable area owned by a particular household. Penalty is also levied on defaulters in each of the committees (by a system locally known as *Kuruki*, an informal customary law that is followed by the society) who are absent at the time of *Dong Bundh* construction/repair works. Habitual defaulters are permanently deprived from using *Dong Bundh* water, including access through their neighbours.

The main task of the committees is to regulate and control the flow of water from nearby streams and from the main Pagladiya River by constructing *Dong Bundhs* (Figure 1). Each member provides free labour in return for assured drinking and irrigation water for household use. The amount collected from membership fees is used for buying construction materials. Construction of a *Dong Bundh* is hard labour as almost all the work is done manually. Heavy river boulders are lifted and bamboo and timber poles are joined to construct required structures such as 'Porcupines'¹. Construction of

¹ A water deflector made of bamboo and locally available material. (Figure 3, Step 4).

Table 1: Summary table of the 13 clusters under DBSSFs of Manas Biosphere Reserve (Das, 2014).

	Name of Dong Bundh Committee	Villages (No)	Conserved Catchment Area (Sq km)	Household (No)	Total Population
1	Diring <i>Dong Bundh</i> Committee	6	11.43	673	3,365
2	Chowki Pagladia <i>Dong Bundh</i> Committee	32	30.34	1500	7,500
3	Dakshinkuchi <i>Dong Bundh</i> Committee	13	3.57	256	1,438
4	Jalahbasti <i>Dong Bundh</i> Committee	1	2.96	160	800
5	Jopadong Pagladia <i>Dong Bundh</i> Committee	9	30.16	755	3,775
6	Uttarkuchi Subankhata <i>Dong Bundh</i> Committee	11	16.71	780	3,900
7	Jharbasti <i>Dong Bundh</i> Committee	1	2.73	180	6,000
8	Muihabari Pagladia <i>Dong Bundh</i> Committee	9	8.26	369	2,306
9	Sonajuli Pagladia <i>Dong Bundh</i> Committee	2	0.43	98	490
10	Lebra Santipur Pagladia <i>Dong Bundh</i> Committee	2	1.00	109	719
11	Madhpur Mainaguri <i>Dong Bundh</i> Committee	2	4.29	350	1,750
12	Santipur Kaladia <i>Dong Bundh</i> Committee	2	4.51	528	2,640
13	Madhupur Major Supa <i>Dong Bundh</i> Committee	5	3.77	357	1,785
	Total	95	120.16	6,115	36,468

Figure 3: Pictorial depiction of the process of constructing *Dong Bundhs* at Subankhata Reserved Forests, Manas Biosphere Reserve, India.



Step 1: A view of Subankhata river catchment during the peak flood season (August).



Step 2: Construction of *Dong Bundhs* before the onset of the dry season (Dec-April).



Step 3: Collective labour including the physical contribution of one member from each household.



Step 4: Construction of deflectors (called porcupines) using locally available materials and through collective labour.



Step 5: Channelizing the stream as necessary during the dry season for downstream water requirements.



Step 6: Prevention of floods and channelizing the Subankhata River in the upper catchment.

a single *Dong Bundh* can take almost 6-10 days and requires manual labour from at least 150-200 people each day. Similar collective labour is required for maintenance and major repair works.

Although management of the DBSSFs happens throughout the year, the main

construction works are undertaken from January to March. During this time, the main river channel is cleaned. This involves the manual removal of obstructing boulders and de-siltation of the river channel. Porcupines are built from locally available materials such as bamboo and timber poles and are made to deflect

and channelize the stream as required. Reconstruction and repairs of any broken *Dong Bundh* is also carried out during the heavy monsoon season that lasts from May to August. At the end of the monsoon season, members are again entrusted with the task of clearing stones and carry out minor repair works. The

winter season, between October and April, is the critical period during which there is water shortage and it is when the actual water management and distribution is carried out. The *Dong Bundhs* operate on a sound principle of water management, ensuring that there is no waste and water is distributed judiciously and equitably. The DBSSF sub-committees strictly monitor the supply and use of water. Each *Dong Bundh* is opened for a few hours at periodic intervals, for example once a week for one village, so that the residents can store water in their ponds. After a certain period, the *Dong Bundh* channel is opened for another village. The main use of the water is for drinking, irrigation and other household purposes.

3. Result

The DBSSF benefits a population of 36,468 people residing in these 95 villages. It is able to ward off floods and related disasters in addition to providing food security throughout the year. It also ensures the protection of key water sources within Manas Protected Area.

The survey also reveals that the area of the catchment conserved is directly proportional to the number of households contributing to the committee (Figure 4). Since the core strength of DBSSF is the provisioning of collective labour, the villagers are able to expand their agricultural area based on the labour provided.

Preliminary results indicate that the DBSSF has been highly beneficial to the villagers in multiple ways. Major floods, resulting erosion and landslides in the lower catchment have been avoided (Bipul Das, unpublished data).

The area is also dominated by the Bodo tribe (Figure 5), that has witnessed armed conflict in the recent past. Living and working together on *Dong Bundhs* has been beneficial for integration, peace and political stability amongst the diverse communities and has also helped in the economic development of the region.

Additionally, the members are also able to harness water resources through the critical months and do not depend on any artificial water supply. As a bonus they are able to harvest at least four different cash crops (paddy, mustard, lentils and vegetables) throughout the year (Figure 6).

Figure 4: Extent of catchment area (ha) protected through DBSSFs in Manas Biosphere Reserve, India.

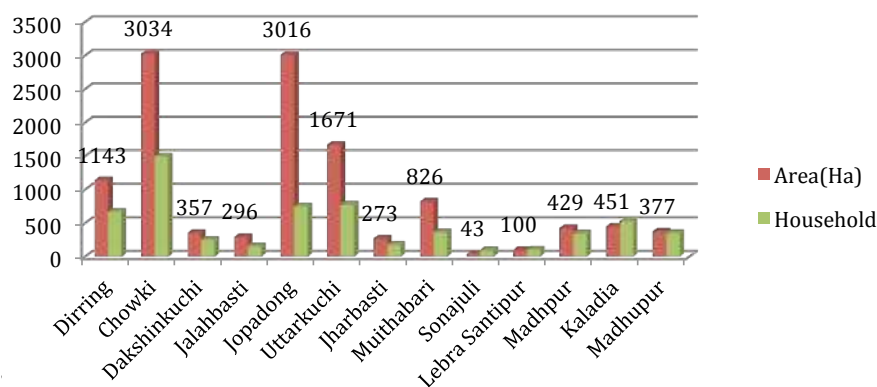
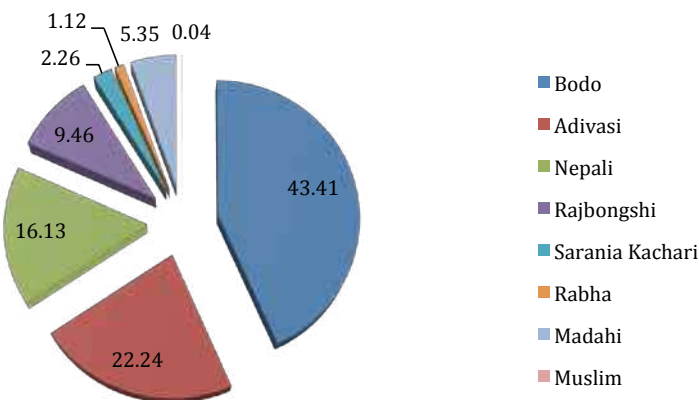


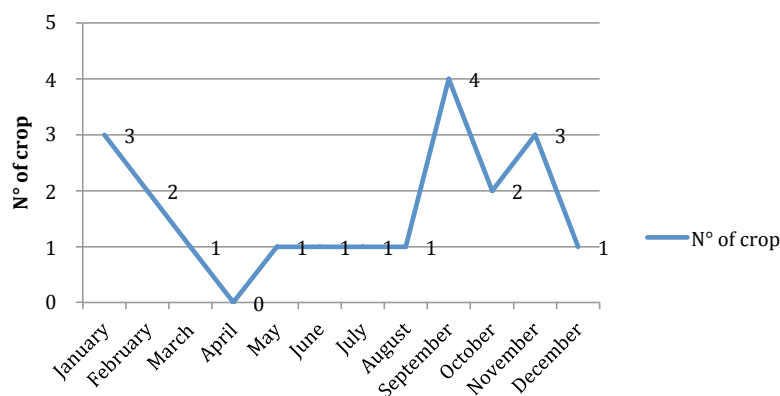
Figure 5: Ethnic composition (in percentages) of community workers under DBSSF of Manas Biosphere Reserve, India.



Bodo	Adivasi	Nepali	Rajbongshi	Sarania Kachari	Rabha	Madahi	Muslim
43.41	22.24	16.13	9.46	2.26	1.12	5.35	0.04

Source: (Das, 2014).

Figure 6: Annual representation of number of crops cultivated by local communities under DBSSFs of Manas Biosphere Reserve.



Source: (Das, 2014).

Interactions with the villagers also indicated that forests in the vicinity of the catchment area had become fragmented in the last few decades. They attribute this to the rising demand for fuel wood and timber resources and the lack of such resources outside the forest areas. They also feel marginalized due to the prohibitory nature of the prevailing government laws and lack of involvement in any joint partnership for the protection of these forests.

4. Discussion

Survival and continuity of traditional water management practices such as the DBSSF in the foothills of the Himalayas has been unique but not uncommon. A number of studies report the existence of such practices evolved indigenously through constant learning, practical application and adoption by the local community (Sharma, 1998; Mishra & Sharma, 1999; Saxena, et al, 2003; Dorjee & Singh, 2006). The ethos of such practices has been conservation, adaptability and use of natural resources in a sustainable manner (Agarwal & Narain, 1997). The continuance of such practices has been shaped through a mechanism of social participation often guided by harsh economic realities and near absence of an overpowering state. However, the proponents of traditional practices often ignore the harsh realities of modern knowledge and its powerful impact. Not only can they be overpowered by the quick benefits of modern technology, but also lack the capacity to justify or articulate the need to continue with traditional practices in the changed and modern environment (Kumar, 2013).

As revealed through the questionnaire-based survey, the community in the periphery of Manas Biosphere Reserve has been able to develop and preserve an indigenous water management practice that has benefitted the Manas Biosphere Reserve immensely. Almost all the respondents agreed that the forests of Manas Biosphere were critical towards conservation of water in the lower catchment and that there should be greater recognition and involvement of local people in protecting such natural resources. Although no direct studies have been undertaken, it was observed that the floods of 2005 impacted the lower catchment to a great extent, especially

in the Manas-Beki river system in Manas Biosphere Reserve, but did not have a significant impact in Subankhata area. Major landslides and flood-related erosion have also been averted due to active management and participation of the local people in actively maintaining the *Dong Bundhs* in the DBSSF.

Manas Biosphere Reserve is inhabited by a multitude of indigenous tribes who have their own unique sociocultural affinity. It has also been a hotbed of armed insurgency movements for assertion of tribal rights. While the socio-political situation is rather volatile in surrounding areas, it has been proved that more than seven indigenous communities are able to live in harmony in Subankhata. This can be directly attributed to the presence of a strong cultural traditional system of water regulation, which has brought in economic security and lasting peace.

However, gradual increase in the use of technology and hard infrastructure such as concrete, following decisions based on stereotyped democratic structure (secret ballot with win and loss outcome) has implications for these evolved traditional practices. State promoted concrete structures (check dams), which lack the necessary flexibility to adapt to the ever-changing river course, may have implications for an increase in disaster events as well as for a reduction in the coping capacity of the community (Agarwal & Narain, 1991). Resource extraction in the form of clearing of forests in the upper catchment, wildlife hunting and the illegal collection of stones and boulders from the lower catchment has impacted the overall habitat quality (Gupta, 2007). At the time of conducting this survey, a few state sponsored concrete structures such as sluice-gates and check-dams were also noticed. The lure of hard technology poses a serious threat to the existence of the learnt adaptable technology by the community in the present DBSSF system. Simultaneously, the constant push for its adoption through the techno-bureaucratic network² will destroy the existing organizing structure of the community and its capacity to adapt in the fragile ecosystem (Agarwal, 2001).

² This network is not premised on localized arrangements of learning and survival, which is the hallmark of DBSSF committees.

Against this background, the management of this protected area assumes significance since it can articulate through advocacy and awareness the implications of hard technology. It needs to position this system as integral to the sustainability plan of overall protected area management. This particular case study provides opportunities as well as possibilities for such integration.

5. Conclusion

Traditional knowledge and practices are not static but continuously evolving in the face of changes in the wider political economy (Gupta 2011). As Sundar (2000) argues, 'indigenous or local knowledge is not a frozen, inert, timeless entity, but dependent on the material conditions of those whose knowledge it is and the uses to which it is put'. This case study makes a fine example of a constantly evolving practice of harnessing the river water judiciously in a collaborative manner and of reducing the risks from natural disasters present in the local ecosystem.

The *Dong Bundh* system of Subankhata forests (DBSSF) system can serve as a model for local communities living in the fringe of Protected Areas in the *Bhabhar* belt of the Indian sub-continent. This practice of constructing micro-dams, channelizing and regulating water as per a systematic plan is almost a century old now. It therefore also has sociocultural significance for the unity amongst the ethnically diverse local community for overall peace. It also results in silt-reduction and assists in the protection of biodiversity.

The DBSSF model of Manas Biosphere Reserve has crucial policy advantages for Protected Area management in high population density areas on at least three counts: *first*, it demonstrates the capability of the local community to self-organize for managing a natural resource; *second*, it reveals that the economic outcome (in the form of benefits of irrigation and reduction in the impact of disaster) of such management is crucial for the survival of the traditional practice; and *third*, it provides opportunities to the state actors, particularly the management of the protected area to use advocacy as a tool for its survival and continuity in the overall interest of the local ecosystem. This case study emphasizes the need to identify and to document such traditional practices,

survived in the periphery of the protected areas, to encompass it in the overall management of the protected areas.

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Chapter 8

Adaptation to Climate Change and Disaster Risk Management in the Po River Delta Protected Area

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Abstract

This study considers the environmental complexity of the Po River Delta, one of Italy's largest Protected Areas (PAs). Environmental complexity is a typical characteristic of every delta in the world, and the Po Delta is unique because of its geographical, social and economic factors, which have shaped its current structure over time. The aim of the study is an analysis of the projects and results of the organizations responsible at different levels for the conservation of the PA, which is under the control of two Regions and is managed by two Parks. The economic importance of the site and the environmental issues deriving from the area's fragility call for the need to face constant emergencies and to intervene on a daily basis for the preservation of habitats. The study stresses the need for the Parks to include at the outset aspects of adaptation to climate change (CCA) and disaster risk reduction (DRR) in their PA management plans.

1. Introduction

The Po Delta is as ancient as humankind and it is fascinating to explore its evolution, as it is connected to the history and economy of the region (Correggiari *et al.*, 2005); as a matter of fact it stands in close economic relationship with local populations, who constantly shape the Delta. In the area of Sacca di Goro, for instance, the residents recently discovered the economic activities of their past, and from an agriculture-based economy they returned to a fishing-based one



(Breber, 1993). The Po Delta represents considerable value for Italian business sectors, for the cultural landscape and for the artistic and historical treasures of the cities sited on the river basin. In 1999, part of the Po Delta belonging to Emilia-Romagna Region was listed as a UNESCO World Heritage Site along with the city of Ferrara. The Delta area, moreover, is a candidate reserve for the Man and the Biosphere Programme (MAB 2013).

The Delta is located in an area below sea level. The part crossed by active branches of the river, called the 'active Delta', is in the Veneto Region. The wide area between the Po and the river Reno, on the other hand, is known as the 'historical Delta' and it is in Emilia-Romagna Region; it is still possible to find vast wetlands and traces of ancient riverbeds here.

Evidence and traces of anthropogenic activities to control water are to be found all over the Delta area; they date back to the time of the dominion of the Este family (11th-15th centuries) to the present day (Cazzola, 1987). The constant coastal evolution and frequent hydrogeological problems cause severe floods and debris. Moreover, the Po Delta is rich in transitional waters (ARPA, 2012), salt pans and mud flats, fish farms (Verza & Trombin, 2012), sandbanks and lagoons (Ferronato *et al.*, 2000). It also hosts several artificial canals; in the province of Ferrara, for example, rivers have an average linear length of 300 km, while artificial canals reach 3,500 km. Here, anthropogenic activities lead to an excess of nitrogen and to the eutrophication of water bodies; this damages water quality with serious economic consequences. The lagoon system of the Po Delta demands constant monitoring and water control interventions. At the end of the 1980s, the Delta lagoons were worryingly degraded because of eutrophication. Therefore, several interventions were carried out within the Integrated Mediterranean Programmes; these included the dredging of the lagoon canals; the reshaping of the lagoon mouths which connect the river to the sea; the renaturation of sandbanks and low waters. Water management allowed the development of navigation among the many Delta lagoons, in addition to benefiting productivity and the environment.

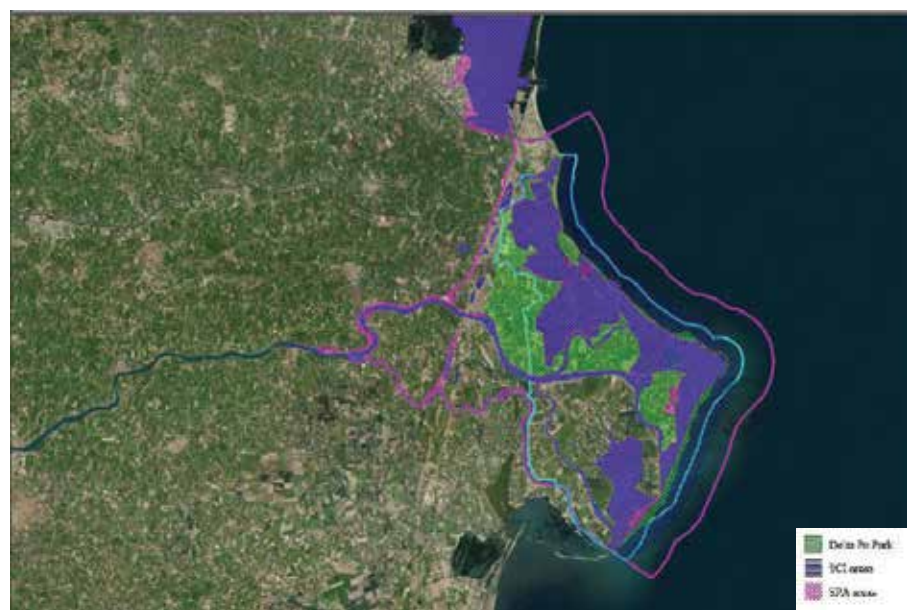
The Po Delta is protected by two Regional Parks, the Po Delta Park of Veneto Region and the Po Delta Park of Emilia-Romagna Region (Figures 1 and 2); in accordance with legal provisions concerning protected areas, these could be transformed into a single National Park. However, the two Parks maintain their separate administrative status, although they share projects and common initiatives (such as the NATREG project, Table 3)

The Po Delta Park of Veneto was established in 1997 by Law no. 36/1997.

It includes almost the whole geographical delta and covers 1,200 hectares. The Park comprises nine municipalities of the Province of Rovigo, and it currently has its own management plan to ensure the protection of local communities as well as their economic development.

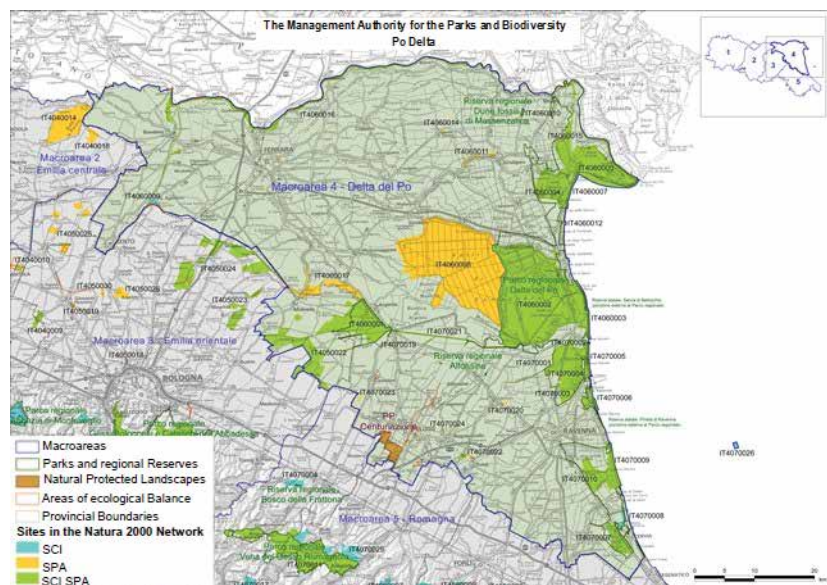
The Po Delta Park of Emilia-Romagna was established in 1988 and it covers a wider area, about 54,000 hectares. It protects the historical Delta of Renaissance times and includes two provinces and nine municipalities. In accordance with Regional

Figure 1: Map showing Natura 2000 sites and the Delta Park, for the Veneto region. Natura 2000 sites have various and large degrees of overlap.



Source: Veneto Park GIS.

Figure 2: Emilia-Romagna Po Delta Park jurisdiction area.



Source: The Management Authority for the Parks and Bio-Diversity- Po Delta.

Law no. 24/2011, Emilia-Romagna Region restructured its PA system; the whole region now consists of uniform macro areas. The Park is under the responsibility of the Management Authority for the Parks and Bio-Diversity- Po Delta. This means a wider jurisdiction and greater possibilities of environmental governance. A peculiarity of the Delta region in Emilia-Romagna is the contrast between its densely populated coast (more than 80 km overlooking the Adriatic Sea) and its rural inland area.

Both Parks include areas in the Natura 2000 network, Sites of Community Importance (SCI) and Special Protected Areas (SPA) (European Commission Environment DG, 2001).

The Po Delta is facing serious environmental challenges. Environmental pressure and threats could be the cause of catastrophes; at the present moment, the frequency rate of disasters due to climate change has increased (IPCC, 2012). Even if CO2 emissions should lower, their negative effects will not stop any time soon, as they will stay in the atmosphere for centuries. This calls for the need to develop an adaptation strategy as well as adaptation plans taking into account the frequency of disasters. Such plans will mitigate or reduce the probability of catastrophic events, which modify habitats and species and damage critical infrastructures, inhabitants and their economy.

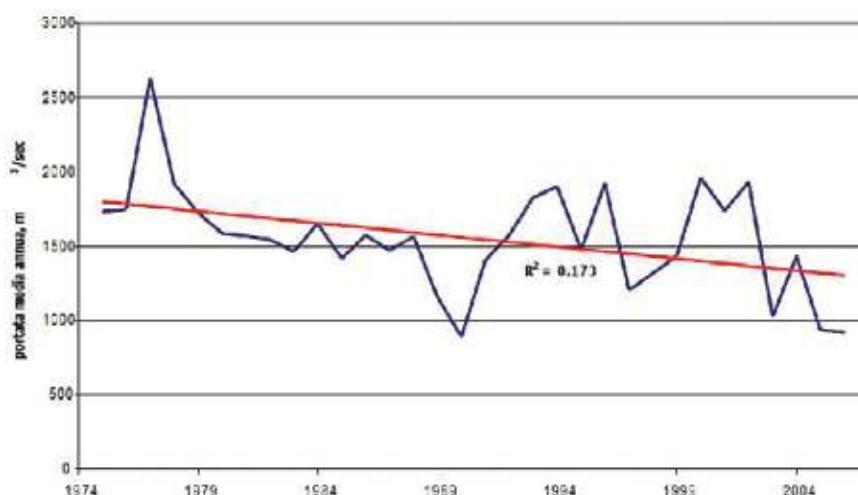
Many of these risks, related to vulnerable areas, threaten both natural habitats and the life of residents. The Parks, therefore, play a key role in preventing risks and adapting to climate change (Ervin, 2011; Rannow & Neubert, 2014), especially in the vulnerable sectors shown in Table 1.

The following investigative analysis will focus on particular Delta areas and on the main actions and projects carried out by the Parks, often in collaboration with other interested parties such as Reclamation Associations, Regions, Provinces and Municipalities. Concentrated within the Delta are risks and dangers concerning the whole river basin (Marchetti, 2002), which is Italy's largest river basin (71,000 km²). Environmental stress and climate change strongly affect river discharge and damage the hydrogeological cycle of basins (Figure 3) (Tibaldi, 2008; Day *et al.*, 2011).

Table 1: The Delta – vulnerable sectors and risks.

Sector	Risks
Water and hydrogeological	Reduced water availability and quality, hydrogeological alterations could increase landslides, flash mud/debris flows, rock falls, floods
Biodiversity and ecosystems	Biodiversity and ecosystem services loss
Coast	Erosion, flood, sea level rise also coupled with subsidence and overwash phenomena
Soils	Soil degradation, erosion and micro-desertification
Agriculture	Loss of productivity
Fisheries and aquaculture	Fish species productivity decline, aquaculture reduction
Energy	Reduction in hydropower production potential
Infrastructures	Urban and periurban inaccessibility, damages to settlements and cultural heritage.

Figure 3: The Po River's annual average flow, measured at Pontelagoscuro between the years 1975 and 2006: 25-30% reduction.



Source: Tebaldi, 2008; ARPA, 2012.

Moreover, the Po River basin suffers from the phenomenon of subsidence, which consists in the compaction of sediments, creating small depressions (Teatini *et al.*, 2006). These lead, on the one hand, to the accumulation of freshwater coming from river floods, and on the other, to infiltrations of brackish water from the sea. The result is the formation of brackish water lagoons.

1.1 Flooding

Although the river embankments are very high, the whole Delta area is subject to hydrological risk and it has become impossible to build on some areas near the riverbank. Floods are often a consequence of rivers having been forced into new courses out of their original channels. The master plan for Emilia-Romagna Park (Rinaldi & Fabbri, 2008) calls for the creation of detention basins, which will retain and slowly release water.

Nevertheless, the flood risk is still high in the whole water collection area.

The EC Floods Directive 2007/60 (EU Official Journal, 2007) was adopted by both regions, which until now have published risk and danger maps. Moreover, Emilia-Romagna also applied the Directive guidelines to its coasts, which are mostly below sea level and lack coastal dunes for many kilometres. Here, floods and overwash events affect a very busy tourist area.

1.2 The subsidence phenomenon and its effects on the landscape

Subsidence phenomena first appeared after the extraction of natural gas and water during the 1940s-1960s, followed by defensive infrastructure works all along the Delta valley (Syvitski *et al.*, 2009). Subsidence and removing water from

soils seriously disturbs soil remediation and irrigation. In addition, it hinders the maintenance of fish farms (Figure 4). Sandbanks along the coasts gradually disappear, while erosion increases. Subsidence also causes irreversible changes to the landscape as well as degradation of the soil, which loses its ability to absorb CO₂ (Caputo *et al.*, 1970).

1.3 Saline wedge

A phenomenon related to climate change is the saline wedge, caused by sea level rise; the average level of the Adriatic Sea currently rises by 1 mm per year, but the expected rise by 2100 amounts to 15 cm. The saline wedge is the intrusion of saltwater from the bottom of canals up the river. This phenomenon is actually just one part of a more complex problem, the spreading of salinity in coastal areas, which includes the salinization of groundwater. In 1930, the saline wedge pushed inland up to just 2-3 km of the river mouth. In the last few decades, though, it reached a distance of 20 km from the sea, seriously damaging agriculture. The causes of the Delta's saline wedge are poor use of water resources and a combination of natural and anthropogenic factors; these include the increasing of shallows and the lowering of the river bottom due to excessive extraction of building materials.

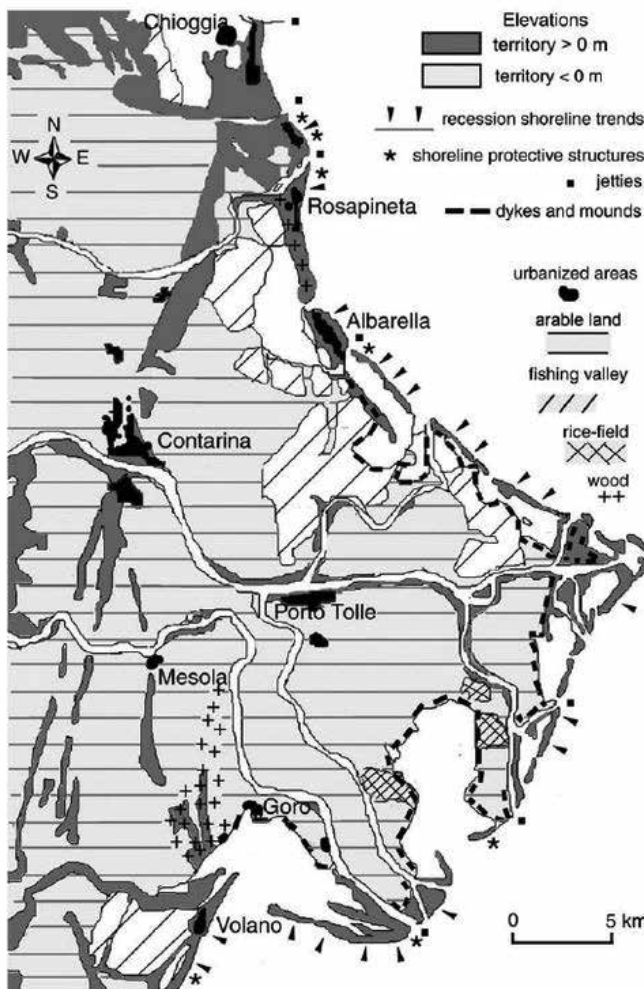
The saline wedge causes:

- Damage to agriculture, with frequent interruptions to irrigation.
- Disruption of water supplies, as the aqueduct is not able to desalinate water.
- Salinization of groundwaters. The progressive saline concentration increases this phenomenon, leading to droughts in coastal areas and micro-desertification due to the local ecosystem change (IMELS, 2013). These problems could be partially solved by the creation of water reservoirs all along the floodplains.

2. Methodology for DRR and CCA in the PA

Confronted with such urgent environmental problems, it seems useful to analyse the engagement of the Parks in implementing CCA and DRR strategies in their management, through the study of completed projects. The implementation of such measures could help reduce

Figure 4: The subsidence risk.



Source: Simeoni & Corbau, 2009.

environmental pressure and threats, not only in the core area but also in the buffer zones, which are often connected to uncontrolled urban sprawl. The PA provides essential ecosystem services (ES); if correctly evaluated, these could really contribute to mitigating risks, as our results show (Table 2).

Analysing these projects and the urgency of these measures, as well as evaluating the current decision-making processes, is a way to propose corrective actions to reduce environmental risks (Table 3) (Andrade *et al.*, 2010). The following points were considered:

2.1 Hazard assessment: mapping for DRR and CCA

The need to define the dangers to the area led to a monitoring campaign and to the mapping of risks, in order to reduce negative consequences for human

health, landscape, environmental and cultural heritage and goods. With regard to Emilia-Romagna, risk maps were drawn up by the River Basin Authority and the Region, with data and studies concerning the safety of hydrological structures. They cover three possibilities: 1) frequent floods, 2) infrequent floods, 3) rare floods. These maps give a preliminary evaluation of flood risks, which leads to the 'Registry of Events', a database containing a description of all past floods, updated to 2011 and connected to a LIDAR-data based digital model of the ground. Floodplains are identified by the hydrological cell, a management tool. The maps differentiate danger classes depending on the event probability. In addition to this, a database of critical infrastructures was produced, to show the distribution of economic activities which are most at risk. Finally, risk maps were

Table 2: Benefits delivered by ecosystems in the PA and suggested management actions.

Ecosystem Services delivered by Protected Areas	Description	Management Actions
Livelihood	Water and food provisioning for people, water for agriculture, pollination processes.	Preservation of natural habitat; restoration of ecological functions.
CO ² storage	Carbon capture and storage in soils and vegetation.	Forest and natural habitat preservation. Afforestation.
Territorial protection	Maintenance of integrity of ecosystems : floods and waves absorption by vegetation; soils stability against landslides; water retention against drought; fire protection.	Monitoring, management evaluation.
Resilience enhancement	Connections with national ecological networks.	To promote the extension of natural and artificial corridors between protected areas, regarding threatened species' displacement.
Climate regulation	Protection of biodiversity, environmental protection, disaster risk mitigation.	Evaluation of management efficacy.

created; they are connected to the map of potential damage and to the map of potentially affected population.

A few experiments are currently being carried out to implement CCA measures, starting from the downscaling of EU CLIM-RUN climate data (www.climrun.eu). Updated hydrometric data and precipitation data will allow an assessment of climate change impacts, using trends and points of non-stationarity in the series of observed data concerning precipitation (ARPA, 2012). This is going to be the first case of integrated planning between DRR and CCA, according to the results of recent evaluation methods (www.KULTURisk.eu).

2.2 Flood management in application of EU Directive

In order to reduce the threats indicated, in December 2015 the Region will implement the first 'Flood Risk Management Plan', in compliance with the EC 2007/60 Directive, adopted by Law no. 49/2010. Its objective is to minimize the negative consequences of floods on human health, landscape and socio-economic activities. In the meantime, in 2012, the Region approved guidelines for the environmental regeneration of Emilia-Romagna's drainage canals, within the 'Life Econet' project. These guidelines propose innovative forms of channel management, such as the creation of wetlands in the river basin, in order to improve water and ecosystem quality and reduce maintenance costs. Reclamation Associations, Regions and Parks are in

charge of planning the ecological network 'Natura 2000' and SCI and SPA areas. However, only a few of these detailed management plans have been completed at the present day.

2.3 Supporting decision making for DRR

The Reclamation Association of the city of Ferrara successfully tested and recently implemented a Decision Support System (DSS) for managing the increasing hydrological risk (EEA, 2013). This DSS consists of a collection of the best weather forecasting information available, in collaboration with the Environmental Agency. This information is carefully evaluated and processed by the system, which is based on the knowledge of hydrological networks and their real maintenance situation. This allows the prediction of possible events in several catchment areas and to make the best possible use of human and operational resources. Moreover, the DSS also works as an early-warning system for the most at risk populations and infrastructures.

In addition to this, Emilia-Romagna Region defined priority actions and PA management objectives, in order to support the decision-making process. These priorities, with regard to DRR and CCA, mainly concern:

- Dunes, coastal dunes and coastal lagoon habitats;
- Monitoring of physical and ecological parameters to mitigate the salinity of surface waters and groundwaters;
- Protection of shores and preservation

of river outlets;

- Acquisition/Reforestation of land and forests through the creation of carbon sinks;
- Integrated management together with institutional stakeholders of the areas of Sacca di Goro (salinity and eutrophication) and Comacchio Valleys (subsidence).

DRR is aimed at short- and middle-term emergencies, while CCA is considered to be a long-term strategic complement to DRR whose prescriptions should be included in the adaptation plans. Accordingly, ARPA published a Bioclimatic Atlas (Regione E.R., ARPA, 2010) where the main climate change parameters are displayed and described.

2.4 Analysis of activities undertaken in the Po Delta.

Table 3 shows projects and activities implemented for DRR and CCA.

3. Results: DRR approaches

The analysis of these projects and methods promotes a culture of prevention throughout the Delta; it is already widespread and can be further refined over time (Table 4).

3.1 Hazard maps

In Emilia-Romagna, the first Flood Management Plan is almost completed (Figure 5); flood risk and erosion, fire, avalanche and coastal evolution risks are all reproduced in the cartographic representation. Consultation with citizens and interested parties has already started,

Table 3: Main Projects for DRR and CCA in the Po Delta.

Project	Field of Intervention	Problem to address	How (activities/proposed actions)	Kind of activity
UNESCO World Heritage management plan	Heritage restoration; Biodiversity protection.	Historical and artistic heritage restoration; Protecting the increasingly difficult relationship between humankind and environment.	Landscape rediscovery; Agriculture development through certified products; Aquatic vegetation improvement enhancing denitrification.	CCA (Water-management).
Regions/ Natura 2000/ Park plans	Implementation of European Directives financed by LIFE Nature; Rural landscape; Delta lands; Coastlines.	To protect and enhance the biodiversity and environmental services of the protected area; To boost the quality and multifunctional agriculture; Plans and projects evaluation with European procedures: the Incidence Assessment (EincA); Artificial coast nourishment technique; Erosion hazard.	Environmental restoration, renaturation; wildlife species reintroduction; reforestation; Environmental education; Afforestation projects; Active protection of landscape through periodic monitoring; Promoting local agro-environmental cooperation agreements; Sustainable management of coasts and sediments; Gis-based coastal information system; Subsidence monitoring network.	CCA and DRR; Risk reduction implementing preparedness, response and recovery actions.
NATREG project	Core area of Delta.	To share management for the sustainable development of the two Delta Parks; Water resources planned for a multi-utilization management; Irrigation enhancement; Economic evaluation of natural capital.	Natural capital guidelines; Improvement and remediation of electrical power lines; Ca' Mello wetland and canal restoration; Economic evaluation of Bertuzzi fish farms.	CCA ; Risk management approach proposing multi-utilization water resources management.
ClimaParks	Impacts of climate change in Emilia-Romagna Delta Park.	The impacts of climate change in protected areas; Defining a range of management strategies to climate change; Weather station installation complete with sensors for temperature, relative humidity, rainfall, wind speed and direction.	Scientific surveys and constant monitoring; sources of historical measurements from meteorological stations; Monitoring climate change impact on biotic communities; Monitoring of the climate change perceptions of tourists in the Parks; Plan on renewable sources of energy.	CCA and DRR; Defining bioclimatic indicators; Risk reduction response.
Reclamation Associations management plans	Reclamation plans and projects with Regions, Parks and Environmental Regional Agencies collaboration.	Climate change impacts and DRR.	Decision Support System on hydrological risk; To increase the volume of the reservoir; Construction of new flood control basins to defend towns, production and service areas from the hydrogeological risk; Strengthening of existing and new construction of pumping equipment; New infrastructures to expand the irrigated area.	CCA and DRR; Risk reduction implementing emergency response and recovery in programmes and realizations.

Table 4: Risk management approach in the Po Delta.

Hazard Assessment	Risk Assessment approach	Planning	Implementation
Monitoring campaign	Vulnerabilities assessment	Plans of hydrogeological assets	Yes
Hazard identification	Database of critical infrastructures	Registry of disaster events	Yes until 2011
Hazard classes according to events probability	Floodplains, coastline management tools	Coastal Management Plan; Risk emergencies plan	Yes
Hazard scenarios definition	Potential hazard maps and risk maps	Flood Management Plan	Already developed but not adopted yet

and as required by the EU directive, all stakeholders are taking part in the drafting of the plan. Once adopted, the plan will be completely reviewed every six years. Implementing risk maps in these plans means preparing people for risks; it also makes it necessary to have management tools and funds ready for vulnerable areas. The aim is to reduce risks and to define priority intervention areas, modelling potential scenarios and acting on a political and economic level.

3.2 Flood management

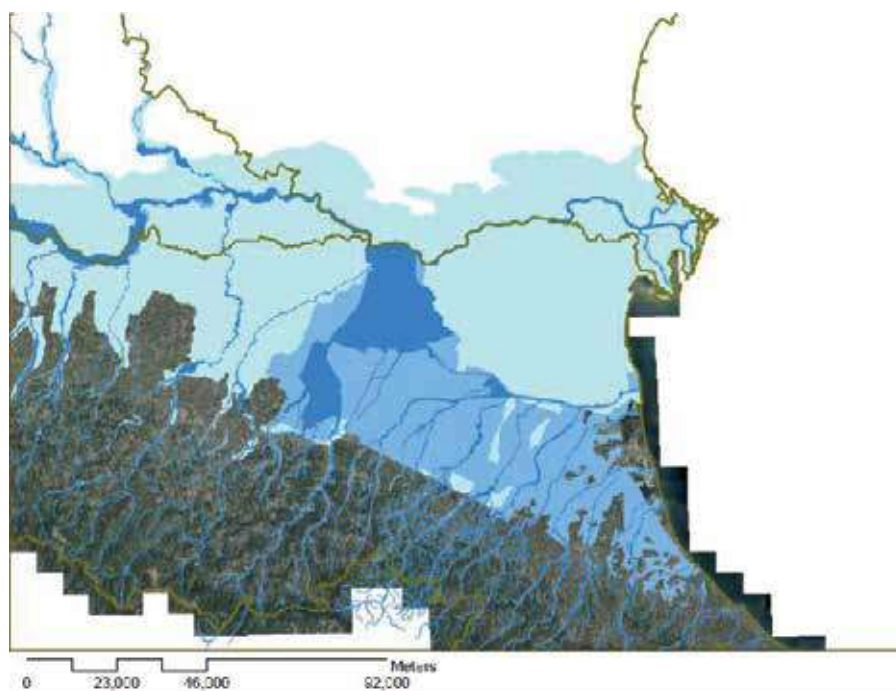
Emilia-Romagna Region also adopted a Ten-Year Coastal Management Plan (2010-2019) for a new defence strategy and for the implementation of acceptable-risk measures.

It was the first Italian region to choose beach nourishment measures over traditional 'hard' coastal protection works (IMELS, 2013). The Coastal Management System Cells (SICELL) support a database recording every defence intervention realized, in addition to the health status of the coastal area, that is to say its resilience (Regione E.R., 2011). SICELL is also used for Sediment Management Plans and for interventions against erosion risks. Researchers are currently considering an indicator to measure the marshes' ability to retreat inland from the coast (Torresan *et al.*, 2008). Finally, Emilia-Romagna Region is the only one to have developed and adopted Integrated Coastal Zone Management (ICZM) guidelines in 2005.

3.3 Decision making

After the implementation of DSS, the Reclamation Association of Ferrara successfully executed the Hydrological Risk Emergencies Plan. It was put into effect with integrated and preventive actions in order to reduce the negative consequences of floods, both potential damage and environmental costs. At the

Figure 5: Flood map indicating three different levels of hazard for the Po Delta area. The colour intensity relates to flooding frequency.



Source: Geoportal of the Italian Ministry of the Environment.

present day, it is able to avoid damage to people and infrastructure both during and after disasters.

3.4 Projects implemented

The study of the main projects carried out led to important considerations:

The UNESCO World Heritage Management Plan highlights the importance of PAs for the development of agriculture in their fragile landscape (AA.VV., 2013). The Park's engagement strengthened the connection between landscape, cultivation and quality products (many of them can display an eco-friendly certificate). The Park also concluded important agreements with the private sector, promoting local agro-environmental cooperation, increasing quality and multifunctional agriculture, improving governance and biodiversity

preservation. All these results are just a contribution to a bigger adaptation strategy. The prevention of nitrate pollution is another result of this newly rediscovered relationship between agriculture and cultural values.

The European Directive concerning waters restored the canals' aquatic vegetation, removing nitrates and improving ecological functions. This brings benefits to several production sectors and to very distant areas and ecosystems. Restoration of ecological functions, moreover, fosters a sustainable management of the Po Delta. An example is the renovation of the wetlands near the lock gates of the centuries-old Abate Tower (Mesola), with the reclamation of the landfill site and the development of cultural tourism routes.

The Park's engagement in DRR and CCA measures (Table 3) led to significant reforestation projects, a 'provincial ecological network' which will reconnect the fragmented landscape. Near Pomposa Abbey, in the SCI area of the Argenta Valleys, specific projects have been conducted, such as the Kyoto Parks. This project was funded to fight climate change and to fulfil the requirements of the Kyoto Protocols, through renaturation, riverside woodlands and connections with the sites of the Natura 2000 PAs network.

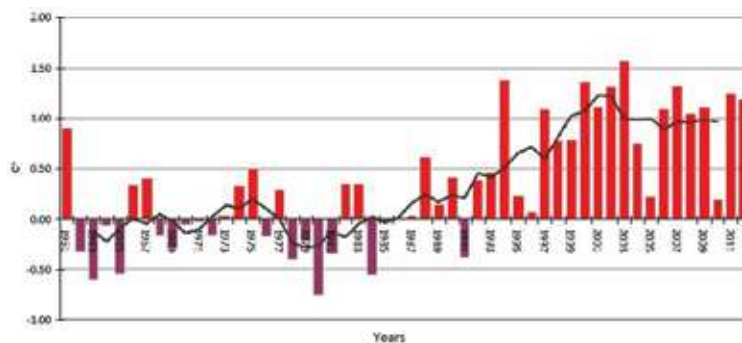
To comply with the EC Habitat Directive 92/43 and the EC Birds Directive 79/409, the Institute for Research and Preservation (ISPRA) created NatureMaps. This work consists of models and of several mappings on different scales of the territory, which was divided into uniform zones called 'physiographic landscapes'. The models assess the ecological and environmental fragility of these units according to the following indicators: 'Ecological Value', 'Ecological Sensitivity' and 'Anthropogenic Pressure'. NatureMaps evaluates new plans and the impact on nature of new projects, proposing modifications. In spite of the usefulness of habitat maps (Odum, 2000), ES maps have not been produced yet, because the EU Habitat Directive behind NatureMaps defines only natural habitats, and not ecosystems. However, even if the inventory of ES indicators is still missing, ARPA indicators can come in useful, as they are organized in annual region-based inventories (ARPA, 2012). These ARPA inventories classify each indicator according to the well-known DPSIR model (EEA, 1999).

The NATREG Project evaluated the joint management of the two Delta Parks. It demonstrated the necessity of their water management and showed how water resources need to be managed for multifunctional purposes, so as to reduce risks and conflicts. Renaturation of wetlands, creation of ecological corridors and natural capital assessment (Table 3) were included in the guidelines for DRR and CCA measures.

3.5 Climate change

According to ARPA monitoring data, the average annual precipitation level in the Po River basin dropped by about 20% during the past 30 years, while since 1960 the

Figure 6: Anomaly trend of annual mean temperature in Emilia-Romagna.



Source: ARPA, 2012.

average annual temperature increased by about 2°C (Tibaldi, 2008). Single rainfall events intensified, and consequently so did the number of extreme events, while the number of rainy days diminished, especially in spring and summer. In Emilia-Romagna, minimum temperature increased by 0.2°C in 10 years. This annual trend is even higher for maximum temperature, which increased by 0.4°C in 10 years. Annual rainfall dropped, with a significant negative trend during winter which grew over the past 10 years. However, in summer and autumn, precipitation is tending to increase slightly. In conclusion, in Emilia-Romagna both minimum and maximum temperatures are clearly rising, and so is the duration of heat waves (ARPA, 2012) (Figure 6).

Climate change within the PA was further investigated in the ClimaParks project (Table 3), particularly regarding its effects on ecosystems. In order to analyse climate change in the Delta, weather stations were made available with series of historical climate data. Moreover, a monitoring unit was sited to measure temperature, relative humidity, precipitation levels, wind speed and direction. Since 1990, historical series show an increase in temperature trends in the subject area, with a considerable rise of minimum, average and maximum temperatures by around +0.8°C per decade (that is to say, +8°C per century) (Masseti, 2013). The Historical Museum of Ferrara also monitored the effects of climate change on biotic communities. Following this project, the Parks sited some weather stations to monitor climate and preserve biodiversity. The project demonstrated the importance of monitoring campaigns, which were previously difficult to implement.

4. Discussion

This study described the activities which help to reduce risks and promote climate change adaptation by improving the quality of PAs and their impact on populations. PA management aims to connect different habitats on a geographical scale and to improve their governance level through the joint use of CCA and DRR strategies by the many interested stakeholders. The analysis of the success or failure of such actions led to a critical evaluation of ES and showed the need for the Delta management to monitor and implement effective CCA actions. Historical series of climate data are not always easily available, and sometimes crucial data is missing. Therefore, there is a strong need for more efficient monitoring and capacity-building systems, in order to raise awareness.

Moreover, it could be useful to implement adaptation strategies to ensure the continuity of the stakeholders' involvement. Some positive experiences have already been concluded: they involved the Fishers' Cooperative of Goro, for the breeding of cockles and shellfish (Quaderni di Ca' Vendramin, 2010), and the Navarra Foundation of Ferrara, regarding agriculture. Nowadays, even institutions have come to see the need for this topic to be discussed in workshops and focus groups (Regione E.R. – SEINONDA, 2013). Some meetings are currently being organized, but there is still scope for improvement, perhaps using specific assessment tools (e.g. choice experiments, contingent valuation). The Italian government developed a National Plan of Adaptation to Climate Change (CMCC, 2013), in response to the need for new governance tools such as local CCA observatories (i.e. a bottom-up

approach coordinated by IMELS). The creation of these observatories could lead to defining a specific role for every PA. It is essential to raise awareness amongst citizens of climate change and to prepare them to better face local disasters. Key to this is including environmental risks in development processes, instead of considering them as an exception.

The PA and Buffer Zone projects considered here strengthen ecotourism and reduce congestion on the Adriatic coast, which is one of Italy's busiest seaside tourist areas. This policy of reconnecting 'Green' and 'Blue' areas could help to address DRR and CCA in managing the PAs. Future research for the integration of current habitat maps could focus on integrating ES maps. With the creation of NatureMaps, the ISPRA Institute significantly contributed to defining the ecological potential of land areas, but did not examine natural capital. ES changes still have not been quantified, but there are a few exceptions, such as the NATREG project and individual studies. There is a real need for a paradigm change, because the evaluation of ES is an essential part of the design of participatory scenarios in which to make the best political and economic choices. ES maps could help identify synergies and trade-offs, in order to improve the management of PA adaptation (Maes *et al.*, 2013).

Emilia-Romagna Region developed a plan of 'Green Connections' and eco-friendly infrastructures to reduce the

fragmentation of the landscape. Such a plan is considered to be a positive starting point for CCA and DRR, because these 'Green' infrastructures also aim to produce and deliver ES, which helps to enhance environmental protection and resilience. All regions along the Po River should implement these 'Green' policies, as the problems of the river begin at its source and affect its whole hydrographic basin. The University of Urbino recently undertook a study on ES variations in Emilia-Romagna (Cataldi *et al.*, 2010); this study proves that it is possible to carry out analyses and assessments of land-use change dynamics concerning ES, and to obtain information about landscape vulnerability and risk management models. ES assessments could serve as the basis for ecological compensation in new adaptation plans. Moreover, they could be vital for corporate sustainability and mitigation banking projects.

5. Conclusion

In order to effectively protect environmental processes it has become impossible to continue a fragmented preservation of isolated areas. PAs should rather promote a dynamic conservation of habitat connections, so as to face climate change challenges and natural as well as anthropogenic dangers, both on a local and a global scale. These new PAs open further perspectives of sustainable development and innovative environmental theories (e.g. ecosystem services, road ecology). Uncontrolled urban sprawl is one of the causes of hydrogeological risks in

the Po Delta; considering the importance given to the Parks by Italian Law, it could really become one of the PAs' interaction and governance fields.

This case study also highlights the importance of communicating scientific results to decision makers (Naustdalslid, 2011). For the foreseeable future it is going to be important to allow cooperation between all management organizations, in order to define the same priorities. Another important aspect is the dynamic of climate phenomena, which are still followed by inactivity and a lack of adaptation strategies. Regions and Parks still have not agreed an official adaptation strategy, but there are already a few operational tools available: EU Guidelines and Directives and ICZM for coastal risks (Ballinger *et al.*, 2010). Common denominators are system resilience and risk management approaches. Moreover, there is clearly the need for middle- and long-term infrastructural works. Real time management skills are also required, in order to implement win-win or no-regrets actions which demand integrated planning and coordination with previously unrelated sectors.

The PAs could be managed in such a way as to strike the right balance between science, communication and politics. It could also promote the continuity of CCA and DRR at different levels (global, regional and local), creating a solid knowledge system able to integrate all the interests in the area.

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Chapter 9

Pioneering climate change adapted Marine Protected Area management in Madagascar

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Abstract

Nosy Hara Marine Protected Area (MPA), located in the northwest of Madagascar, west of the town and large bay of Antsiranana, is the first protected area in the country to incorporate climate change aspects into its management. It is managed by Madagascar National Parks (MNP), in collaboration with local mechanisms (namely, multi-stakeholder orientation and monitoring committees, formed by local communities). The park's total population is about 16,000 inhabitants. The whole region is increasingly affected by climate change impacts, including sea level rise, changes in precipitation patterns and a higher frequency of extreme events such as cyclones. Since 2008, the World Wide Fund for Nature (WWF) and MNP have combined their efforts to build a resilient MPA as a tool for increasing socio-ecological resilience to climate change in the region.

Nosy Hara has been selected as a case study under the **Blue Solutions** initiative, because it demonstrates a successful and scalable approach to marine resource management. The approach is a first local-level response to climate change through considering it in MPA management. It was done in a participatory way by reviewing the strategic links of key components of the MPA while taking account of climate

change (CC) issues. Nosy Hara can serve as an exemplary solution for replication in Madagascar and beyond where vulnerability to climate change is of the same nature and level.

1. Introduction

Nosy Hara consists of an archipelago located West of Antsiranana town (or

Diego Suarez), the capital of Diana Region, between Cap Sébastien to the South and Cap Ambre to the North. The archipelago stretches within four rural Communes.

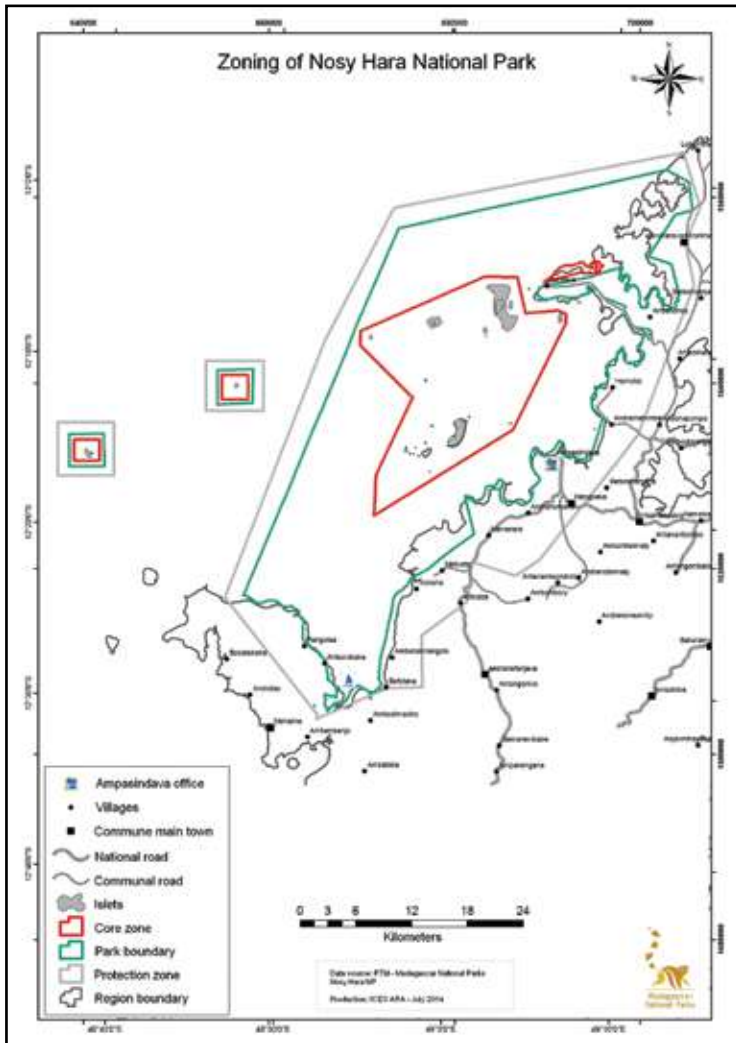
This MPA covers 125,471 hectares and is divided into three zones: the core zone (32,310 hectares), buffer zone (93,161 hectares), and service area (10 hectares) (Figure 1). Nosy Hara habitats include karst and basaltic islets, coral reefs, sand banks, mangrove forests, dry forests, rocky

Nosy Hara biodiversity



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Figure 1: Zoning map of Nosy Hara National Park



Coastal erosion due to sea level rise



coasts, beaches, savannah and open sea, all hosting a rich and unique biodiversity (MNP, 2010). Nosy Hara coral reefs are among the most intact in Madagascar and the wider Northern Mozambique Channel area. The marine biodiversity surveys in northwest Madagascar, which were led by Conservation International in 2002, confirmed the outstanding value of the sites in that region (McKenna and Allen, 2005). In addition to being an area of high ecological significance, the archipelago's natural resources ensure the livelihoods of local communities who are dependent on subsistence fishing and farming. Nosy Hara was awarded its definitive status as an MPA in 2011 (IUCN PA Management Category II).

Coastal areas of Madagascar are home to 40% of inhabitants (PNUE, 2004). Apart from pressures such as pollution and degradation of river basins and poorly regulated exploitation of natural resources, these areas and communities have more recently been affected by climate change. According to the IPCC (2007), for coastal systems and lowland zones, expected climate-related changes are composed of: a sea level rise from 0.2 to 0.6 m or more by 2100, a gradual sea surface temperature increase of 1 to 3°C, tropical and extra-tropical cyclones of increasing intensity, more frequent extreme waves and storms events, a modification in the rainfall (distribution and quantity), and ocean acidification. In Nosy Hara, strong winds, which make traditional fishing difficult, now occur during about 8 months of the year in Nosy Hara archipelago, whereas it used to be 5 months in the past. In the village of Fararano (village surrounding the MPA), which is strongly affected by sea level rise and coastal erosion, local people are already considering moving to a location at higher elevation (Ralison *et al.*, 2011).

It is widely recognized that protected areas play an important role in supporting ecosystems and human communities in adapting to climate change (Dudley *et al.*, 2010). WWF and Madagascar National Parks jointly established a MPA in Nosy Hara archipelago in 2004. Work on climate change issues started in 2007 addressing the following issues:

- Lack of climate change related knowledge among MPA staff;
- Lack of consideration of climate change issues in the marine protected area management, potentially exposing highly resilient areas to harmful use due to limited protection, making ecosystems, species and local communities more vulnerable;
- Absence of long-term local climate data;
- Heavy reliance on small-scale fishery and traditional agriculture by local population, with low resilience to adverse impacts of CC on these livelihood activities;
- Lack of appropriate strategy to address both human pressures and CC impacts.

The work in Nosy Hara has been implemented in two phases. From 2008 to 2010, WWF and MNP have secured funds from the MacArthur Foundation for a project to develop a resilient MPA in Madagascar. The second phase is financed by the European Union from 2011 until 2015, as part of their funding for implementing Climate Adaptation Strategies in the World's Most Outstanding Natural Places. Nosy Hara is one of two pilot sites for this second phase in Madagascar.

2. Methodology

WWF identified three challenges that must be overcome for effective conservation in coastal and marine areas: (i) MPAs should be a part of a broader sustainable resource management system; (ii) climate change impacts appear to be emerging already and can be anticipated to increase in future, thus requiring a flexible, adaptive approach to MPA and marine natural resources management; and (iii) long-term financial sustainability remains an elusive goal for all PAs in Madagascar. In 2008, Nosy Hara was one of the newly created MPAs in Madagascar, and marine and coastal ecosystems were still relatively little understood at this time. WWF and MNP have therefore combined their efforts to identify, test and implement new and flexible management designs with considerations of climate change issues.

Blue Solutions are believed to be comprised of distinct components or 'building blocks', which can potentially be replicated. Building blocks may be adapted

and recombined with others to address specific challenges in other socio-cultural, ecological, political or economic contexts, sectors, or geographies.

The following steps have been identified as 'building blocks':

2.1 Capacity building for MPA field staff

Knowing that climate change impacts could jeopardize conservation efforts of – and long-term benefits from – the MPA, WWF has provided climate change related capacity building to MNP field staff, with the aim of updating their management tools by enhancing knowledge on climate change key concepts and potential impacts for coastal and marine areas. Practical training tools and materials are required. MPA managers were trained to conduct reef resilience surveys, involving the IUCN Climate Change and Coral Reefs working group (<http://cms.iucn.org/cccr>), led by CORDIO East Africa (Obura, 2009). This IUCN working group outlined a series of protocols to quantify basic resistance and resilience indicators for coral reef assessments. This particularly helps in monitoring the effects of sea temperature rise on coral reefs, incidences of coral bleaching and the effects of climate change on small-scale fishing. All initiatives on climate change adaptation (CCA) should start with capacity building to ensure a common understanding of climate change concepts by MPA managers, allowing them to apprehend its direct impacts to biodiversity and livelihoods and its interaction with existing threats. Capacity building allows putting in place appropriate management tools and strategy that helps to build a resilient MPA. Any training tools should consider the local community education level as their involvement in the MPA management is key.

2.2 Use of a participatory tool – Climate Witness Community Toolkit

WWF Fiji has developed a participatory Climate Witness Community Toolkit, which allows the documentation of local impacts of climate change and to devise appropriate adaptation measures that local communities can implement themselves (WWF, 2009). It includes several participatory exercises: mapping, seasonal calendar, community timeline and plant and animal inventory. Based on these tools, the community is asked to identify changes

that have occurred over the last 5, 10, 20 years and beyond. The community discussion will allow for identifying the key problems with the main causes – particularly those linked to climate change – and adaptation options to address them. The final outcome is a community action plan describing the priority adaptation options that should be implemented. The toolkit has been used so far in 10 communities that are adjacent to the Nosy Hara MPA, and the information gathered proved to be highly valuable. Relying on community knowledge, this tool mainly helps to address the lack of long-term climate data and its impacts on livelihoods and natural resources, particularly in a country like Madagascar where this kind of data is missing at local level. It also serves as guidance to and complements further quantitative research, especially socio-economic vulnerability assessments.

2.3 Review of management plan to integrate climate change issues

The Nosy Hara MPA management plan has been revised in 2010 in order to consider climate change issues, updating conservation targets¹, reviewing threats, and adjusting MPA strategy and monitoring protocols. Training for MPA managers on CC integration was followed by a technical workshop with MPA managers, experts related to Nosy Hara conservation targets, stakeholders working in the coastal and marine domains and climate change (authorities, NGOs, etc.) and WWF. The methodology used was adapted from criteria developed by Foden *et al.* (2008) on species susceptibility to CC impacts, and on vulnerability criteria for ecosystems developed by WWF (Ralison *et al.*, 2011).

Conducting a vulnerability assessment (VA) is a pre-condition to including CC into an existing management plan. It provides substantial information on how climate change affects the sensitivity and adaptation capacity of each conservation target, how existing threats are exacerbated and what strategy is appropriate. The management plan can also be updated based on existing information if VA information does not exist, and revised progressively in order

¹ Ecosystems: mangroves, coral reefs and seagrasses – Species: marine turtles, water birds and marine mammals.

to minimize current and future climate impacts. For Nosy Hara, VA carried out in 2011 helped to fill this gap and to complete the management plan updating process. Guidance developed by Morrison and Lombana (2011) provided clear steps on how to mainstream climate adaptation into existing conservation plans.

2.4 Conducting the vulnerability assessment

VA was conducted in Nosy Hara from 2011 to 2013 to identify hotspots of climate change vulnerability and adaptation options that help to strengthen and/or maintain the site's resilience. They allow an understanding of the status of bio-ecological and social targets with regards to climate change impacts and give guidance on how to increase their resilience. Community resilience is the ability of a community to resist, absorb, and recover from the effects of hazards in a timely and efficient manner, preserving or restoring its essential basic structures, functions and identity (CARE, 2009). Ecological resilience can be defined as the capability of a system to undergo, absorb and respond to change and recover in maintaining its structure and functions (Carpenter & Gunderson, 2001). According to the IPCC definition (2007), vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. It is a function of the character, magnitude, rate of climate change and variation to which a system is exposed, and the sensitivity and adaptive capacity of that system.

The assessments were focused on MPA conservation targets as identified in the Nosy Hara management plan, including climate, mangroves, coral reefs, traditional fisheries, seabirds, marine turtles and socio-economic aspects. They were guided by multi-expert and multi-partners processes and carried out respectively with the Meteorology Department, Association Reniala, Blue Ventures, The Peregrine Fund, marine turtle and socio-economic experts. Based on the IPCC's definition, methodologies used in Nosy Hara were mainly focused on the combination of these three elements (exposure, sensitivity and adaptive capacity). Particularly for coral reefs, a renowned methodology on resilience assessment developed by

Community workshop, using Climate Witness Community Toolkit



Obura & Grimsditch (2009) was used. For mangroves, the VA manual developed by Ellison (2012) with WWF was applied.

In order to understand the overall vulnerability of the MPA, links and synergies between the vulnerability assessments of each target should be established. A common scale is therefore needed in order to produce an overall MPA vulnerability map and particularly to identify the most vulnerable area within the MPA that merits particular attention. On the other hand, this work has allowed establishing the first group of experts on multi-target VA methodology for MPAs, which could be applied in other MPAs in Madagascar and beyond.

2.5 Identifying and prioritizing adaptation options

Implementing environmentally sound adaptation will lead to measurably reduced vulnerability, improved resilience to future changes and enhanced well-being (Bizikova *et al.*, 2009). Therefore, identification of adaptation options must be built on the outcomes of VA. For Nosy Hara, this identification process was conducted in three steps: experts' discussion to identify a long list of adaptation options, MPA stakeholders' workshop to prioritize this list and meetings with villages to validate the key adaptation measure to be implemented.

A new methodology² for prioritizing possible adaptation options was developed and tested in Nosy Hara using four criteria: the range of benefits that the adaptation option provides, opportunities that enable its implementation, required costs for its implementation and risks. Adaptation measures providing multi-benefits, supported by several opportunities, lowest implementation cost and lowest associated risks were prioritized. Key lessons learnt in identifying adaptation options are mainly:

- Participants should have at least a basic knowledge on CCA to be able to better participate in the selection of right adaptation options.
- A sound understanding of the four criteria, their meaning, ranges and significance, by the participants before the prioritizing process is needed in order to avoid bias during the scoring exercise and to ensure they have the same level of understanding.
- Existing development and conservation initiatives in the area must be identified ahead to avoid redundancy of activities and to ensure complementarity with existing work that will lower the cost.

² Developed by WWF International, Colombia, Madagascar and Philippines and experts from Equilibrium Research under the project 'Implementing Climate Adaptation Strategies in the World's Most Outstanding Natural Places' through European Union Funding.

The priority adaptation options identified for Nosy Hara include establishment of a nursery for marine turtles, mangrove restoration taking into account resilient areas which will support their role as coastal protection and as bird habitat, and temporary closure of fishing areas where coral reefs are still resilient or start to be at risk. For local communities, these are: improved fishing activities (particularly due to the wind pattern changes) and the establishment of a crab fishery reserve as a new activity in the park. In addition, other alternative livelihoods were also identified such as building water supplies (mainly for domestic use and improved farming techniques), sheep and goat rearing and promoting climate-resilient crops. For each selected adaptation option, a monitoring system has been established in order to track its contribution in reducing climate change impacts on social and ecological targets, to take action in time if adjustment is needed during its implementation and to evaluate its impact on beneficiaries.

3. Results

Nosy Hara is a first initiative where climate change has been integrated into the management approach in Madagascar. Since experience in this field is limited in the country, a 'learning by doing' approach, supported by technical advice from international experts, has been adopted. The key achievements to date in Nosy Hara in the light of CCA work are: training of MPA managers and coastal and marine stakeholders, preliminary revision of Nosy Hara management tools, development of VA and adaptation methodologies for an MPA, carrying out VA of conservation targets and local communities, and identification of adaptation options that will help to increase ecological and social resilience. New conservation targets and threats have been identified. Sandy karst islets have been included into Nosy conservation targets as these constitute important nesting areas for marine turtles. Sea level rise, increased sea surface temperature, ocean acidification and frequency of cyclone are the new added threats. These factors mainly affect coral reefs and mangroves (Ralison *et al.*, 2011).

VAs conducted from 2011 onwards showed that coral reefs in the marine park appear to be recovering. They are largely restricted to the edges of the islets and

the mainland coastal area, and cover an area of approximately 7,000 ha (MNP, 2010). There has not been any significant disturbance to the reefs of Nosy Hara during the last five years and they are unlikely to have been significantly impacted by a bleaching event. High resilience means high levels of hard coral cover and low levels of fishing pressure. Coral reefs in the Nosy Hara Marine Park showed a high coral cover for the Western Indian Ocean, with levels of 34% (Obura and Grimsditch, 2009) and ranked between 2 and 3³ (Gough, 2012). However, fish populations are exhibiting signs of overexploitation and were dominated by fish <10 cm in length (Gough, 2012). As per the definition of 'resilience', this situation could compromise the ability of these reefs to recover in the future. As adaptation options, temporary fishing closures will help to maintain resilient reefs. Given that Nosy Hara's coral reefs are proven to be resilient to climate change, their preservation is crucial for the sustainability of fisheries activities and coastal protection in this region. These resilient reefs will also increase nature's defence capacity and protect coastal communities against hazards. Meta-analyses reveal that coral reefs provide substantial protection against natural hazards by reducing wave energy by an average of 97%. They can provide comparable wave attenuation benefits as artificial defences such as breakwaters, and reef defences can be enhanced cost effectively (Ferrario *et al.*, 2014).

Mangroves as well play a critical role in the ecology of the coastal environment. Mangroves are widely spread along the coast and cover approximately 3,500 ha. High level of vulnerability has been observed where stands have been significantly degraded. Where mangroves are little degraded, their resilience and adaptive capacity are high and vulnerability is low. This applies to all mangrove types that were examined in Nosy Hara (WWF, 2013). Mangrove planting was selected among the priority adaptation options, as it contributes to restoration of degraded areas with consideration of future climate conditions as well as to extension of their current surface with regards to inland migration. It will be very important to support fisheries activities from mangroves

and to ensure coastal protection for local communities living along this ecosystem (UNEP-WCMC, 2006). Mangroves also have an important role in protecting coasts during storm and tsunami events, both by frictional reduction of wave energy and by promoting sedimentary resilience to erosion through the root mat (Ellison, 2012). Considering the relatively small area that is under mangrove cover in the MPA, they play a prominent role in mitigating disaster risks for part of the coastal communities only, rather than for the whole area (6 villages out of 13). The main cause of concern may also be the vulnerability of seabirds and marine turtles, as their nesting sites face compounded threats from both climatic and non-climatic factors. At the very least, these threats need to be monitored closely and appropriate measures taken (WWF, 2013).

According to social VA conducted in 2012 (WWF, 2013), local communities in Nosy Hara depend heavily on marine resources from the MPA and on agriculture. Their relatively low degree of adaptation merits particular attention. As an example, dependence on wood harvesting in mangroves is high. Drought and wind have been the main climate stressors affecting community activities, impacting agriculture and fishing respectively. Wind vulnerability is moderate except where reef and open sea fishing are dominating sectors. The relatively high vulnerability to drought is a significant concern, but is likely not insurmountable if communities could implement potentially viable alternatives. Due to the prolonged wind and drought, the two main livelihood activities are not sufficient to support their daily income. Resilient alternative livelihoods will be promoted (building water supplies, sheep and goat rearing and promoting climate-resilient crops) to help them adapt to climate change based on support from the project implemented by WWF and MNP. These new activities will allow the communities' to increase their adaptive capacity (by diversifying their source of income) and decrease their high dependency on the use of natural resources.

In summary, the following results can be seen as immediate consequences and/or long-term impacts of climate change integration into MPA management:

³ High resilience=5, low resilience=0

- Improvement of MPA manager skills and understanding of climate change issues and their links with 'business as usual' work;
- Better knowledge of the status of conservation targets (species and ecosystems) and their level of vulnerability and resilience;
- Shifting status of key conservation targets from low resilience to medium or high resilience through the implementation of adaptation options;
- Better knowledge of changes in weather patterns and adaptation actions taken by the community;
- Improvement of local communities' adaptive capacity leading to an increase of their resilience through the implementation of climate-smart alternative livelihoods;
- Climate threats and their drivers well addressed in the MPA management tools;
- Gathering local climate information and its impacts on human and natural systems through a rigorous monitoring system;
- Updated version of Nosy Hara management plan that fully integrates climate change issues;
- Increased awareness of climate change and the relevance of marine protected areas in adaptation among practitioners and local communities; both in the project area and beyond, through the experiences and results of this initiative.

4. Discussion

WWF recognizes the vital links that exist between ecosystems and human populations and aims to optimize the role of natural systems for adaptation, applying an ecosystem based adaptation (EbA) approach. This contributes to reducing vulnerability and increasing resilience to both climate and non-climate risks and provides multiple benefits to society and the environment (Colls *et al.*, 2009). EbA is often more cost effective and more readily accepted and understood by local communities than other types of adaptation measures (Colls *et al.*, 2009). Protected, well-managed ecosystems can buffer against many flood and tidal events and storms (Dudley *et al.*, 2010). Therefore, flexible adaptive management should be applied, which means progressively reviewing PA management tools in order to

address any emerging challenges (climate change, DRR⁴ concerns, etc.). Alternatives livelihoods that do not rely directly on the use of goods and services are also key to supporting an EbA approach. It contributes to reducing dependency of local communities on the use of coastal and marine resources, and increasing their adaptive capacity to climate change.

The main challenges encountered during the climate change adaptation work in Nosy Hara are summarized as follows:

- Low technical capacity and knowledge on adaptation, considering that CC is a relatively new and complex phenomenon.
- Distinguishing anthropogenic pressures from climate change impacts. Both threats need to be addressed simultaneously given that CC could be a direct threat and/or exacerbates existing threats to social and ecological targets.
- Lack of historical data and information on climate change impacts on species and ecosystems, which made the VA and the revision of the management plan challenging, as there is a need to have information reflecting changes over time. Development of locally relevant methodology given that there was no standardized methodology for vulnerability assessments.
- Communicating climate change issues to local people has proved challenging. Even though they do not need to understand the scientific aspects of CC, they should be aware that changes happen and need to be addressed.
- Defining the right approach to integrate CC into existing PA management tools.
- Showing the link between adaptation and the work MPA managers are doing, and stressing how adaptation differs from their regular activities.

The approach has proved largely successful, based on the following factors, which should be considered in replication of the process:

- Regular capacity building on CCA for MPA managers and key stakeholders which helps them to understand the practical sense of adaptation and how it can be integrated into business as

usual work.

- Support from experts to ensure homogenization of the approach particularly across the region and credibility of the results.
- Using traditional knowledge to capture climate evolution and its impacts which can complement lack of historical data.
- Involvement of local communities during the whole adaptation process, which reinforces their ownership and is also a contributing factor to the success of adaptation work.
- Consideration of climate and non-climate factors in all vulnerability analysis especially in a country like Madagascar where communities' livelihood dependency on natural resources is very high.
- Use of standardized analysis tools which will facilitate cross-referencing of individual assessments, the identification of complementary results and comparisons between study sites in Madagascar and elsewhere.
- The prior existence of an operational management body with good relations to the local community.
- Implementation of this pilot process in a well-established protected area well rooted in the national protected area system and in a sufficiently large MPA.
- Progressive updating of PA management tools according to existing competencies and information which allow minimizing climate impacts and maintaining resilient areas.

5. Conclusion

Climate change is already affecting marine and coastal areas and could compromise the long term use of goods and services provided by MPAs. Nosy Hara is among the first MPAs in Madagascar demonstrating how to strengthen MPA resilience and its vital role for adaptation. Developing resilient MPAs is therefore crucial in order to help biodiversity and people to adapt to current and future climate change. The integration of climate change into the management of Nosy Hara has shown the way to build MPA resilience. Consideration of climate change does not only allow to quickly address current effects but also to respond to expected future impacts (Ralison *et al.*, 2011). It creates the need for better integrated approaches of conservation and development that benefit both sides.

⁴ Disaster Risk Reduction.

The main 'building blocks' for developing a resilient MPA are regular capacity building, developing climate information, conducting vulnerability assessments using credible methodology and traditional knowledge, implementing adaptation options that differ from 'business as usual' work, putting in place sound monitoring and relying on flexible management tools that can address any emerging challenges. It can also be concluded that EbA is not a stand-alone approach, but should be combined with development of alternative livelihoods that do not use goods and services provided by the PA.

The pilot approaches from Nosy Hara are the foundation to later ensure application of climate change adapted MPA management throughout the country, both in existing and new PAs, by integration into the Madagascar Protected Area Network Framework (known as 'Système des Aires Protégées de Madagascar – SAPM'). The next step is the establishment of a rigorous monitoring system (bio-ecological, socio-economic and climate protocols) to

better track local climate change impacts, adjust ongoing vulnerability assessments and adaptation strategies as well as management tools. Marine and climate stations will be set up in the MPA to track local climate data and its impacts on biodiversity and people. Priority selected adaptation options will be implemented from 2014 onwards. Considering new information gathered from the last VA, the Nosy Hara management plan should be reviewed.

In summary, protected areas are increasingly recognized as an adaptation tool to support nature and people in adapting to climate change. They also play a vital role in reducing disaster risk. Given that both impacts are rising and are closely interlinked (UNISDR, 2008), the need for coherent responses is increasingly evident (Shamsuddoha *et al.*, 2013). Strong linkages between them should be established, addressing both shared and specific issues. To better incorporate DRR and CCA principles in Nosy Hara MPA management, larger areas need to

be surveyed, including those outside the MPA, to ensure adequate protection of highly resilient reef areas by the MPA's zoning system. Refugia, which are places where favourable habitat will persist or develop as the climate changes (Taylor *et al.*, 2007), need to be identified and protected. The Nosy Hara management plan should consider the establishment of an early warning system that will help MPA managers and local communities to better address hazards and minimize loss and damages. In spite of the adverse impacts caused by CC, some opportunities can occur, providing benefits to natural and human systems.

This work helps to raise the profile of marine protected areas in climate change adaptation in Madagascar. By partnering with WWF and MNP, IUCN will share learning and experiences from Nosy Hara through various communication channels being developed by the Blue Solutions initiative, promoting them for replication in other parts of the region and beyond.

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Related links

- Blue Solutions: Pioneering the thinking about climate change adapted MPA management in Madagascar
<http://bluesolutions.info/climate-change-adapted-mpa-management-madagascar/>
- Video WWF: Nosy Hara - Jewel of the Western Indian Ocean
<http://www.youtube.com/watch?v=kGnwiw9l9f8>
- WWF: Marine park bolsters community facing climate change
<http://wwf.panda.org/?199906/madagascar-nosy-hara-mpa>
- WWF: Climate Witness Community Toolkit (download):
<http://wwf.panda.org/?uNewsID=162722>

Related publications

- Ralison, H.O., Rakotondrazafy, H.H., Leone, M. and Rakoto Ratsimba, H. *et al*, (2011). *Aires Marines Protégées et Changement Climatique Les expériences du Parc National Marin Nosy Hara*. WWF.
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About Blue Solutions

Blue Solutions are demonstrated, scalable approaches that inspire and facilitate action towards healthy and productive marine and coastal ecosystems. The Blue Solutions Initiative is implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), in direct partnership with GRID-Arendal, the International Union for Conservation of Nature (IUCN) and the United Nations Environment Programme (UNEP). It is funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) through its International Climate Initiative (ICI).

www.bluesolutions.info

About Madagascar National Parks

Madagascar National Parks is a Malagasy association mandated by the State in 1991 to manage Madagascar protected areas. Initially called Association Nationale pour la Gestion des Aires Protégées (ANGAP), it adopted its current name in 2008 in parallel with the tripling of the country's protected areas surface area within the Durban Vision (2003).

MNP still holds the State mandate for the management of 52 protected areas composed only of strict nature reserves, national parks and special reserves (categories I, II and IV according to the IUCN categorization). These 52 PAs represent a total area of 2.8 million ha or a third of the country's PAs that is almost 5% of the national territory. MNP has a strategic plan which serves as a guide to all stakeholders in achieving their vision. This plan is composed of four major themes which are conservation, co-management, management and priority markets.

www.parcs-madagascar.com

About WWF Madagascar Country Office

Starting with our first programme in 1963 to protect the aye-aye lemur, WWF has been one of the leading conservation organizations in Madagascar for the past 50 years. Originally, our activities were focused on research and training. This focus gradually expanded into an extensive and comprehensive programme of conservation, education and capacity building. An office was established in Antananarivo in 1979 and an official agreement between the Malagasy Government and WWF was signed in 1996. We know that strong partnerships with local authorities and communities are a key to our success. That's why we work with local partners to implement our conservation strategy in our priority landscapes. WWF Madagascar has been working on climate change adaptation since 2007.

www.wwf.mg

Chapter 10

Potential roles for coastal protected areas in disaster risk reduction and climate change adaptation: a case study of dune management in Christchurch, New Zealand

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Abstract

Dunes provide a range of benefits for coastal hazard management. This includes protection from erosion, inundation, and storm surge events, and may include disaster risk reduction benefits in large magnitude events. However, New Zealand's coastal dune ecosystems have become heavily modified in recent decades and the space available for dunes has become severely restricted in many areas. The restoration and protective management of indigenous dune ecosystems is now an urgent conservation issue.

Since plant communities influence dune form and dynamics, the protection of dune biodiversity is important to their coastal hazard management role. The management of dunes as Protected Areas is now a common approach and can be especially important in locations where development and land use patterns have encroached on the space available for dunes, or where intensive management responses to other threats are required.

There are now many examples of dune restoration projects at sites where former dunes had largely disappeared, or where the dune plant community has been impacted by invasive species. These projects provide opportunities to assess the potential for protected area management to deliver benefits for coastal hazard management within an integrated approach to coastal management. Additionally, forward planning for the adaptive management of coastlines is needed in the context of predicted sea

level rise, and includes consideration of the values of protected areas and the future roles they may play. This case study presents results from an example of restorative dune management within the Christchurch Coastal Park network with a focus on the potential roles of these parks in disaster risk reduction and adaptation to climate change.

1. Introduction

1.1 Disaster risk reduction as an aspect of coastal management

International evidence suggests that a variety of disaster risk reduction benefits could be generated from targeted management of coastal protected areas. The disaster risk focus implies that there may be benefits additional to direct coastal protection functions, for example whereby the impacts of a large magnitude event might be reduced by natural ecosystems in the coastal zone (Noguchi *et al.*, 2012; PEDRR, 2010; Shaw *et al.*, 2012). It follows that the risk reduction perspective involves consideration of the relative benefits of various mitigation measures against both repeat and extreme events.

The need for strategies, planning and implementation of mitigation measures for coastal hazards and climate change is well documented at the national level (e.g. Department of Conservation, 2010; Ministry for the Environment, 2001, 2008). This is reflected at the regional level in documents such as climate change and coastal strategies and in Regional Policy Statements. There has also been

some research on processes for coastal adaptation in New Zealand (e.g. Britton, 2010; NIWA, 2011) and elsewhere (e.g. Kay & Travers, 2008; Klein *et al.*, 1999). However it is important to note that climate change adaptation considerations extend to managing effects on the natural ecosystems themselves; a subject which has received considerably less attention. Within this context it is timely to consider the existing and potential role of natural ecosystems and coastal protected areas alongside the other mitigation and adaptation measures available.

1.2 Coastal dune ecosystems in New Zealand

Coastal dune ecosystems in New Zealand have been heavily affected by human activities as is common worldwide (Nordstrom, 1994). They are among the most modified of all New Zealand ecosystems having undergone major decline since the arrival of humans (Dahm *et al.*, 2005; Hesp, 2000, 2001). The area occupied by dunes is now drastically reduced (Hilton, 2006) and in most places where the underlying landform persists there have been significant changes to the vegetation, morphology, and dynamics of dune systems (Cockayne, 1909, 1911; Dahm *et al.*, 2005; Hilton *et al.*, 2000). Both active and stable sand dunes were recently rated as 'endangered' against the IUCN Red List criteria for ecosystems (Holdaway *et al.*, 2012).

In addition to their conservation values dunes provide protective functions for coastal communities that may be expected to become more important with current

predictions of sea level rise (Dahm *et al.* 2005; Spence *et al.* 2007). As described by Carter (1991, p38), dunes also serve as 'natural, front-rank coastal defences'.

1.3 Case study: management of dune ecosystems in Christchurch's coastal parks

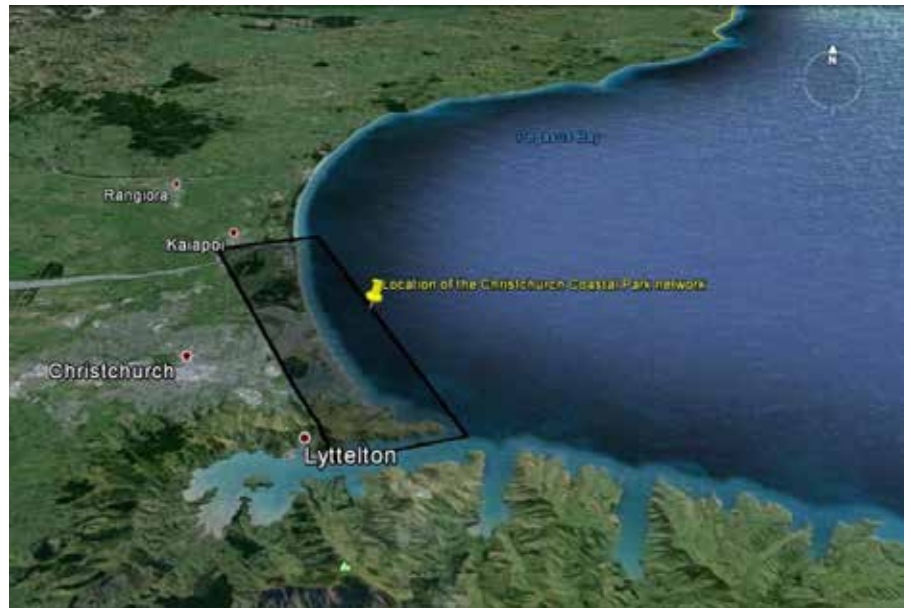
The focus of this case study is the coastal parks of Christchurch, New Zealand. These coastal parks are a network of protected areas owned and managed by Christchurch City Council (CCC) on behalf of the community. There are other similar examples of coastal parks under the control of local authorities throughout New Zealand, and these include many examples where beach and active sand dune systems are the underlying landform.

Christchurch is located in the southern corner of Pegasus Bay, a large sandy bay covering 54 km of coastline on the South Island's east coast (Hicks, 1993). This part of Pegasus Bay is characterized by fine sediments forming sandy beaches, with an increased proportion of larger grained sediments found on beaches to the north (Allan *et al.*, 1999; Hicks, 1993; Kirk, 1979). The Christchurch coastal park network consists of 12 parks which together stretch across most of the City's east facing Pacific Ocean coastline (Figure 1).

In terms of the IUCN WCPA definition of Protected Areas these coastal parks can be characterized as Category IV. As detailed by Dudley (2008), Category IV are protected areas sufficient to maintain particular habitats and/or species, and are often fragmented ecosystems that may not be self-sustaining without active management interventions. In addition, Category IV protected areas will generally be publicly accessible and often involve management of areas that have already undergone substantial modification and/or require protection of remaining fragments. All of these conditions are found in the Christchurch Coastal Parks.

These parks are managed by the CCC Parks and Waterways Unit under the Christchurch Beaches and Coastal Parks Management Plan 1995, and guided by the Coastal Parks Strategy 2000-2010 (CCC, 1995; CCC, 2000) in addition to individual management plans in some cases. The Coastal Parks Strategy 2000-

Figure 1: Overview map showing the location of the Christchurch coastal park network



2010 details the purpose and priorities for management of these parks (Table 1). The protection of ecological values and the management of sand are key aspects. As is discussed below, both topics are important to the potential disaster risk reduction benefits of these parks.

Since the Coastal Parks Strategy 2000-2010 was written Christchurch has experienced a sequence of major earthquakes including the catastrophic 6.3 magnitude quake of 22 February 2011 which killed 185 people. The earthquake sequence began on 4 September 2010 with a 7.1 magnitude quake centred 40

Table 1: Management priorities for Christchurch's Coastal Parks. Adapted from CCC (2000).

- Ecological protection, enhancement and restoration
 - Native planting
 - Weed and pest control
 - Habitat enhancement
- Planting focus on high use areas
 - Native plants
 - Exotic plants for use as feature trees, shade trees and amenity plants
- Sand management for coastal protection to include the planting of sandbinding and native species
 - Development of back dunes to include picnic areas and walkways
- Walkways
 - Linking of natural areas, and loop walks
 - Improved access for pedestrians and wheelchairs
- Picnic areas
 - Walkways to include more picnic areas
 - In high use areas, more facilities such as barbeques, showers, drinking fountains, and shade trees
- Signs and education
 - More signs depicting interpretive and walkway information
 - More coastal education to encourage better care and respect for the environment
- Other
 - Complete existing landscaping projects
 - Further investigation to support the construction of an artificial surf reef
 - Improved maintenance and rubbish reduction
 - Improved dog control

km west of the city and has included many other large quakes including a second 6.3 magnitude quake centred close to the city on 13 June 2011. In addition to loss of life the earthquakes have caused severe damage to infrastructure, property and land. Total repair costs are predicted to be in excess of NZ\$ 40 billion being New Zealand's costliest natural disaster and complete economic recovery is not expected for 50 to 100 years. Although there was little direct damage to beaches, earthquake damage included widespread settlement of land in the east of the city that has resulted in greater vulnerability to flooding, coastal inundation and storm surge events (Figure 2).

These circumstances have contributed to a greater awareness of natural hazard management issues in the post-quake landscape, including greater attention to the potential effects of sea level rise. A recent report which documented key

issues for responding to sea level rise recommended that Christchurch prepare a Sea Level Rise Adaptation Strategy as a priority matter (Tonkin & Taylor, 2013). Questions around the maintenance and potential functions of coastal parks are especially relevant and include consideration of disaster risk reduction concepts (Estrella *et al.*, 2013; PEDRR, 2010; Shaw *et al.*, 2012).

1.4 Clifton Beach study site

The coastal park referred to in this case study is situated to the south of the Avon-Heathcote Estuary outlet where there are two beaches either side of a prominent local landmark known as Cave Rock or Tuawera. The beach to the northwest is known as Clifton Beach (Figure 3) and further to the south is Scarborough Beach (see Figure 4).

Studies have shown that the beach profile at Clifton Beach has typically been

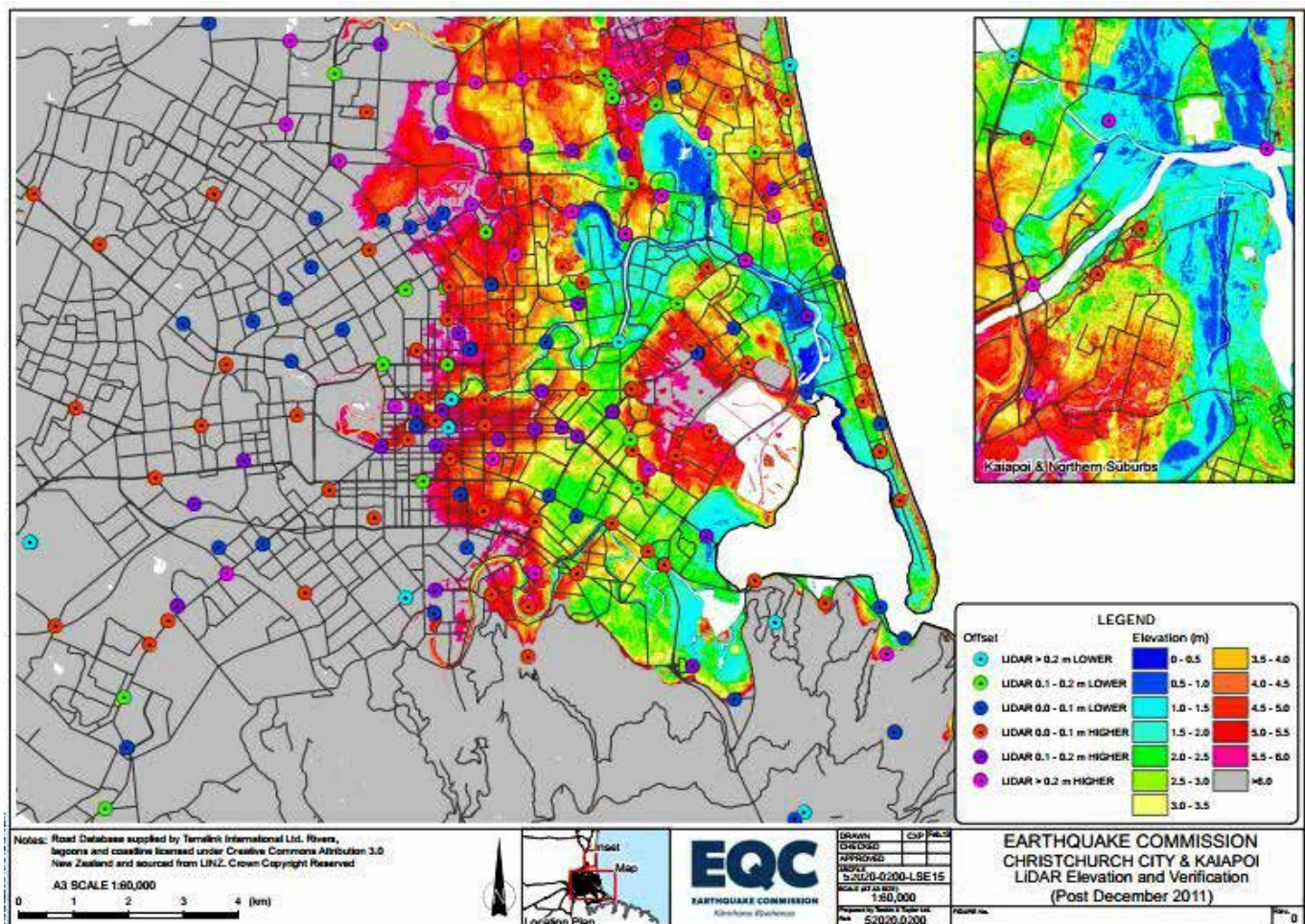
variable, as can be expected due to influences from the nearby estuary outlet (Cope *et al.*, 1998). However, a sandy beach environment has been consistently present (Findlay & Kirk, 1988; Kirk 1979; Macpherson, 1978). Historical records show that the beach was backed with sand dunes until the late 1800s. Since then progressive developments, and the construction of hard defences for the protection of infrastructure, have led to degradation of the dune system (Findlay & Kirk, 1988).

2. Methodology

2.1 Background

The current focus on restorative management of the dune ecosystem at Clifton Beach represents a substantial change in the management of the coastal park from its former state. For several decades the site was characterized by a depleted dune system with limited

Figure 2: Recent imagery showing the low lying eastern suburbs and ground level changes resulting from the Canterbury earthquakes.



Source: Earthquake Commission.

Figure 3: Clifton Beach at Sumner, Christchurch, showing the coastal park area currently being restored.



Figure 4: Historical photo of Clifton and Scarborough beaches either side of Cave Rock / Tuawera ca.1895 showing some of the early infrastructure developed in the coastal zone. The tramway no longer exists.



vegetation. This was accompanied by substantial wind erosion which frequently led to sand being deposited on nearby roads and otherwise lost from the active beach system. In some parts of the beach dunes were completely absent and at times there was no physical barrier between high seas and local roads.

The success of various methods for the restoration of dune ecosystems in New Zealand has been generally well researched and will not be covered in detail here. A key aspect is that appropriate sand binding species are critical for the natural repair process on the seaward face of dunes following storm events (Given, 1981). Although a variety of species

have been used to stabilize dunes the indigenous sand-binding species (Figure 5) are now regarded as being the preferred option in New Zealand (Bergin, 2008; Bergin & Kimberley, 1999; Bergin *et al.*, 1997, 1999; Dahm *et al.*, 2005; Unsworth *et al.*, 2003). Marram Grass has been used worldwide and proven successful in stabilizing areas of unstable sand, but creates steep parabolic dunes that are prone to wind erosion and blow outs (Gadgil, 2002; Hilton *et al.*, 2005).

An important aspect for management is the perception that a community-based approach is beneficial for the restoration and ongoing maintenance of coastal dunes (Dahm *et al.*, 2005; Dahm & Spence, 1997; Fagan *et al.*, 1997; Jenks, 2005). Reasons for this include promoting increased community awareness and/or participation with dune management projects, and instilling a dune care ethic to assist the human behaviour change often necessary to achieve long-term success. An aspect of this is assisting communities to understand the coastal environment's natural processes and dynamics (Dahm *et al.*, 2005).

2.2 Management, restoration, and monitoring activities

Reserve management activities at Clifton Beach are consistent with recommended methods for dune restoration using indigenous species in New Zealand (Bergin & Kimberley, 1999). These methods have been adapted for the local conditions of the site and the resources available to implement them over a realistic timeline (Orchard & London, 2012). They are being progressively implemented to sections of the beach as part of the Sumner Coastcare Project. This is an example of where a partnership has formed between the local community, city council, and other stakeholder organizations interested in improving the values of local coastal parks.

A collaborative and community-based vision for the area was established and management objectives were identified at the scale of the site. These included a specific restoration plan for the dune system at the site, together with a monitoring plan and other initiatives to promote education about the area and the dune restoration initiative. These activities also sit within the wider context of relevant CCC plans and strategies, and the

Figure 5: The indigenous sand binders Spinifex (*Spinifex sericeus*), left, and Pingao (*Ficinia spiralis*), right.



latter are enabling and supportive of the approach being taken. Some of the key management actions for this site are:

Management planning:

- Development of an overarching plan or strategy for the coastal parks confirming objectives for protection and management
- Development of individual management plans to detail specific restoration interventions, long term maintenance, and other aspects of park infrastructure for particular areas

Restorative management:

- Recognizing and supporting the biodiversity values of indigenous ecosystems at these sites. Management objectives include recovery and protection of indigenous plant communities appropriate to these sites using local (eco-sourced) varieties
- Ensuring sufficient maintenance resources are available to address ongoing threats to the park and its values (including to newly restored areas)
- Keeping the community involved and informed about the site

The availability and enthusiasm of volunteers within the community (both individuals and groups) has been a key aspect of the restorative management process. Implementation of a regular maintenance programme to help ensure the establishment and survival of new dune vegetation and coastal forest is one aspect where community participation has been especially useful.

For this site a monitoring programme was developed to measure the success

of the key actions and provide useful information for future management decisions. Monitoring is undertaken biannually and consists of dune profiles along fixed transects, vegetation plots, and photo-points. In addition, a survey of public perception on support for restoring and protecting the dune ecosystem at the site was conducted in 2012 (Anderson *et al.*, 2012). A quantitative approach was employed using a questionnaire distributed around the local Sumner area and to people using recreational areas along the coastline. A total of 160 responses were received. The questionnaire identified perceptions on the status quo management of the coastal area and preferences towards five foreshore development proposals which had previously received media coverage within the community. Focus groups were also organized with recreational users of the area and local Sumner residents to provide additional information on attitudes to foreshore management and potential developments.

Figure 6: The east end of Clifton Beach in 2003 at the time dune restoration was first initiated (left) and at December 2013 (right). Note that before the change in management the level of the road was higher than the level of the beach and there were no protective dunes present.



The change in management towards restoration of indigenous plant communities in the coastal park creates an opportunity to measure changes in other attributes of the site that may be useful to objectives such as disaster risk reduction. Relevant research questions include whether specific management interventions (in this case focused on the indigenous plant community) may also offer co-benefits in terms of improved disaster risk reduction benefits relative to previous state. Related questions could include how disaster reduction benefits of dune systems might be maximized at sites such as this where urban infrastructure is in close proximity.

3. Results

The monitoring programme has clearly shown changes in the dune system in response to the new management activities. The most obvious examples are the areas in which dunes had formerly disappeared. Even though the space available for the rebuilding of dunes in this area is very limited, a consistent line of dunes of up to 1.5 m in height above the high tide beach has been achieved providing a protective barrier between local roads and buildings and the sea (Figure 6).

The dune crest is now approximately 1 m above the level of the road. The width of the dune system has also been successfully increased and now is approximately 25 m in this location. This represents a substantial volume of sand that has been trapped within the reserve area through the ecological functions of the restored plant community (Figure 7). Beach nourishment has not been required.

Figure 7: An example dune cross section from the eastern end of Clifton Beach, December 2013, in the same location as the photo-point in Figure 6. The dune height datum is the level of the road.

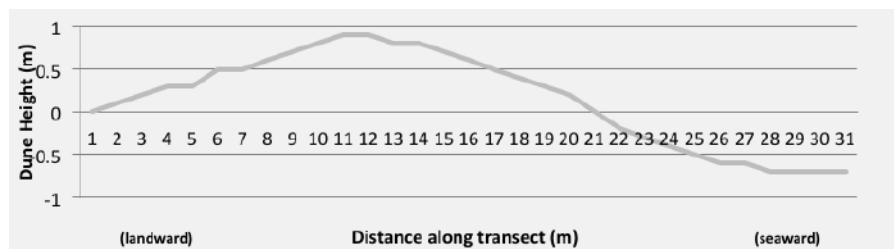


Figure 8: Example of changes in the percentage cover of fore-dune plant species within a 10x20 m monitoring plot over a 1-year period at Clifton Beach with strong Spinifex growth evident.

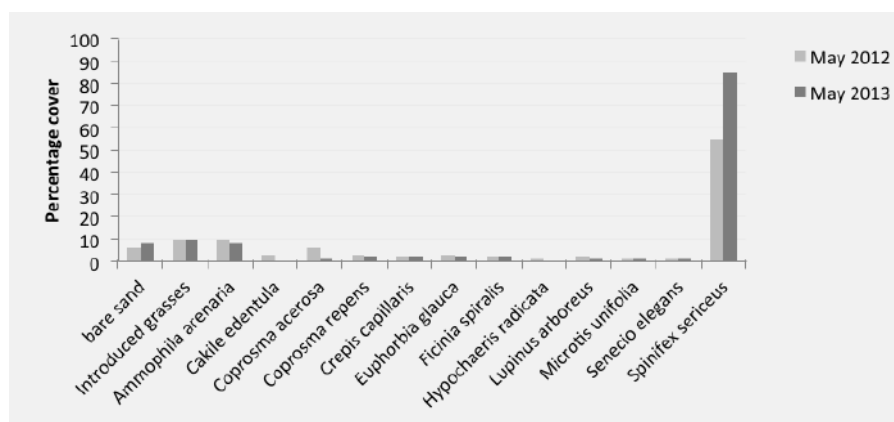


Figure 9: Photo-points taken in December 2011 and May 2013 from the same monitoring plot as Figure 8.



In addition to providing a direct barrier to coastal inundation this sand reservoir may provide some degree of risk reduction benefit in large and repeat events through dissipating wave energy should the sand be washed into the surf zone. The sand trapped in the dune system represents sand that would have otherwise been lost from the active beach system in the local area (Carter, 1980).

Early indications show that the reintroduction of Spinifex has been particularly successful at the site, both in terms of improving indigenous vegetation cover (Figure 8) and extending the current dune system seaward (Figure 9).

The public perception survey revealed considerable support for the change in management towards restoring and protecting the dune ecosystem. Dune restoration was the most popular of the five foreshore development proposals canvassed, followed by re-creation of a high tide beach along the coastline currently protected by a seawall (Figure 10).

These results demonstrate considerable support within the community for the use of natural solutions to coastal protection and foreshore management. This is consistent with other public perception surveys on coastal management options which have found support for soft engineering techniques that help retain the natural values of the coastline (e.g. Polyzos & Minetos, 2007).

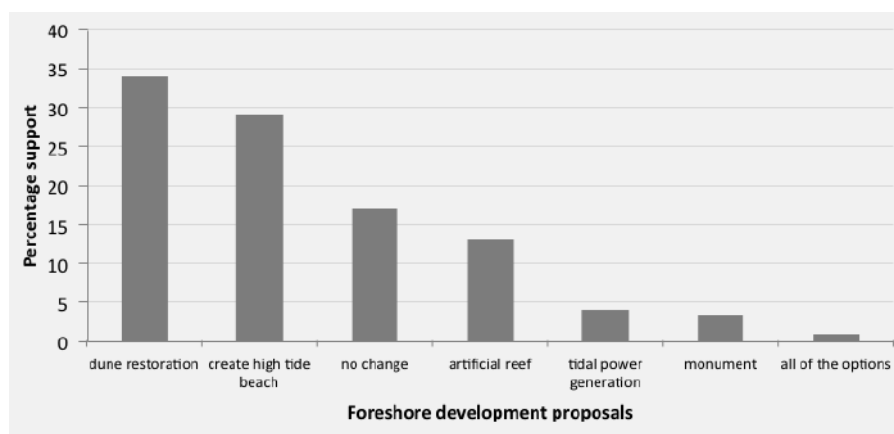
4. Discussion

Results from the Clifton Beach site demonstrate that degraded dunes can be successfully rebuilt through restorative management assisted by protected area status. It is important to note that there have been many similar results already reported in the New Zealand literature (Bergin, 2008; Bergin *et al.*, 1997; Dahm *et al.*, 2005; Jenks & Brake, 2001; Dahm & Spence, 1997).

Additional points of interest related to management of the Clifton Beach site include

- The presence of, or plans for, a variety of amenity developments within or close to the active dune system of the coastal park consistent with being a high usage area. These include a high

Figure 10: Popularity of development types for the Sumner foreshore. (Adapted from Anderson *et al.*, 2012).



- density of formed beach access-ways, a coastal trail, and a surf lifesaving club building and associated infrastructure;
- The presence of urban infrastructure in close proximity to the back-dune area; and
- Variation in the natural landforms which are present behind the active beach and dune system. The west end of the beach is backed by volcanic cliffs whilst at the east there is a considerable coastal plain behind the beach (now occupied by Sumner village).

These circumstances create an excellent opportunity to consider how coastal parks in constrained locations might be used for a variety of purposes and how these can be best integrated to achieve multiple benefits.

4.1 Protected area status and role of coastal vegetation

Current evidence strongly suggests that protected area status is an important aspect of effective management in addition to restoration activities where required. Protection of the plant community is particularly important due to the influence of plant cover on the size and dynamics of the sand reservoir. This includes the critical role of plants in natural dune recovery processes following periodic erosion events (Dahm *et al.*, 2005).

Although the protection of sand binding species is especially important, the potential role of back-dune vegetation and coastal forest should not be overlooked. Although there has been only limited work

on relationships between coastal forest and coastal protection or disaster risk reduction in New Zealand, benefits may include a degree of mitigation against rushing waters and debris flows, and against damage from wind events (Carter, 1991; Dahm *et al.*, 2005; Shaw *et al.*, 2012). In Japan and Sri Lanka, post-disaster studies suggest that a thick swath of coastal vegetation can produce risk reduction benefits in large events such as tsunami. In both countries governmental responses following such events have included recommendations for the re-establishment of protective coastal forests (Figure 11).

In New Zealand the protection and/or recovery of coastal forests is also a highly desirable activity for biodiversity conservation since lowland forest and coastal vegetation types are among the most heavily modified habitats on a national scale (Ministry for the Environment & Department of Conservation, 2007). When considering adaptation to climate change, the role of coastal forests

Figure 11: Example of a coastal forest restoration programme implemented in Sri Lanka following the 2004 tsunami.



could also be important assuming that landward migration of coastal riparian systems will need to occur. In coastal dune environments this is likely to involve a sequence of mobilization and redeposition of sand during storm events. Without suitable conditions sand may be transported further inland and effectively lost from the active beach system, contributing to the progressive depletion of the dune system in that location.

4.2 Spatial considerations for maintaining protected area functions

The above discussion illustrates that spatial considerations are a key management concern. These include the inland extent available for adaptation of coastal protected areas vulnerable to sea level rise. The location and style of development permitted within or adjacent to coastal protected areas may also become increasingly important to maintaining both their ecological and disaster risk reduction functions.

Post-tsunami studies in Sri Lanka found that the determination of development setback distances for mitigation of tsunami risk was complicated by small scale topographical variations that might channel water further inland (Kaplan *et al.*, 2009). This demonstrates the importance of understanding the underlying landforms, and ideally accommodating these within the design of protected areas and/or development setbacks. In Christchurch similar aspects have been evident in the pattern of damage experienced in the Canterbury earthquakes which has drawn attention to avoiding areas of heightened vulnerability to natural hazards at both macro and micro scales.

The Clifton Beach site provides a useful case to consider the relative benefits of

different options for hazard management, amenity, and ecological benefits, in relation to urban dune ecosystems as protected areas. The role and thus management of the coastal park is complex due to many competing interests for land use in the area, and options for adaptation are limited. Ideally, a buffer area behind the current dune system would be a feature of the coastal park, performing a climate change adaptation function with regard to the expected inland migration of the beach and dune system, whilst also contributing to amenity values through providing shade, shelter from wind, and interactions with nature (Sallis *et al.*, 2006).

However, the space available is already constrained and potential coastline retreat is expected to be in the order of a 60 m migration inland for a sea level rise of 1.0 m (Tonkin & Taylor, 2013). The area affected is currently occupied by a range of infrastructure including buildings, below ground services, and a major road, and even if natural dune system migration was possible this would push the dune system hard up against coastal cliffs at the west end of the beach. Such settings challenge thinking on the longer term role of the coastal park.

The likely scenario is that dune systems will migrate inland as far as they are able until they run up against existing urban infrastructure. Where the latter is to remain within the coastal hazard zone it will require protection which may necessitate the use of hard defences or other engineering solutions for making the infrastructure more resilient to periodic events. However such hard defences must also be designed to cater for a range of event types and magnitudes over long periods, and ideally be integrated with natural environment values where possible (Granja & de Carvalho, 1995). To assist this, natural solutions such as dunes and forest may have a continuing role to play albeit within a progressively modified or ecologically 'engineered' protected area concept. This can clearly be accommodated within IUCN Category IV and VI Protected Area definitions and may be the best option for adaptive management of the existing protected areas whilst taking other resource and hazard management considerations into account.

4.3 Natural solutions within an integrated approach to hazard management

New Zealand coastal literature suggests that dune restoration should not be seen as a means of preventing natural erosion processes. These processes can become a source of 'erosion hazard', a term which refers to situations where there is likelihood of loss (e.g. of assets). However the distinction between erosion hazard and other coastal hazards is important, and there is a need for action across a range of risk concepts (Jacobson, 2004). Dunes can certainly be beneficial in short-term events, and disaster risk reduction provides a useful perspective due to its focus on short duration high intensity events.

Mitigation strategies for *future events* of this type have received less attention compared to responses to longer term coastal erosion trends. This may in part be due to experiences of loss being a key driver behind the development of risk management responses in general (Dahm, 2002), compounded in New Zealand by an absence of large magnitude coastal disaster events in recent history.

In contrast, Japan has had a long history in both recovery from tsunami and the use of coastal protected areas for disaster risk reduction. Evidence from post-disaster studies suggests that structural protection benefits from sand and soil accumulation around the footings of hard defences, and potentially also from bio-shields, may be of benefit in catastrophic events (Feagin *et al.*, 2010; Harada & Imamura, 2005; Tanaka, 2009). In the case of the 2011 tsunamis many coastal defences that were engineered to withstand tsunami were instead toppled by the force of the initial waves, leading to the perception that complementary and overlapping lines of defences may be a better option for disaster risk reduction (Renaud & Murti, 2013; Shaw *et al.*, 2012).

Studies elsewhere have also concluded that hard defences may not provide a long-term solution when used in isolation due to maintenance problems, or being undermined by repeated exposure to hazard events (Granja & de Carvalho, 1995; Tonkin & Taylor, 2013). Even in constrained locations the presence of

a dune ecosystem can facilitate the accumulation and seaward advance of sand deposits following periodic erosion events (Dahm, 2011). This in turn may improve the risk reduction attributes of an engineered system in relation to the range of hazard types that may be the subject of a future event.

5. Conclusions

This case study demonstrates a range of possibilities and issues for managing coastal protected areas for disaster risk reduction in a manner compatible with other resource management and conservation objectives. Key aspects include responding to current threats whilst also planning for future scenarios in a dynamic environment. For dune ecosystems the protection, and where necessary re-establishment of appropriate vegetation is an example of where protected area status has an important role to play. Specific management interventions are typically required to address threats to key system attributes and this is exemplified by the critical role of natural dune rebuilding processes between storm events and the plant communities that facilitate them.

Coastal systems also exemplify the importance of spatial considerations for effective protected area management. This includes attention to adjacent land uses and requires a particular focus on the land available to maintain or restore natural values. In addition to opportunities for engineering anthropogenic benefits, spatial adaptation of the natural system must be taken into account. In situations where the land availability is limited, a combination of hard, soft, and 'green' engineering approaches may offer the best approach to disaster risk reduction whilst also providing some opportunity to maintain the natural and other values of coastal areas. However forward-thinking strategic planning is perhaps the most essential activity to reduce the number of areas potentially exposed to these difficulties and ensure that there is room for the inland migration of coastal systems wherever possible.

At sites such as Clifton Beach spatial constraints could lead to the loss of the natural coastal dune system. To address this there are possibilities for hybrid

configurations to retain some values and benefits, such as supporting the front face of a fore-dune by a line of hard defences. Where spatial availability leads to the complete loss of opportunities for natural riparian systems it is important to recognize that the reliability of hard defences may also become questionable in large magnitude events. This suggests greater emphasis on managed retreat of infrastructure as the best long-term solution where possible, and in turn places greater emphasis on forward thinking land-use planning as a key activity for coastal

management. In this respect coastal protected areas and 'green infrastructure' can be expected to have an important and continuing role to play as inland migration of coastal systems occurs. To address adaptation needs it makes sense to plan for plausible scenarios now to enable the greatest range of mitigation measures to be usefully employed.

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Chapter 11

Climate Change Adaptation in the Peruvian Andes: implementing no-regret measures in the Nor Yauyos-Cochas Landscape Reserve

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Abstract

Potential climate change impacts in the Peruvian Andes, could include longer drought periods and more intense (but shorter) rainfall patterns, which will significantly affect the local communities' livelihoods (MINAM, 2010). The Nor Yauyos-Cochas Landscape Reserve (NYCLR), located in the Peruvian Andean highlands, is one of 76 natural protected areas managed by Peru's National Service of Natural Areas Protected by the State (SERNANP). As part of the Mountain Ecosystem-based Adaptation (EbA) Project¹, IUCN and its partner, The Mountain Institute (TMI), are implementing no-regret EbA measures in the communities of Canchayllo and Miraflores within the reserve. Approaches

used include a participatory methodology to select potential no-regret measures, and a process to analyse, design and validate the options through a multi-stakeholder Integrated Participatory Rural Appraisal. The no-regret measures encompass a range of ecosystem management activities to increase resilience and reduce the vulnerability of local people and the environment to climate change. The measures being implemented include: a) sustainable water and grassland management, where upper micro-watersheds, wetlands, water courses, and their associated vegetation (mainly grasslands) are managed to provide water storage, groundwater recharge and regulation services, and b) community-based sustainable native grassland management to enhance pastoral livelihoods and increase resilience to extreme climatic events. These activities aim to support integrated sustainable land management and the enhancement of both the ecosystem services and the livelihoods of the communities. This case study describes the process of designing and implementing no-regret adaptation measures in the two communities. In addition, it highlights the role that the NYCLR plays in these processes and in including Climate Change Adaptation (CCA) goals in its planning instruments,

drawing on experience to date. The participatory approaches used so far in the planning, design, validation and implementation phases have been key to delivering bottom-up activities that empower and enhance local community ownership. Implementing no-regret measures within the reserve has set an important governance basis to facilitate working with the communities and mainstreaming EbA and CCA into the planning instruments. With respect to the coordination with the reserve, it has been important to learn how to work as a team towards common goals, understanding their role as facilitators in this process and the importance of their participation to ensure the sustainability of CCA in the long term.

Key words: climate change adaptation, ecosystem-based adaptation, no-regret measures, landscape reserve.

¹ The Ecosystem-based Adaptation (EbA) in the Mountain Ecosystems Programme is a collaborative initiative of the United Nations Environment Programme (UNEP), the International Union for Conservation of Nature (IUCN), and the United Nations Development Programme (UNDP), funded by Germany's Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). In Peru, the programme is commissioned by the Ministry of Environment of Peru (MINAM) and is implemented in the Nor Yauyos-Cochas Landscape Reserve (NYCLR) with the support of the National Service of Natural Areas Protected by the State (SERNANP). The activities under IUCN's responsibility are implemented in partnership with The Mountain Institute (TMI).

1. Introduction

The Nor Yauyos-Cochas Landscape Reserve (NYCLR) is located in the Andean highlands in the southern part of the departments of Lima and Junín. Its main goal is to conserve the Cañete and Pachacayo River watersheds (important rivers for hydroelectricity), which include



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various ecosystems in an area of great landscape beauty and unique value (INRENA, 2006). The reserve has an area of 221,268.48 ha, of which 62.1% is located in the Cañete River watershed and 37.9% in the Cochabamba-Pachacayo basin (MINAM, 2011). This reserve is mainly classified as a direct-use protected area, in which natural resource extraction and use are allowed, primarily by the local populations in the areas defined in the management plan (Q'Apiriy, 2012). It falls within IUCN's protected area category V.² Land tenure in the reserve is mostly communal (no individual land rights), with land use according to the reserve's guidelines.

The NYCLR's geomorphology is dominated by landscapes with high mountains (between 2,000 and 5,800 metres above sea level), steep slopes and hillsides, as well as deep valleys (MINAM, 2011). These landscapes have been shaped by the long presence of and use by their inhabitants; hence, there is a rich cultural heritage including diverse traditional knowledge, vast ancestral agricultural terraces and water courses, and archaeological sites (INC, 2006).

There are 19 communities located within the limits of the reserve, divided into 12 districts, with around 14,919 inhabitants (INEI, 2007). As these communities rely primarily on livestock farming and subsistence agriculture for their livelihoods, access to water and pastures is essential.

According to local stakeholders, the reserve has been experiencing increasing pressures, mainly due to grassland overuse by the local people and changes in precipitation patterns. Low agricultural production, especially of native crops, associated with the loss of traditional knowledge and the lack of market access has led to the migration of the local population, especially youth. This migration (especially high during the 1980s and 1990s), along with other market-driven factors, led many households to shift from a livelihood consisting of a variety of agricultural activities towards less labour-intensive cattle farming. This shift towards cattle farming, with weak community organization and dense cattle distribution³, is causing degradation of the native grassland ecosystem in certain areas.

According to the Vulnerability Impact Assessment (VIA) for the NYCLR and its buffer area,⁴ there is a high level of uncertainty regarding climate trends and future scenarios for the Reserve (FDA, 2013). The most precise projections indicate that temperatures will increase between 0.61°C and 1.12°C between 2011 and 2030. Regarding precipitation, trends indicate no changes in annual rainfall, but changes in patterns will occur, as well as a reduction in surface water runoff (*Ibid*, 2013). Other climate trends and scenarios until 2100 developed for the Mantaro River watershed (based on the IPCC A1B emissions scenario,

which can be taken as a reference for the NYCLR) indicate that in general there will be: a) increased minimum and maximum temperatures, on average 2.7°C and 2.3°C respectively in relation to the current climate; b) reduced precipitation during summer and winter in the northern and central sectors of the watershed; and c) increased frequency of frosts in certain areas (SENAMHI, 2009). The potential scenarios for the NYCLR suggest changes in hydrological patterns that may affect grassland and water resources, which are vital for livestock-dependent communities.

Local actors have observed that most grasslands in the reserve are becoming less productive. Cattle and sheep farming have replaced native camelid farming (llamas, alpacas and vicuñas) in higher areas where grasslands are more limited. The main breed of cattle adapted to these high-altitude conditions is a local variety that has low market productivity (e.g. low milk and meat production) but better adaptive capacity (e.g. it does not require high quantities of water and high-quality pastures).

Acknowledging the challenges faced in the area, the Mountain EbA Project has been implemented in the NYCLR since 2012. Its aim is to reduce the vulnerability of the reserve's populations to climate change and increase their capacity for resilience through the EbA⁵ approach (Mountain

² 'A protected area where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.' (IUCN, 2014).

³ In addition to this, a number of households have migrated to the cities, but have bought cattle and have their family members taking care of them in the reserve, which has increased the livestock population.

⁴ Conducted as part of the Mountain EbA Project in Peru and led by UNEP (See FDA, 2013).

⁵ Ecosystem-based adaptation (EbA) is defined as the use of biodiversity and ecosystem services as part of an overall adaptation strategy that aims to be cost-effective and generate social, economic and cultural co-benefits while contributing to the conservation of biodiversity. It integrates the sustainable management, conservation and restoration of ecosystems to provide services that help people to adapt to the adverse effects of climate change (CBD, 2009). Its purpose is to maintain and increase resilience and reduce the vulnerability of ecosystems and people facing



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EbA Project, 2014). At the national level, the project's strategic partners are the Ministry of Environment, the main political partner that promotes synergies between the project and other actors, and SERNANP, which governs protected areas management in Peru. The main local partner is the NYCLR (part of SERNANP); the reserve has a management committee comprised of local stakeholders, including the mayors (district municipal authorities). In addition, the regional governments of Junín and Lima and the municipalities of the communities in the reserve are strategic partners, as well as the reserve's Board of Trustees⁶.

IUCN's role in the project focuses on the design and implementation of EbA measures and capacity building activities on the ground. These activities are being implemented in partnership with TMI in Canchayllo and Miraflores.

The community of Canchayllo is located in the Jauja Province, Junín Region (Figure 1). Founded in 1942, the community has around 800 inhabitants; it has an area of 7,650 ha and it is located at 3,610 m above sea level. Their main livelihood is

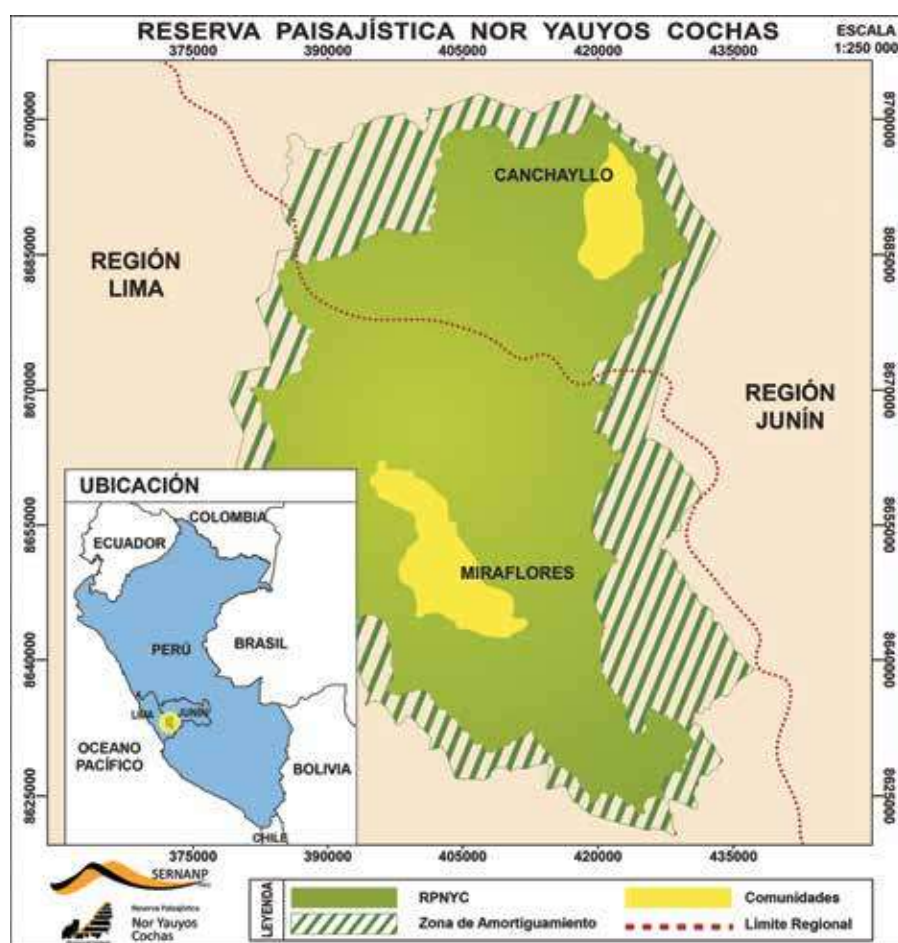
livestock farming (mainly sheep), although many families supplement their income with other activities (e.g. employment with nearby hydro-electric company). The community is part of the Cochas-Pachacayo watershed, which drains into the Mantaro River (TMI, 2013b).

The community of Miraflores is located in the Yauyos Province, Lima Region (Figure 1). Founded in 1925, it covers an area of 17,385 hectares ranging between 3,000

m and 5,400 m above sea level and belongs to the Cañete River watershed. It has around 100 inhabitants. Their main livelihood is cattle farming, together with small scale cultivated agriculture. In this community, there is a high level of migration and a low birth rate (TMI, 2014a).

The average, maximum and minimum temperatures in these communities are 8°C, 19°C and 0°C, respectively. Precipitation ranges between 650 to

Figure 1: Nor Yauyos-Cochas Landscape Reserve where the Mountain EbA Project is implemented in Peru; Canchayllo and Miraflores communities where the no-regret adaptation measures are being implemented (Elaborated by IUCN).



the impacts of climate change. In EbA, the role of ecosystems and the traditional knowledge of local communities are crucial to the development of climate change adaptation measures and the reduction of the impacts of extreme weather events. EbA activities that are appropriately planned and designed can improve livelihoods, food security, and disaster risk reduction (DRR), as well as promote the conservation of biodiversity and carbon sequestration (Ibid, 2009).

⁶ The reserve's Board of Trustees is an association between private enterprise (a hydropower company, CELEPSA, which leads the Board of Trustees, and two mining companies) and public partners. It seeks to contribute to the conservation of agro-biodiversity and natural and cultural heritage of the reserve by carrying out participatory monitoring and capacity building in the area.

Miraflores



750 mm/year, with a dry season and a rainy season (SENAMHI, 2009). Both communities are characterized by communal areas with degraded pastures due to overgrazing. An important driver of this pattern is the weakness of community organization for the management of water and grassland resources on community lands⁷. However, the local communities want to recover their traditional knowledge of how to manage their ecosystems and adapt to extreme weather events.

This paper describes the process of designing and implementing no-regret EbA measures for these two communities⁸. It also highlights the role that the NYCLR plays in this process, and in including CCA goals in its planning instruments, drawing on the experience to date.

2. Methods

Several actions and (participatory) methods have been used to select, analyse, design

and validate the no-regret measures through a multi-stakeholder process.

2.1 Actions

To date, the IUCN-TMI partnership has implemented several key actions using a bottom-up approach in response to potential climate change impacts and the social and environmental context. Firstly, the project sites (communities of Canchayllo and Miraflores) were selected jointly by the project partners and the NYCLR based on environmental, social, ecological, political and operational criteria (TMI, 2013a). Then, field trips and workshops were carried out to identify vulnerabilities based on local perceptions, the local communities' needs and priorities, and ideas to address the vulnerabilities. With the initial results of the field trips and workshops, an analysis of the proposed no-regret measures took place with expert assistance.

staff belonging to both communities. The goal of the IPRA was to validate the previously identified no-regret measures, prepare a final design, and analyse the environmental and social impacts of the measures (TMI, 2013b; TMI, 2014a). The IPRA results were presented and validated by the local stakeholders, reserve staff and project partners. These results were also presented to SERNANP locally and nationally for the purpose of discussing next steps and how to incorporate the experience to date into the protected area planning instruments.

Following these actions, implementation of the no-regret measures was begun in each community (described later in this section). Also, from the initial stages of the project, there were several capacity building actions with the communities and reserve staff to identify local vulnerabilities to climate change and support them in understanding EbA, as well as to build trust and confidence among stakeholders.

2.2 Approaches, methods and detailed process

The process of consultation, diagnosis and design of the measures lasted eight months¹⁰. Participatory approaches have been applied throughout the process of identifying and designing them. The conceptual framework used for this



Local researchers

⁷ According to Anelí Gómez (2014), based on what community members have explained: 'in the past a good community organization implied the whole communal land use, knowledge of the ecological zones, climate and ecosystem management in which they rotated through the grasslands of the whole community at different times of the year. Now, even though the land is communal, it has a kind of (inherited) ownership so the community cannot rotate anymore; people are losing their traditional knowledge and it is becoming more difficult to reach agreements amongst community members.'

⁸ Based mainly on the information generated by TMI in the past year.

Then an Integrated Participatory Rural Appraisal (IPRA) using a participatory action research approach took place. Each community selected a team of local researchers⁹ to participate in the IPRA together with a team of external experts (anthropologist, agronomist, archaeologist, hydrologist and pasture specialist), led by a scientific coordinator. The teams of local researchers included reserve

⁹ Two women are on each team.

purpose is the socio-ecosystem approach (used by TMI in their work), in which the landscape and its management are the result of ecological and social processes governed by changing variables (both

¹⁰ It is worth mentioning that the conceptual proposal, the methodological approach, the design of the participatory process and the implementation of the no-regret measures are carried out by TMI in Canchayllo and Miraflores, based on experience of over 30 years of participatory management work of mountain ecosystems in the world.



fast and slow), which require integrated management to address both social and ecological dimensions (Chapin et al., 2009). In this respect, in a socio-ecological system (also termed a coupled human-environment system), people depend on ecosystem resources and services, but also, to varying degrees, influence ecosystem dynamics (*ibid*, 2009).

No-regret adaptation measures are defined as adaptive measures that are worthwhile (i.e. they bring net socio-economic benefits) and will yield positive outcomes regardless of future climate change scenarios or how climate plays out. 'These types of measures include those justified (cost-effective) under current climate conditions (including those addressing its variability and extremes) and further justified when their introduction is consistent with addressing risks associated with projected climate changes' (UKCIP, 2007, p. 15).

The IPRA is a bottom-up approach which was used in this case to incorporate local and traditional knowledge, institutions and opinions of local stakeholders into the design of the no-regret measures, legitimizing the stakeholders' knowledge and promoting their empowerment (TMI, 2013b; TMI, 2014a). The IPRA was carried out during five days in each community, after which a results analysis and discussion workshop took place. It integrated and linked the knowledge and work of the various stakeholders, including local and external experts and reserve staff. The main results of the IPRA were the design of the no-regret measures and an agreement on the planning process for their implementation. The results of this process were validated with SERNANP, and discussion focused on how to incorporate aspects related to CCA, EbA and lessons learnt into the Master Plan for the reserve, currently in the process of

being updated¹¹.

The proposed no-regret measures were presented and validated (end of 2013) at community assemblies in Canchayllo and Miraflores, in which the mayors and aldermen participated. This validation process, with the active participation of the local people, included the presentation of the results of the participatory design phase and the assessment of the different options. It is important to emphasize that the communities' priorities and interests were taken into account from the beginning as part of the identification of priorities, the pre-selection of measures, the IPRA and design of the measures (TMI, 2013b; TMI, 2014a).

Furthermore, it is important to note that the reserve staff participated actively in this process to represent the priorities of the NYCLR. Specific actions carried out jointly with the reserve include: i) active engagement of reserve staff in the process of designing, analysing and validating the no-regret measures; ii) capacity building for park rangers on different topics, including sustainable pastoralism; iii) the role of Traditional Knowledge in CCA workshop; and iv) the participation of reserve staff in activities to implement the no-regret measures, including the development

¹¹ This process, which began in 2013, is led by SERNANP and the reserve's Board of Trustees. It involves a series of meetings with other actors working in the reserve (i.e. Mountain EbA Project, NGOs such as FIDA & AIDER) and the use of an 'open standard' planning methodology that brings together common concepts and achievements to design, manage and monitor conservation projects in a participatory manner. The five most relevant areas that are being assessed include: vicuñas, pasture and livestock management, agro-biodiversity, tourism, and hydrological systems. This updating process follows the 2006-2011 Management Plan and is envisioned to continue for 20 years. The Mountain EbA Project is part of the 'technical committee' that was created to support this process.

of community water and grassland management plans.

In addition, it is important to stress that the recently completed VIA suggests implementing measures based on a combination of actions to improve and generate ecosystem services over the long term. Ecosystem services are the basis of the livelihoods for the families in the NYCLR and also provide short-term benefits for the economy of the communities (FDA, 2013). This suggestion ties in neatly with the no-regret measures being implemented in the communities of Canchayllo and Miraflores. A process is underway to link the no-regret measures with the VIA results in order to support the measures with the climate scenarios generated.

2.3 The no-regret adaptation measures

The no-regret EbA measures chosen by both communities include a range of ecosystem management activities to increase resilience and reduce the vulnerability of local people and the environment to climate change. They consist of the following:

- a) Community-based sustainable water management, where upper micro-watersheds, wetlands, water courses, and their associated vegetation (mainly grasslands) are managed to provide water storage, groundwater recharge and regulation services.
- b) Community-based sustainable native grassland management to enhance pastoral livelihoods and increase resilience to drought, frost and other extreme events.

Each measure is composed of three pillars (Figure 2): 1) institutional strengthening and community organization; 2) capacity building to enhance local and traditional knowledge; 3) green-grey infrastructure (TMI, 2013b; TMI, 2014a). The measures

are slightly different in each community because they respond to specific environmental and social conditions and priorities. However, both communities are willing to promote sustainable water¹² and grassland management.

The institutional strengthening and community organization pillar aims to improve governance arrangements among different stakeholders in the landscape reserve. Its main goals will be the implementation of a community water and grassland management plan for both Canchayllo and Miraflores and the creation of a natural resources management committee in each community. Another important goal will be to implement a pilot community grazing area on community lands.

The pillar of capacity building seeks to create capacities and awareness for the implementation of the community management plans, including working with stakeholders at the pilot sites in each community. Its main goal will be to link local and traditional knowledge with new technological knowledge with the aim of identifying best practices to apply on the ground. In addition, this pillar will document local and traditional knowledge related to water and grassland management and will focus on capacity building related to legal instruments such as the updated water regulations.

The green-grey infrastructure activities include the development of water channels and reservoirs, piping systems and fences, as well as green infrastructure such as wetlands, grasslands and natural water courses and reservoirs.

In the community of Canchayllo, the green-grey infrastructure consists of the restoration of a natural water reservoir dam to reduce water filtration and ensure its storage during the dry season. Furthermore, an underground pipe is being restored to transport water from the upper part of the watershed (near *Chacara*

Figure 2: Components of the no-regret adaptation measures for the local communities of Canchayllo and Miraflores in the Nor Yauyos-Cochas Landscape Reserve, in the Peruvian Andes (Adapted from TMI, 2013b).



Lake) to the community farm (*Jutupuquio*), where the water will be distributed through ditches to promote its infiltration into the soil thereby regulating water availability in the upper and middle micro-watershed. The restoration of the underground pipe channel will dampen around 800 ha of grasslands during the dry season, contributing to wetland restoration in the upper part of the watershed and the creation of natural watering troughs for livestock (TMI, 2013b).

In the community of Miraflores, the green-grey infrastructure includes enlarging protected zones around the *Yanacancha* lakes encircling the upper micro-watershed in order to prevent cattle and other animals from entering the area. This will help promote wetland enhancement and to naturally restore the surrounding areas with native species. In addition, an ancient water channel is being restored to transport water to the *Curiuna* grazing area. The water channel is expected to create new natural watering troughs for livestock and/or restore the wetlands as a result of the increase in water availability; however, this is something that needs further analysis (TMI, 2014a).

The communities are contributing with in-kind support to carry out the proposed infrastructure improvements. The district municipalities are also supporting with machinery and some material. The

reserve is contributing with in-kind support through facilitating communications with community members for several meetings and workshops, as well as by actively participating in these events.

3. Results

To date, the project has achieved two main results: a) the engagement and capacities of the local communities and reserve staff in the process of building 'robust'¹³ adaptation measures, including awareness of their main vulnerabilities and needs in a changing environment, and b) the selection and design of two no-regret measures that are being implemented together with local stakeholders in each community.

The no-regret measures in Miraflores and Canchayllo aim to provide environmental and socio-economic benefits. Environmental benefits are expected to be achieved through better management and protection of native grasslands, as well as the restoration of upper micro-watershed wetlands. These measures respond to the climatic vulnerability of the highland pastures, where wetlands have been reduced in size. These expected outcomes and benefits include (TMI, 2013b; TMI, 2014a):

¹² Integrated Water Resource Management (IWRM) has been defined as a 'process that promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems' (GWP, 2000).

¹³ In the project, the term 'robust measure' is used to refer to no-regret measures aimed at strengthening the communities' conditions and capacity to face climate change.

- a. Hydrological regulation: Water storage, groundwater recharge and regulation services will be enhanced.
- b. Fire prevention: The occurrence of natural fires during the dry season can be reduced by enhancing wetlands in grassland ecosystems.
- c. Minimum impact of extreme events: The higher frequency and intensity of frosts and increased droughts as a result of extreme temperatures can be minimized by restoring healthy grassland/wetland ecosystems, which will also reduce impacts on pasturelands.
- d. Other ecosystem services such as biodiversity conservation and enhancement of carbon storage in the preserved/restored grasslands.

Even though the infrastructure component of the no-regrets will have fast results in terms of water distribution and supply, other benefits (e.g. hydrological regulation, minimum impacts of extreme events and carbon storage in preserved grasslands) will also become obvious in the longer term.

Short- and long-term socio-economic benefits are expected to be produced through:

- a. Strengthened institutional arrangements and capacities for community management of water, grasslands and livestock, aimed at increasing livestock productivity and quality through improved grazing distribution and pasture quality and the creation of natural troughs.
- b. The community water and grassland management plans will seek to improve grassland productivity by organizing grazing activities in the different areas, reducing pressure on over-grazed areas and distributing livestock across the landscape to where pastures have a higher livestock carrying capacity. In addition, the plans will aim to improve community management of these shared resources.
- c. Capacity building in sustainable natural resource management (i.e. related to water and pastures) as an essential component of the water and grassland management plans.

Several of these socio-economic benefits are processes that will also take time to be consolidated, as they constitute social

changes that are taking place in local governance structure and enhancing local and traditional knowledge.

In the context of climate change, the no-regret measures are designed to increase the resilience and adaptive capacities of both communities. In this regard, having better preserved and managed grasslands as a result of regulating the hydrological system and strengthening community organization and capabilities will prepare people to cope with uncertain climate scenarios. A baseline and indicators are being developed to monitor these diverse benefits, with the reserve taking a lead role in monitoring, in the future.

4. Discussion

Overall, the project has shown the importance of: a) building trust and understanding with the communities by working with them on the analysis of ideas to address climate change vulnerabilities; b) building local adaptive capacities (including those of the reserve) and strengthening community-based institutional arrangements; c) having a multidisciplinary team comprised of local stakeholders and external experts involved in defining the no-regret measures by analysing pre-selected measures and their potential social and environmental impacts; d) using participatory approaches in the planning, design, validation and implementation phases, which has been key to delivering bottom-up activities that empower and enhance the local communities' ownership; and, e) ensuring diverse multi-stakeholder participation at different levels, including not only the direct stakeholders (i.e. the communities and the reserve), but also others such as the municipalities, which will ensure the sustainability of the no-regrets.

The participatory approaches used to define and design the no-regret measures have presented both successes and challenges. On the one hand, they have generated solid adaptation options based on the knowledge and needs of the local communities (and backed up by expert technical support) which can be sustainable if adopted and embraced by the communities and the reserve. On the other hand, these processes require a great deal of time and effort, including an in-depth understanding of the local context (TMI, 2014b). Additionally, the

benefits are sometimes seen by local stakeholders as mainly being indirect – for example, capacity building and awareness, which cannot be compared to other more immediate and/or direct socio-economic benefits. Although infrastructure activities will provide benefits in the short term, it is important that local stakeholders understand that EbA benefits (both at the institutional, socio-economic and ecosystem dimensions) will take time to consolidate as in many cases these have been until now process-focused to assure their sustainability.

Moreover, it is pivotal to consider that, in addition to climate conditions, other factors will also determine outcomes in the future, especially issues such as migration and market-driven forces which are beyond the influence of this project. Also, commitments have been established at different levels (i.e. local community members, local researchers, mayors, the reserve), but tangible activities such as green-grey infrastructure were needed in order to reaffirm local commitment to the project (TMI, 2014b).

Regarding institutional and governance arrangements, it is critical to work with all direct stakeholders (including in this case, the reserve) from the beginning of any process, and also to consider that these processes take time to consolidate. The management of the NYCLR as a landscape reserve is largely dependent on several stakeholders¹⁴, including SERNANP at local and national levels, local and regional governments, private/public initiatives, and the local populations; therefore, a challenge for the reserve's co-management model is the overlapping of responsibilities among the local communities, local governments and the reserve director in a same geographic space, in which their roles to achieve the reserve's goals are not completely clear (Q'Apiriy, 2012). It is imperative for the project to take into account this particular context and complex governance scenarios and to work not only with the reserve but also with these other actors

¹⁴ 80 stakeholders were identified who have some management relationship with the reserve, and who serve on the reserve's Management Committee, creating a complex governance environment (Q'Apiriy, 2012).



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in order to ensure the sustainability of the adaptation measures.

Implementing the no-regret measures in a protected area has some important advantages; for instance, by having governance and institutional settings with conservation and sustainable management goals (i.e. the reserve), provides the way in with local communities and facilitates mainstreaming the EbA approach in the reserve's planning instruments.

It is also important to highlight the crucial role that the NYCLR has in implementing the no-regret measures in several activities: i) the daily management of the reserve, including the two communities; ii) the 'future' monitoring of the community water and grassland management plans, and even more comprehensively; and iii) the updating of the Master Plan and other planning tools including EbA and CCA. Adequate participation of the reserve and other local stakeholders will ensure the sustainability of any CCA measures adopted as part of the management of the reserve.

Some factors that need to be taken into account in order to replicate the process include:

1. Balance between planned implementation times and the time required to take into account the priorities of the communities as well as the possibility of addressing them through the project. Also, additional time should be allowed¹⁵ for activities

¹⁵ The infrastructure component was planned to start in December 2013; however, it experienced some delays, mainly due to the following: a) SERNANP's national offices asking for a review and validation process and b) delays in certain activities (i.e. of the counterparts) for which the community leaders are responsible.

like the validation processes with local and national authorities such as SERNANP (TMI, 2014b).

2. Enhanced multi-stakeholder coordination is crucial in any participatory CCA-related process. In this case, this has entailed coordination among project partners and reserve staff to ensure the alignment of project objectives with the priorities of the reserve and local stakeholders (TMI, 2014b).
3. Comprehensive CCA measures should be designed based on local knowledge and external expertise, and aim to produce environmental and socio-economic benefits (TMI, 2014b). Providing a balance between the expected direct and indirect benefits (and ensuring their timely delivery) will maintain the interest and commitment of the community members and reserve staff (*ibid*, 2014).

Focusing on no-regrets measures is particularly appropriate for the near term as they are more likely to be implemented and provide experience on which to build further assessments of climate risks and adaptation measures (UKCIP, 2007, p. 15). Since there is high uncertainty about the precise impacts that climate change will have at the local level, no-regret measures can be considered a quick cost-effective measure that focuses on strengthening overall resilience and reducing vulnerability. In this case, the no-regret measures are achieving this by strengthening community livelihoods, governance arrangements, and capacities which will deliver longer term benefits. In addition, by engaging the reserve in the process to ensure the sustainability of the measures.

5. Conclusions

Protected areas are vital in responding to

climate change; they have advantage over other ecosystem management systems in terms of governance clarity, capacity and effectiveness (Dudley et al., 2010). As stated by M. Arenas (2014): 'Landscapes under conservation and sustainable management frameworks guaranty healthier ecosystems, and hence, higher resilience to climate change.' The no-regret measures in Canchayllo and Miraflores aim to provide higher resilience to climate change by: a) organizing and strengthening the local governance structures and capacities; and b) enhancing the ecosystem services related to water and grasslands management, and hence, ensuring the communities' livelihoods. A key factor is that the no-regret measures are being implemented with the support of the reserve, having the potential of becoming long-term solutions for CCA within the reserve, and potentially of Peru's PAs management framework.

There are several lessons learnt with respect to the role and coordination with the NYCLR. First, it is important to work in a coordinated manner from the beginning since protected area institutions have their own strategic goals and ways of working. In this sense, A. Gómez (2014) commented, 'We have spent some time getting to know and understand NYCLR-SERNANP's working approaches and dynamics; it has been a useful learning process and now we are on the same track.' Reserve director G. Quiroz (2014) reaffirmed: 'We have learned to work as a team towards the reserve's goals.' In this sense, the project's engagement in the process of updating the Master Plan ensures that the EbA measures will follow the vision of the reserve.

Second, it has been critical to understand the role of the reserve in this process,

which was characterized in workshops as both a regulator (i.e. controlling and monitoring land use) and facilitator, acting as a liaison between the various actors in the reserve, taking into account their objectives and strategies. The reserve staff highlighted the role of communicating with and raising the awareness of the local communities about sustainable land use. The fact that the park rangers are from the same communities, and are familiar with the local needs and socio-ecological context, has increased their support for the implementation of the no-regret measures. However, capacity building for park rangers on both technical aspects (including climate change and EbA) and tools to communicate/facilitate these aspects was identified as an important need to enable them to play an effective facilitation role¹⁶.

Third, the reserve plays an important role in ensuring the sustainability of the CCA measures. The reserve director stated that in the long term the Master Plan will serve as a liaison mechanism between the reserve and the communities, thus ensuring the sustainability of the no-

¹⁶ Nevertheless, some park rangers have the perception that communities see them as monitors rather than facilitators, which can reduce their ability to work closely together to achieve these goals.

regret measures. After all, CCA is being incorporated as a cross-cutting issue in the reserve's main areas of activity with support from the project. In addition, the director mentioned that 'the no-regret measures can serve as a model for other communities within the reserve to implement water and grassland management plans... and the reserve is a pioneer among other protected areas of Peru in incorporating CCA aspects into its vision and planning.' For this, a priority is to institutionalize the protected area's capacities and role as manager of the landscape. As seen by M. Arenas (2014), 'The model of enhancing farming practices with both traditional and technical knowledge, can be replicated in other communities and protected areas, if this process is also built with the protected area managers; therefore, the project's challenge is to consolidate and institutionalize the reserve staff in the EbA approach and processes.'

Finally, effective local and national coordination of the implementation of the no-regret measures (and of the overall project) is critical to enhance understanding and ensure that the impacts of these activities are mainstreamed into national and regional policies/strategies.

A final recommendation to incorporate and implement CCA in protected areas is to follow a horizontal model of co-management with all the various actors at different levels. Overall, the no-regret measures presented in this case study, aim to strengthen the overall governance of ecosystem management as a nature-based solution towards CCA including the main stakeholders – the local communities and the reserve.

As a final note, TMI, leading the implementation of the no-regrets on the ground, is also documenting the experience and will publish the results soon.

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Chapter 12

The role of conservation agreements in disaster risk reduction: the case of Mount Mantalingahan Protected Landscape (MMPL) in the Philippines

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Abstract

As a protected landscape, Mount Mantalingahan's importance lies in it being a Key Biodiversity Area (KBA) and one of ten Alliance for Zero Extinction (AZE) sites in the Philippines. However, prior to its declaration as a protected landscape, its forest area was not only in danger of mining activities but also of several hazards such as flooding and landslides. The declaration of Mount Mantalingahan as a protected landscape, along with its associated livelihood programmes for the mountain's inhabitants, allowed for participatory activities that contributed to reduction of flooding and landslide risks in addition to livelihood improvements in three out of five municipalities that are included in the protected landscape. Disaster risk reduction in protected landscapes is best pursued in conjunction with conservation and development objectives. Through several conservation agreements with Conservation International-Philippines (CI-P), local communities in the Mount Mantalingahan Protected Landscape (MMPL) restored and conserved watersheds and, in the process, developed soft skills in managing community forestry enterprises and local water cooperatives.

1. Introduction

Mount Mantalingahan Protected Landscape (MMPL), proclaimed in June 2009, is one of the more recent

protected areas (PAs) in the United Nations Educational, Scientific and Cultural Organization (UNESCO) Man and Biosphere Reserve in Palawan, Philippines. The mountain range covers 120,457 hectares in Southern Palawan and cuts across five municipalities namely Rizal, Bataraza, Brooke's Point, Española, and Quezon with 36 villages (called barangays) in total. It is located approximately 140 km southeast of Puerto Princesa City, the capital of Palawan and has a rugged terrain with slopes greater than 50% in areas above 500 m, most of which are covered by natural forest (Cruz *et al.*, 2008). The mountain range has limestone formations and has Beaufort Ultramafics, Panas Sandstone, and Espina Basalt as its most common geological material; it is also rich in nickel deposits (Cruz *et al.*, 2008).

During 2004, a protected area suitability assessment by Conservation International – Philippines (CI-P) showed that the distinct aesthetic, ecological, and cultural character of MMPL results from socio-ecological interactions of Mount Mantalingahan with indigenous Palawans. This was a valid argument for Mount Mantalingahan to be declared not only as a PA but as a protected landscape. The National Integrated Protected Areas System (NIPAS) Act of the Philippines (1992, p. 43), defines a protected landscape as:

'...areas of national significance which are characterized by the

harmonious interaction of man and land while providing opportunities for public enjoyment through the recreation and tourism within the normal lifestyle and economic activity of these areas.'

This resonates with the International Union for Conservation of Nature (IUCN) Protected Area Category V of Protected Landscape/Seascape (Stolton *et al.*, 2013, p. 20), which is defined as:

'a protected area where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic value; and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.'

Several unique characteristics define Mount Mantalingahan and serve as important reasons for its declaration as a protected landscape: (1) MMPL is the highest peak of Southern Palawan's mountain ranges and is the main source of the 33 rivers that drain the Mantalingahan Mountain Range; (2) As of 1998, Mount Mantalingahan has an estimated 64% forest cover, 75% of which is considered primary forest and the remaining 25% as secondary forest; (3) MMPL is a Key Biodiversity Area (KBA), an Alliance for

Zero Extinction (AZE) site, and one of the 11 important bird areas in Palawan. It is the habitat of most of the threatened and restricted range birds¹ of the Palawan Endemic Bird area. CI-P (CI-P, 2008a) presented these to the country's Department of Environment and Natural Resources (DENR) Protected Areas and Wildlife Bureau (PAWB) 2nd National NIPAS Review Committee as the basis for the formal declaration of MMPL.

The majority of the occupants (91% of the area's total population) of MMPL are indigenous peoples called Palawans (CI-P, 2007). Part of the MMPL overlaps with an ancestral domain of Palawans, whose claim covers almost 70,000 hectares of five villages (Panalingaan, Latud, Taburi, and portions of Culasian and Canipaan) in the municipality of Rizal (see Figure 1). This ancestral domain claim was recognized by the Philippine government in July 2009 and formally awarded in 2012. The boundaries of the MMPL include two of the aforementioned ancestral domain villages, namely Panalingaan and Culasian. The proclamation of the MMPL imposed new rules on the mountain's occupants,

but still recognized the legal claims of these people, including the indigenous Palawans who were awarded a Certificate of Ancestral Domain Title (CADT). According to the indigenous Palawans, it took 15 years before their ancestral domain application was approved. On a similar vein, the establishment of MMPL took several years (from 2004 until 2009) of scientific research, strong partnerships, and participatory consultations before it was formally declared as a protected landscape (CI-P, 2011). Conservation International – Philippines (CI-P) was instrumental in this endeavour.

The declaration of the MMPL and its associated activities has been weighed through a Total Economic Value (TEV) framework developed by CI-P consultants where direct use values were based on timber, water, indigenous peoples' land use for agroforestry and non-timber forest products (NTFP) collection while indirect use values were based on carbon stock, soil conservation, watershed and biodiversity functions, and marine biodiversity (CI-P, 2008b). The resulting TEV at 2% discount rate is PHP 149.79

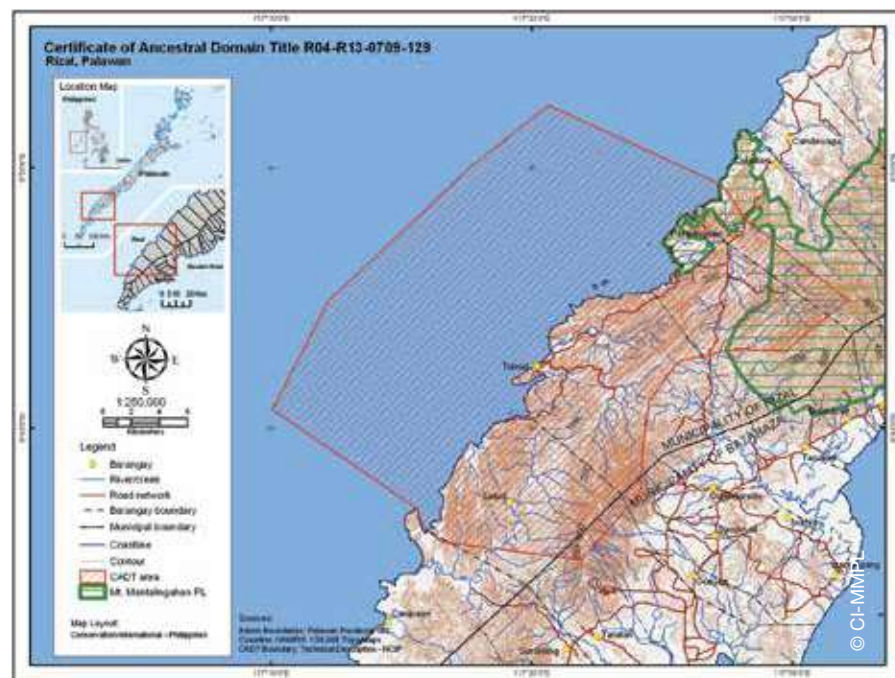
billion (US\$ 3.38 billion) and TEV at 5% discount rate is PHP 94.85 billion (US\$ 2.14 billion). The CI-P report compared these TEVs to the value of mining based on its total resource rent, which was estimated to be PHP 15.02 billion (US\$ 340.50 million), which is essentially PHP 2.21 billion (US\$ 50.10 million) worth of sand and gravel and PHP 12.81 billion (US\$ 290.4 million) worth of nickel (see Figure 2). The valuation report, thus, concludes that the value derived from the environmental goods and services from Mount Mantalingahan far exceeds the potential benefit from mining (CI-P, 2008b). This information is displayed graphically in Figure 2.

Disaster risks in MMPL

Among the several challenges that MMPL is facing, the various disaster risk profiles of the five municipalities in MMPL is of particular concern. According to the Geological Database Information System (GDIS) of the Mines and Geosciences Bureau (MGB) of the DENR, several parts of Bataraza, Quezon, and Rizal are highly susceptible to flooding while some parts of Bataraza, Brooke's Point, and Sofronio Española have high susceptibility to both flooding and landslide. Areas with high susceptibility to flooding are mostly adjacent to rivers, while those highly susceptible to landslides are mostly in the mountainous area (Figures 3 to 7). Areas with high susceptibility to landslide are shaded red (■), while those with moderate susceptibility are shaded green (■). Areas shaded yellow (■) are those with low susceptibility to landslide. Those with violet shade (■) are areas with high susceptibility to flooding while those shaded beige (■) have low to moderate susceptibility to flooding. MGB (2008) defines these as the following:

- 1) High susceptibility to landslide (■) – Areas with high landslide susceptibility rating have active/recent landslides and tension cracks that would directly affect the community. Those with steep slopes and drainages that are prone to landslide damming are also highly susceptible to landslides.
- 2) Moderate susceptibility to landslide (■) – Areas with moderate susceptibility to landslide rating have inactive/old landslides and tension cracks which are located away from the community. These areas usually have moderate slopes.

Figure 1: Map of overlapping ancestral domain of indigenous Palawans and MMPL.



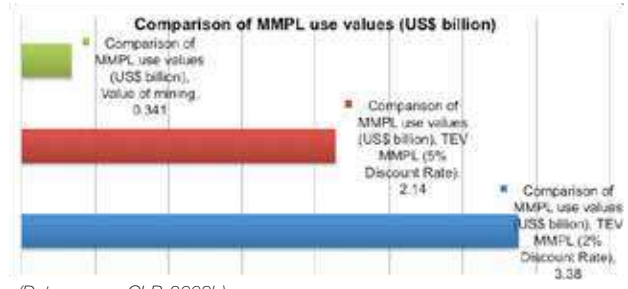
¹ These are the Philippine cockatoo (*Cacatua haematuropygia*), Palawan peacock pheasant (*Polyplectron napoleonis*), Palawan flycatcher (*Ficedula platenae*), Palawan hornbill (*Anthracoceros marchei*), Philippine duck (*Anas luzonica*), Philippine

dwarf kingfisher (*Ceyx melanurus*), Palawan striped-babbler (*Stachyris hypogrammica*), Palawan blue flycatcher (*Cyornis lemprieri*), Palawan scops owl (*Otus fuliginosus*), Blue-naped parrot (*Tanygnathus lucionensis*), and Palawan talking myna (*Gracula religiosa palawanensis*).

- 3) Low susceptibility to landslide (■) – Areas with low to gentle slopes and lacking tension cracks have low landslide susceptibility rating.
- 4) High susceptibility to flooding (■) – Areas with greater than 1 metre flood height. These areas are usually flooded for several hours during heavy rains; include landforms of topographic lows such as active river channels, abandoned river channels and areas along river banks; also prone to flash floods.
- 5) Low to moderate susceptibility to flooding (■) – Areas with less than 1 metre flood height. These are usually inundated during prolonged and extensive heavy rainfall or extreme weather condition.

Parts of Rizal and Brooke's Point are moderately or highly susceptible to landslide, with the latter being also highly susceptible to flooding. Sofronio Española has a similar disaster risk profile.

Figure 2: Comparison of MMPL use values.



(Data source: CI-P, 2008b)

Figure 3: Landslide and flood susceptibility map of Rizal, Brooke's Point, and Sofronio Española.

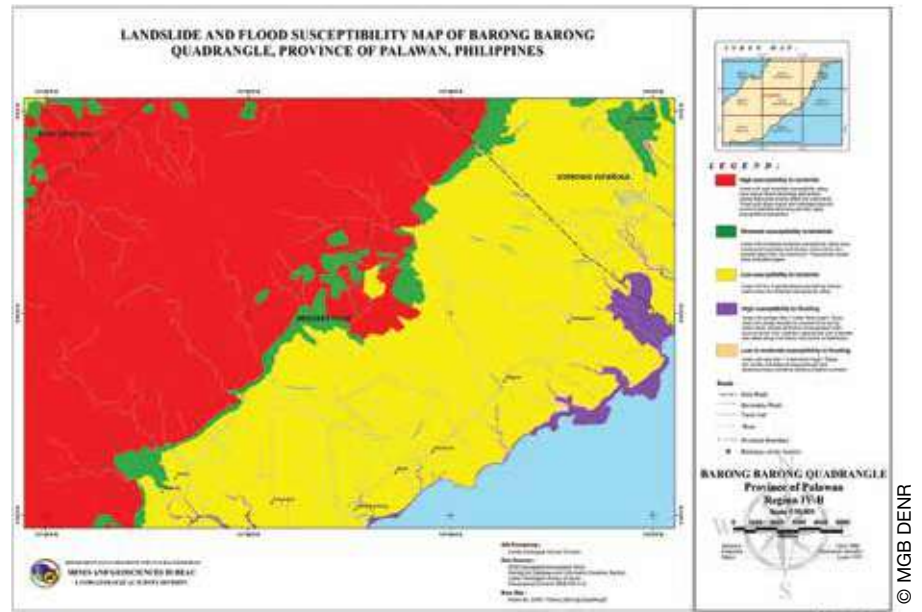
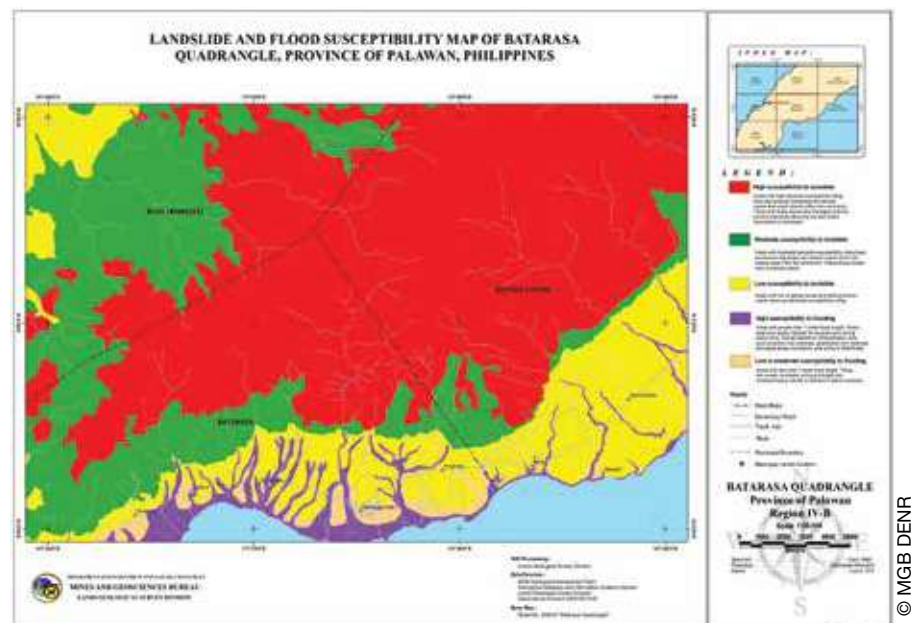
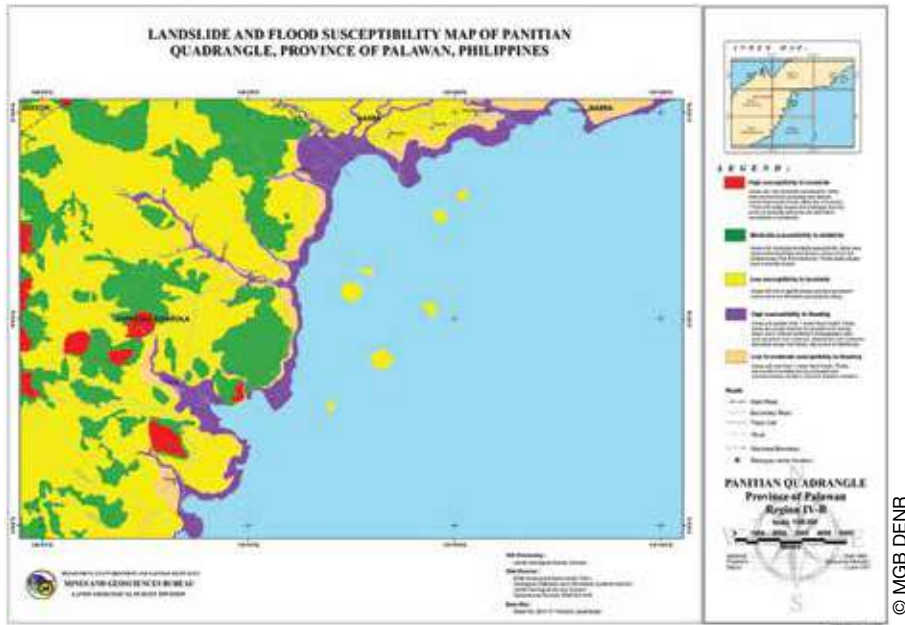


Figure 4: Landslide and flood susceptibility map of Bataraza, Brooke's Point, and Rizal.



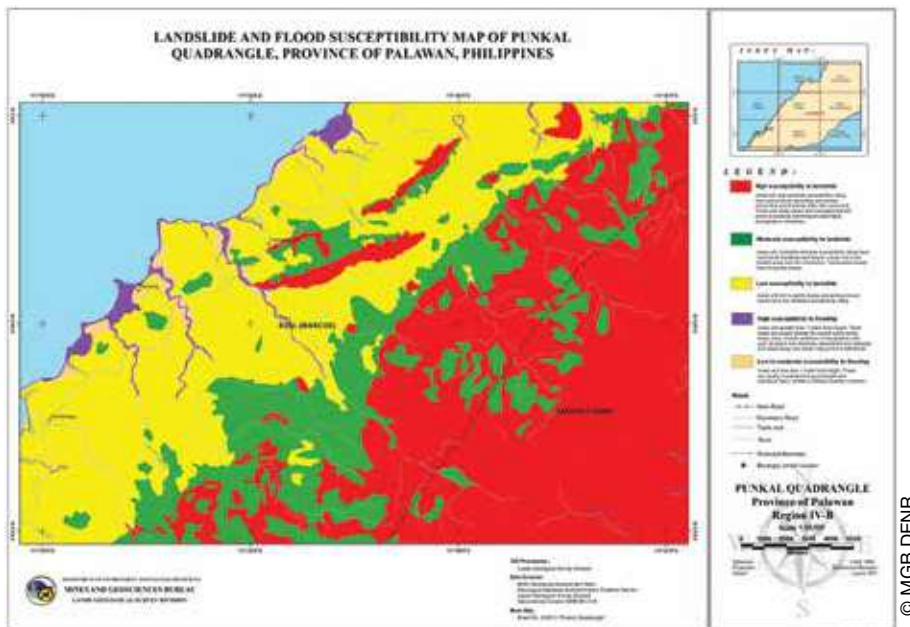
Parts of Bataraza, Brooke's Point, and Rizal have moderate to high susceptibility to landslides. Parts of Bataraza and Brooke's Point also have high susceptibility to flooding.

Figure 5: Landslide and flood susceptibility map of Sofronio Española.



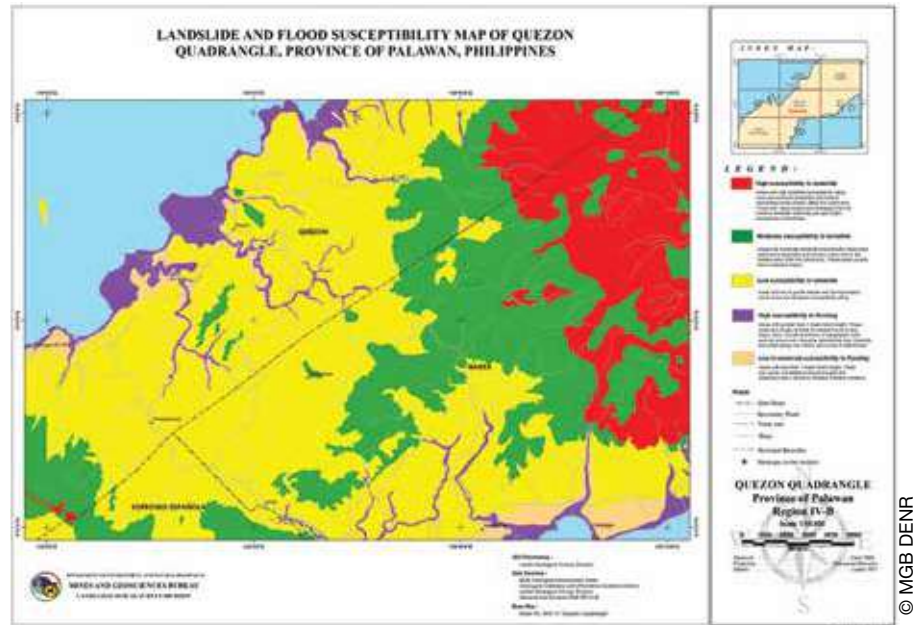
Sofronio Española has areas with low to high susceptibility to landslide as well as areas with high susceptibility to flooding.

Figure 6: Landslide and flood susceptibility map of Rizal and Brooke's Point.



Parts of Rizal and Brooke's Point are moderately or highly susceptible to landslide, with the latter being also highly susceptible to flooding. Rizal has high landslide and erosion risks due to agricultural activities by non-indigenous individuals who were able to buy parcels of land in the ancestral domain.

Figure 7: Landslide and flood susceptibility map of Sofronio Española and Quezon.



Parts of Quezon have high susceptibility to flooding with some areas having low, moderate, and high susceptibility to landslides.

Secondly, MMPL suffers from various socio-economic pressures. As mentioned earlier, MMPL is occupied by indigenous peoples whose livelihoods depend on the mountain's resources (Barraquias, 2005). In addition, MMPL is also threatened by illegal activities such as wildlife poaching and timber logging, land cover change from forest to agricultural land, tan barking from mangroves, and mining interests (Anda, 2010; CI-P, 2011).

The declaration of MMPL in itself has contributed to reducing disaster risk and socio-economic pressures on Mount Mantalingahan because it brought attention to the area's conservation and development needs. Interventions were then properly targeted towards addressing these challenges. While much work still needs to be done to ensure that MMPL and its people and resources are continually safeguarded from disasters and socio-economic pressures, CI-P continues to work in MMPL by providing financial and technical support to the MMPL's institutions and occupants. Several of CI-P's efforts have partially addressed the main challenges in MMPL including disaster risk reduction. These efforts are described in the following section, focusing on the activities undertaken in cooperation with

the local communities of five municipalities in MMPL.

2. Methodology

Throughout the preparation phase for Mount Mantalingahan to be formally declared as a protected landscape, CI-P and the newly-organized Protected Areas Management Board (PAMB) strived for a participatory approach with the communities that were affected by the changes brought about by the declaration of MMPL. The communities had to comply with the prohibitions of the NIPAS Act (1992, p. 38), which includes *'hunting, destroying, disturbing, or mere possession of any plants or animals or products derived from the protected areas without a permit from the Management Board'*. With these prohibitions in place, it seemed that the traditional lifestyle of the indigenous peoples living within MMPL was no longer in accordance with the law. This was one of the challenges that the MMPL's PAMB along with CI-P have worked on in order to find a solution that was satisfying on both conservation and development levels.

Another challenge was addressing the disaster risks in MMPL (outlined in the previous section) due to its topography and

anthropogenic activities² by the protected landscape's occupants and outsiders. These disaster risks fall under 'shocks' if scrutinized under the Sustainable Livelihoods Framework (SLF) of Ellis (2000) (see Table 1). Access to livelihood assets is influenced by social relations and institutions in the context of trends and shocks (Ellis, 2000). These then result to livelihood strategies that are composed of natural resource-based activities, which have corresponding effects on livelihood security and environmental sustainability.

In the case of MMPL, disaster risk reduction (DRR) was carried out alongside conservation and development activities. While DRR can certainly be pursued as a standalone endeavour, in the face of limited budgets, it is more cost-effective to implement DRR along with other activities in the protected landscape. The following subsection describes the tool that CI-P has used in implementing DRR as well as conservation and development actions in MMPL.

² A study conducted in 2013 revealed that landslide risk in MMPL is exacerbated by agricultural activities in open forest areas. These induce soil erosion and landslides due to overturning of the soil during cultivation and removal of vegetation, leading to loose soil during heavy downpours and/or very dry conditions (Garinga, 2013).

Table 1: Sustainable livelihoods framework (Ellis, 2000).

Livelihood Platform	Access modified by	In the context of	Resulting in	Composed of	With effects on
Assets Natural Physical Social Human Financial	Social relations Gender Class Age Ethnicity etc.	Trends Population Migration Technological change Relative prices Macro policy National economies World economies	Livelihood Strategies	Natural Resource Activities Collection Cultivation (food & non-Food) Non-farm natural resource	Livelihood Security Income level & stability
	Institutions Rules Customs Tenure Property rights Markets	Shocks Drought Floods Pests & disease Civil war Economic crisis		Non-Natural Resource Activities Rural trade Other services Rural manufacturing Remittances Other transfers	Environmental Sustainability Soils & land Water Rangeland Forests Biodiversity
	Organizations Associations NGOs Local government State agencies				

2.1 Conservation agreements

CI-P used Conservation International's (CI) 'conservation agreement' approach under its Conservation Stewards Program. A conservation agreement (CA) is a negotiated arrangement between the resource owners – in this case, MMPL's occupants – and a proponent of conservation (CI, 2007). CI-P used CAs in mitigating the impacts of hazards as well as the conservation actions for Mount Mantalingahan alongside the pursuit of socio-economic benefits for its communities.

There are several steps involved in the crafting of a conservation agreement and its implementation (Figure 8). The CA model is a mix of top-down and bottom-up processes. Phase 1 involves a rapid feasibility analysis by an external proponent (or so-called non-local experts) in order to assess whether an area based on several criteria such as biological priority, biodiversity threats, and ability of resource users to be effective conservation partners (CI, 2007). In the case of MMPL, the external proponent is CI-P and the resource users are the occupants of MMPL from five different provinces. Phase 2 is where the external proponent presents the terms of a conservation agreement to the resource user and where decisions are made to pursue such agreement or not.

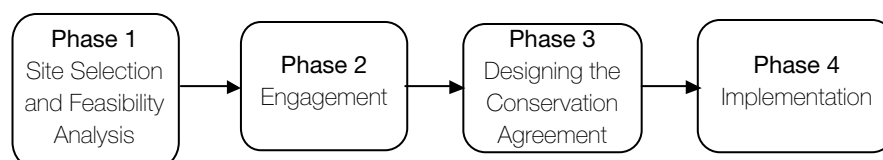
Once the resource users and the external proponent agree to work together, further steps (Phase 3) can be taken to design the actual conservation agreement (CI, 2007). When the agreement is formally signed, Phase 4, implementation of the CA, may take place.

Community-based forest restoration

Conservation agreements with one *barangay* in each municipality under the MMPL included interventions on forest protection and restoration. CI-P used CAs in addressing resource exploitation, which can be in conflict with conservation of biodiversity in MMPL. Concurrently, these were also important steps towards participatory DRR in Mount Mantalingahan. In the case of MMPL, CAs served not

only as vehicles for conservation, but also for addressing landslide and flooding risks as well as livelihood improvement. Reforestation is seen as a DRR tool against landslide and flooding, with the awareness that native forests can reduce the frequency and severity of floods (Bradshaw *et al.*, 2007 as quoted in Laurance, 2007) and of landslides (Forbes and Broadhead, 2013).³ In the reforestation activities described in the following subsections, most have tried 'rainforestation' or reforestation using native tree species instead of exotic timber species (RIP, 2010).⁴ CAs in MMPL took advantage of the multiple benefits of reforestation and incorporated conservation, DRR, and livelihood improvement. These benefits resonate with the social and ecological

Figure 8: CI's Conservation Agreement Model.



(Data source: CI, 2007).

³ Note, however, that increasing the number of forest plantations may lead to longer and more frequent floods (Bradshaw *et al.*, 2007 as quoted in Calder *et al.*, 2007).

⁴ For more information, see <http://www.rainforestation.ph/index.html>.

indicators (see Table 2) that the PAMB is using to monitor and evaluate MMPL's progress. The following subsections detail the CAs made with the barangays in MMPL. All of the barangays were involved in CAs with CI-P; however, only three barangays reported back to CI-P. Only these three barangays are included in this paper.

Bono-Bono Watershed, Bataraza

In July 2009, the Palawan Tribal Council of Marinsyawon, the Local Government Unit (LGU) of Bataraza and CI-P agreed to maintain and protect the forests of Marinsyawon, Bono-Bono, and Bataraza in MMPL. The tribal council has agreed on specific conditions for the protection of the forest and associated habitat and species within Marinsyawon as part of the entire MMPL.

Five hundred (500) hectares of primary forest classified as core zone are maintained through forest patrolling of four trained and equipped community volunteers. The community-based patrol was responsible for securing the area from illegal activities and in disseminating conservation messages to neighbouring villages. Three hectares of denuded areas reforested in the first year were expanded to ten hectares in the second year and an additional three hectares in the third year (Figures 9 and 10).

Lamikan Watershed, Quezon

In April 2012, CI-P concluded a 30-month grant partnership with the NGO Institute for the Development of Educational and Ecological Alternatives, Inc. (IDEAS) for the implementation of a conservation agreement in Lamikan watershed in the municipality of Quezon. The area covered by the project is comprised of 65 percent of the 15,000-hectare Lamikan watershed within MMPL, an area where around 150 households live. A total of 18,000 indigenous tree species were planted in two sites designated for enrichment planting. Seventy-one (71) households participated in a number of agroforestry activities, including capacity building, farm planning and farm improvement implementation. These activities included the planting of agroforestry species as a means of fostering long-term food and income source. In addition, two nurseries

Figure 9: Before planting in the year 2009.



producing indigenous fruit and forest species were established (Figure 11).

Two community associations were also organized, trained and mobilized towards protecting MMPL and promoting complementing livelihood activities through NTFP enterprises. The organizations are called the *Samahan ng mga Magsasaka sa Kakawitan at Linaw (SMMKL)* and *Samahan ng mga Magsasaka sa Sitio Malinaw, Calumpang (SMSMC)*. They were trained in organizational management, livelihood enhancement and forest protection. These two community organizations also became members of the Quezon-based federation being facilitated by IDEAS which can somehow provide continuity of the engagement even after the end of the project.

Community-managed water system

One of the CAs used positive reinforcement in pushing for reforestation and conservation in MMPL. As mentioned in the previous section, Panalingaan's susceptibility to landslide and erosion is partially caused by agricultural activities by outsiders. Integrating means of reducing disaster risks while addressing the needs of Panalingaan's community maximizes

Figure 11: Seedlings production at a nursery in Lamikan using native and adapted agroforestry species.



Figure 10: After planting in the year 2011.



both limited resources and chances of sustained community involvement in DRR.

Panalingaan Watershed, Rizal

Through a conservation agreement, CI-P worked with the indigenous people's organization Bangsa Palawan Philippines, Inc. (BPPI) in a watershed management initiative in the *barangay* of Panalingaan in the municipality of Rizal. One of the components of the conservation agreement is the construction of a water system that will benefit Kadulan village. The water system was completed in 2012, benefiting 100 households. To ensure continuous flow of clean water in the pipes, the agreement included a forest protection and restoration component, covering the headwaters of Panalingaan watershed. A nursery with a capacity of 5,000 indigenous forest and fruit tree species was established and managed by the community. As of 2013, the reported and validated reforestation area with regular maintenance by the community members themselves is 21 hectares.

Bono Bono Watershed, Bataraza

A water system (ram pump) was installed in Bono Bono through the facilitation of CI-P; this was sourced through another funder and, hence, not under a CI-P CA. However, elements of a CA were still used in the project implementation. Prior to the installation of the ram pump in the forested spring in Bono Bono, the villagers used to get water 'from the next mountain', which was – at least – an hour's trek away. The community members can only carry up to two gallons of water at a time. This difficult situation made it easy for the mountain settlers to agree to the ram pump project terms, which required them to provide the construction labour and to take care of the water facilities on their own thereafter.

Table 2: Minimum monitoring indicators in MMPL.

OUTCOMES	MONITORING CATEGORY	INDICATORS	MONITORING METHODS
Avoiding species extinction	State of biodiversity		
	IUCN-listed, endemic and locally-important	Number of IUCN-listed species	Verification from IUCN Red list updates. An MMPL database of species exists.
	Change in the number of IUCN-listed species	Percent change in number of individuals	
	Change in category of the IUCN-listed species	Number of enlisted/delisted/downlisted species	
	Pressure on biodiversity		
	Exploitation of threatened species	No. of individuals/species confiscated/apprehended	Verification from apprehension records of DENR and the Palawan Council for Sustainable Development (PCSD)
	Presence of exotic/invasive species	Relative frequency and percent cover of invasive/exotic species	Key informant interviews, in the interim because no formal monitoring exists yet
	Institutional response		
	Species-specific legislative protection	No. of policies and legislations in place	Verification from PAMB and PCSD and DENR archives of policies/resolutions
	Research on threatened, endemic and locally-important species	No. of species-related research conducted	Research database
	Contribution to human well-being		
	Decreased dependency on threatened species as source of income	Percent income derived from livestock and agricultural goods	Community-based monitoring system (CBMS) conducted annually; an organized survey questionnaire carried out every 2 years by the local government units
Area/site protection	State of biodiversity		
	Change in habitat cover	Percent change in forest cover	Forest change detection analysis
	Change in land-use	Hectares of forest converted to other land-uses	Forest change detection analysis
	Water quality of river system	Deviation of physical and chemical parameters from national standard range values.	Laboratory results from PCSD's water quality monitoring
	Pressure on biodiversity		
	Habitat destruction /loss	Percent of land within critical habitats subjected to destructive activities	Forest change detection analysis; site verification
	Population movement	Population growth rate	CBMS
	Community built-up areas adjacent to MMPL	Percent of built-up areas in MMPL buffer zones	Forest change detection analysis; site verification
	Institutional response		
	Establishment and management of local conservation areas	No. of well-managed local conservation areas	Maps
	Contribution to human well-being		
	Livelihood support services	No. of livelihood/projects implemented	Project reports, focus group discussions and key informant interviews
Increased importance for tourism	Income derived from tourism in MMPL	CBMS	
Types of land tenure within and adjacent to MMPL	Hectares of land with tenurial instruments within and around MMPL	Verification from DENR and NCIP records; maps	

A water users' association called *Penegsulutan et Gensan Peg Eepat kay Danum Amason* (DOLE Registration No. 012-1249) was also founded. A Bono Bono Watershed Management Plan with a strong solid waste management component was put in place and a community common fund was established along with initial policies that detail how members may benefit from the fund. This community common fund is able to support capital investments needed for the community's NTFP enterprise. This is being augmented by a crude payment for ecosystem services (PES) scheme from monthly payments by the water users.

2.2 Monitoring and evaluation

CAs with MMPL communities follow the monitoring indicators laid out in the Mount Mantalingahan Management Plan. These are focused on two outcomes: (1) avoiding species extinction and (2) area and/or site protection. These are monitored based on four categories: state of biodiversity, pressure on biodiversity, institutional response, and contribution to human well-being. Monitoring methods range from desktop-based research such as forest change detection analysis⁵ to field-based key informant interviews, focus group discussions, and community-based monitoring systems (CBMS).⁶ The list of minimum monitoring indicators can be found in the following table:

3. Results

DRR is not only a matter of reducing vulnerabilities or mitigating the impact of hazards; it is also about developing and enhancing adaptive capacities of individuals, communities and institutions (Dumsey, n.d.). The CAs signed by CI-P with five barangays in the five municipalities in MMPL incorporate mitigation of hazard impacts through community-based reforestation as well as development and/or enhancement of community adaptive capacity through livelihood opportunities. The results of these are discussed in the following subsections.

3.1 Controlled soil erosion and flooding

The CAs described in the previous section detail tree planting activities carried out in three out of the five villages of MMPL. This component is seen as mitigating hazard impacts in MMPL. One CA was made per village and three out of these five conservation agreements reported increased forested areas, which have contributed to controlling soil erosion and flooding based on reports from the communities to CI-P regarding the community-based forest restoration activities. Most of the trees planted were in the headwaters. One of the elders in *barangay* Panalingaan, in the municipality of Rizal mentioned that:

'We, Palawans in the Panalingaan community, are aware that the trees within the aquifer should be kept intact; otherwise, we might lose our water source. This is why we make sure that we continue planting (fruit) trees especially near our water source and any agricultural activities especially in the high sloping areas are discouraged in our community.'

Another elder, the *Panglima* or the highest official in the tribe in *barangay* Bono Bono in the municipality of Bataraza, also said the following:

'We can no longer burn in the areas where the water comes from. We need to work together to protect the water.'

Community-based reforestation along with protection of existing vegetation – as exemplified by the forest patrol in Bono Bono Watershed in Bataraza – synergistically work to reduce the risk of landslide in the area. For CI-P, this leads to increased regulating ecosystem services in MMPL; it also consequently shows how interventions can strengthen the ability of protected landscapes to provide natural hazard regulation and contribute to DRR.

The forest protection and restoration activities have corresponding co-benefits to the well-being and livelihood of the local communities. These co-benefits were (and still are) important in engaging the local communities in conservation and in sustaining DRR in their respective areas in MMPL.

3.2 Livelihood enhancement

The development of livelihood opportunities and enhancement of livelihood skills in selected MMPL communities was related to the forest protected and restoration activities discussed in the previous subsection. Most of the livelihood opportunities were derived from forest products. For instance, the aforementioned elder in Panalingaan also mentioned:

'We are optimistic about the potential of non-timber forest products such as fruits that can be gathered from the trees we planted near the water source and the slopes. We can benefit from this in the long-term. For that we are thankful to MMPL and CI-P.'

To provide supplemental supply for a family's daily food consumption, multi-cropping among upland farmers was promoted in Panalingaan. CI distributed crops such as cassava, banana and pineapple to several households. This was complemented with coconut seedlings, fruit trees, livestock, and water buffalo intended for farm use and transport of products. After several harvests, another community member testified that he had saved enough food stocks for his family and sold the extra produce in the market. He belongs to the first batch of recipients of the livelihood support project in Sitio Kadulan, Barangay Panalingaan, Rizal. In early 2013, some community members also participated in an organic farming demonstration project introduced by another organization and a local university.⁷

In the Bono-Bono Watershed in Bataraza, prior to the implementation of the CA, the average annual income per household was PHP 11,306 (US\$ 226) based on estimates of both cash and non-cash incomes from the produce of their upland farms,⁸ livestock, rattan, handicraft and wild fruits sold (cash income). Cash income constitutes 70% of the total income, which is approximately PHP 7,876 (US\$ 157). Through non-timber forest product (NTFP) utilization, the community was able to

⁵ The forest change detection analysis includes data from the years 2003-2010. The next analysis will be carried out for the years 2010-2017.

⁶ For more information, see <http://cbmsphilippines.webs.com/>

⁷ Shell Foundation and Western Philippines University.

⁸ Includes rice, *kamote* (sweet potato or *Ipomoea batatas*), banana and pineapple for household consumption only (non-cash income).

sell *tingkeps* (native baskets), placemats, *biday* (native blinds and table runners), and *walis tambo* (brooms)⁹ in shops in the municipalities of Puerto Princesa City (capital of Palawan), Brooke's Point, and Bataraza, with a total accumulated gross sales of PHP 107,800 (US\$ 2,695) as of June 2013. The community, at this stage, was able to strengthen their marketing skills by being able to establish a regular and permanent market for their handicrafts. With the increasing demand for *tingkep* in and outside Puerto Princesa, the community intends to augment the supply by buying from neighbouring producers.

In the Lamikan Watershed in Quezon, a buy-and-sell enterprise of agroforestry products such as peanuts and fruits gave an additional income of PHP 5,940 (US\$ 136) for the organization. Part of this income was distributed to the association members while the rest was set aside to form part of the association's funds.

4. Discussion

4.1 Conservation and disaster risk reduction

While different trees with different root systems were planted, this paper assumes that planting trees and preserving existing vegetation synergistically work to reduce disaster risks especially against landslides. Preti's (2013) study cited the role of forest cover in reducing shallow landslide hazard and this supports what Rice mentions in his 1977 study that there is increasing evidence that more vegetation on a site lowers its susceptibility to landslides. In his appraisal of landslide risks, Rice discussed the roles of physiography (slope, position in relation to drainages, and unstable areas), soil and geology (rock type, weathering, stratigraphy and structure), climate, and vegetation. Among these, the most accessible to human intervention is vegetation. Reduction of shallow, rapidly moving landslides can be achieved with the contribution of deep-rooted trees and shrubs through strengthening soil layers and improving drainage (Forbes and Broadhead, 2013). Trees contribute as well to high infiltration capacity of forest soils through removal of water from soil

pores, which consequently create space for additional water storage (Makuch, 2008). Reforestation may, therefore, also contribute to reducing flood risk. CI-P's efforts have, thus, focused on improving forest cover and/or conserving existing vegetation.

The construction of water reservoirs is important in encouraging communities to conserve forests and restore degraded areas. They were made aware that the trees in the watersheds should be kept intact; otherwise, water flow to water sources (through aquifer recharge) might be reduced (USDA Forest Service, 2013). Efforts by CI-P to increase local stewardship and governance of the area's resources have been instrumental in the good performance of MMPL, which has been awarded the best protected area under the category of partnership with civil society during the first protected area awards of the Department of Environment and Natural Resources (DENR) of the Philippines in 2013. The success can be attributed to two things: first is ample financial support – MMPL has been supported by the Global Conservation Fund (GCF) of CI. Note, however, that this type of financial support did not equate to mere dole-outs. The conservation agreements served not only to outline roles and responsibilities but to also train the local communities in soft skills such as accounting and financial management, business marketing, and administrative organization. A second contributor to success is the dedication of CI-P in addressing knowledge gaps of the affected communities and involving them in decision-making – this was crucial in building the confidence of communities in managing their ancestral land in a culturally, ecologically, and socially sound manner.

4.2 Challenges and lessons learnt from CAs

The success of CAs constitutes part of MMPL's progress towards sustainability, and the short-term nature of CA fund grants allows for a periodic evaluation of both institutional and community-level performance. Several lessons learned from the CA process were given by grantees through their reports. These are as follows:

1. Institutional and community-level participation – In principle, participation and engagement are recognized

as important in most landscape conservation work. However, it is not as easy in practice. Meaningful participation of directly affected stake- and rights-holders (especially the communities and the local government unit) throughout the implementation process (and not only during the initial stages) is critical to ensure strategic direction of the project will be upheld.

2. Community organizing – In order to encourage local community participation, they must be organized in a way that gives them a greater role in implementing a project especially when livelihood efforts will be pursued. Institutional mechanisms must be set up amongst themselves and external parties need to recognize that community organizing is non-linear. It is a cycle of ups and downs and reinforcing community actions will still be needed as more and more development opportunities and actions emerge. This was especially true in Lamikan, Quezon where the sense of community was less evident compared to those in Panalingaan, Rizal. It is definitely easier to work with organized communities who already have institutional mechanisms in place and/or are in the process of developing such.
3. Cultural sensitivity and making use of anthropological studies – The Palawans still have nomadic kinsmen called Ke'nuy (or Ke-nuy or Ke'ney) who are harder to organize under CAs designed for non-nomadic Palawans. Anthropological studies would have been useful in understanding the dynamics and tendencies of the Ke'nuy tribe as well as their relation to other tribes and stakeholders in MMPL. In addition, there have been instances where young half-Palawans (not pure indigenous) put in leadership positions have forsaken their kinsmen. It is important to empower pure indigenous Palawans and believe in their potential for leadership, because they are more likely to have empathy towards their kinsmen.
4. Types of intervention – Long-term livelihood interventions must be complemented by livelihood opportunities with short term economic benefits in order to address immediate concerns such as poverty survival.

⁹ 4,000 *tingkeps* (native baskets), 800 placemats, 1,200 *biday* (native blinds and table runners), and more than 1,000 pieces of *walis tambo* (brooms) were sold.

5. Exploring other approaches – It might be worth exploring a watershed approach that covers the entire watershed of Lamikan within Mt Mantalingahan covering the *barangays* (or villages) of Sowangan, Tagusao, Calumpang and Quinlogan in the municipality of Quezon and part of Bunog in the municipality of Rizal. A watershed management structure may be set up solely for this purpose. However, in order to realize this, bigger resources are required.

5. Conclusion

There are still a lot of challenges in MMPL but its successes in several municipalities throughout the years have established a model of partnership with local communities that can be referenced for work in other protected landscapes on disaster risk reduction or conservation.

MMPL now serves as a field model, demonstrating how protected area management, which values and protects nature's assets, can foster human well-being at the community level and support communities for their sustainable sources of livelihood. The current level of good progress within MMPL is largely due to the socially-inclusive processes that CI-P and the PAMB have painstakingly observed even before the protected landscape was formally declared. The conservation agreements between CI-P and several communities under the MMPL did not only contribute to landslide risk reduction through vegetation management but also to improvements in community livelihood through water reservoir installations and development of community forestry enterprises. The positive outcomes from the conservation agreements show that social processes in protected area management should be taken seriously. Through the use of both local knowledge

and external knowledge, MMPL benefited from a holistic perspective that was able to look at the common interests of the people and the protected landscape and design interventions that have both of these in mind.

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Chapter 13

Human perturbation and environmental governance of the coastal lagoon of A Frouxeira, Spain, for seasonal flood mitigation of suburban dwellings

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Abstract

The coastal lagoon A Frouxeira is a natural protected area, declared as a Ramsar Convention wetland (1993) and a European Site of Community Importance (2004). It comprises various interrelated habitats that are home to a number of threatened species. The shallow lagoon undergoes seasonal variation between low-water and high-water (already featured by Pardo in 1948 and Dalda in 1968) following the spontaneous opening of a canal or closure by a sand bar. The seasonal strengthening of the sand bar increases the level of freshwater and causes periodic flooding of housing units developed in the lagoon shoreline. Continued human disturbances in the canal – and the whole wetland system – have modified ecological processes and increased the flooding hazard while suburban encroachment increased vulnerability. Various consecutive flood events triggered dissenting views regarding mitigation of multiple stakeholders and ultimately social and political conflict. Environmental restoration has managed to stabilize some components of the system, but the floods are a symptom of more general ecological instability and a factor for social disruption.

1. Introduction

The A Frouxeira protected area is a complex of interrelated habitats with a shallow coastal lagoon at its core, located at the northwest of the Iberian Peninsula,

where rias¹ are a more common coastal form. Water in the lagoon has a strong salinity gradient from the outlet, with estuarine conditions, towards the inner area with freshwater supply. The regional dominant biome is composed of temperate broadleaf and mixed forests – associated with oceanic wet climate, with weak hydric deficit. This site comprises cliffs, a sand dune system with both mobile and fixed sand dunes with herbaceous vegetation and forested areas, humid dune slacks, watercourses, reed beds, and an alluvial forest associated with watercourses. A total of 160 protected species (including some endangered or vulnerable) of plants, invertebrates, amphibians, reptiles, birds and mammals are found in the area (Xunta de Galicia, 2014). For some migratory bird species the wetland is a key habitat area for winter. Protection of biodiversity, ecosystem services and the landscape has been made possible through the designation of the wetland with different categories:

- Ramsar site (1993), whose boundary limits were modified in 2006 to exclude those sections of the site which were already a built-up area
- BirdLife International Important Bird Area (IBA) in 2000
- Special Protection Area (SPA), under the European Union Council Directive 79/409/EEC on the Conservation of Wild Birds in 2001, enlarged in 2003

- Site of Community Importance (SCI) Costa Artabra, under the Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora in 2004
- Regionally designated as an area for the protection of natural values in 2004 and a protected wetland in the same year.

The lagoon is a multiple stable state system, with an annual oscillation of the water level (Figure 1) caused by the natural seasonal intermittent aperture of a canal through the dune system at the seashore, and a horizontal variation of the salinity. Water level rise is influenced by the rainfall regime, with higher precipitation and increased freshwater supply from contributing watercourses in autumn combined with the formation of a sand bar (and the closure of the canal) by accretion. In winter, the combined action of the water pressure of the lagoon from one side, and the erosion by ocean waves and high tides from the other side, causes the occasional rupture of the sand bar and the aperture of a canal, rapidly releasing the water and making the lagoon behave as an estuary, with continued admission of marine saltwater during high tide. Thus, the lagoon, with a cyclic seasonal behaviour, moves from a state of low water with saltwater intrusion and a state of high water occasionally causing flooding in the surrounding natural and built-up areas. Sand is mobilized by natural processes of wind erosion but also by the flow of seawater into the lagoon during high tide, when the canal is open, particularly after human historical perturbations in the canal,

¹ Rias are coastal submerged fluvial palaeo-valleys, commonly wedge-shaped, flooded during the last post-glacial marine transgression.

Figure 1: The lagoon seen from the outlet with high (a) and low (b) levels of water (where the bottom crust and rip-rap groyne that keep the water base level can be identified).



with the occasional mechanical aperture of the canal when this did not occur naturally. The sand gets deposited in the northern part of the wetland, reducing the coverage of finer organic matter sediments in the lagoon bed, and causing a change in the environmental conditions for species.

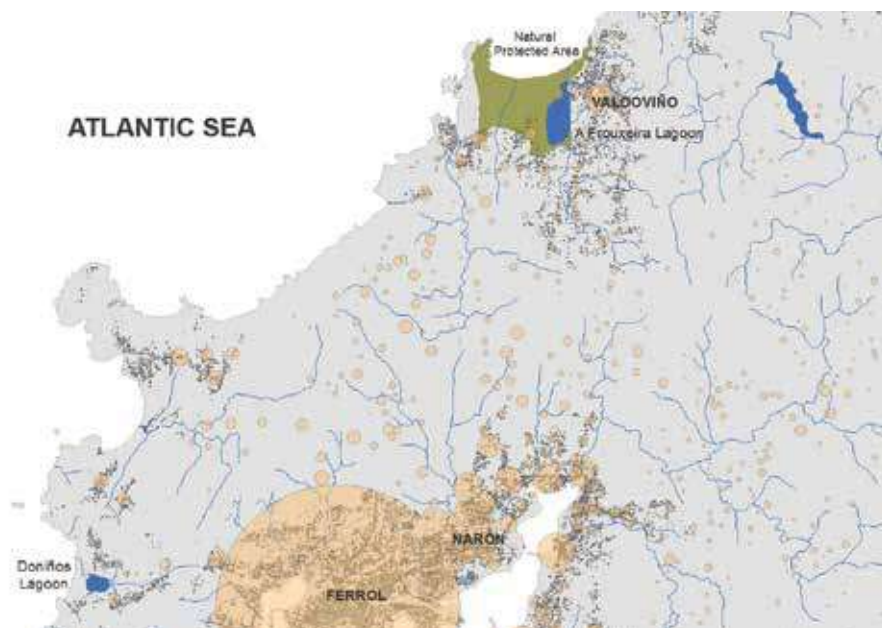
The process of suburbanization of the town of Ferrol (at a distance of 15 km from the protected area), with an estimated population of 71,232 in 2013, and Narón, with 32,924, has led to a progressively low-density encroachment of the surrounding area of the lagoon, particularly along the eastern and southern sides, where the village of Valdoviño (population of 2,285) (INE, 2013) is located (Figure 2). The area has a high population density (259 inhabitants/sq km) that exceeds by large the already high regional density (93 inhabitants/sq km). Population pressure increases gradually from spring and sharply in summer due to the arrival of holiday residents and tourists who make intensive use of the beach for recreation. Sunbathing started in the 1930s but both the process of suburbanization and the issuing of the Blue Flag to the beach within the protected area by the Foundation for Environmental Education (FEE) in 1993 made it a popular tourism destination. Today the economy in the area is based on the service industry, while farming, the former key economic basis, has sharply declined and has now almost disappeared. Recreational activities are not restricted to the sand beach area and tourists can also access the dune system area, as

pedestrians, with their pets, or with light motor vehicles. This can have negative impacts on the area, such as trampling on sensitive plant species or disruption of nesting of endangered bird species (i.e. *Charadrius alexandrinus* L). In order to increase access to the beach, paved roads and parking lots have been built inside or next to the protected area, as well as boardwalks through sand dune areas. Thus, these areas can accommodate a much larger number of visitors, who are allowed to enter with their motor vehicles the core of the protected site and the human pressure on the eastern

shore increased sharply. The contiguous suburban area is an open door for the entrance of invasive species used in private gardens or landscaping, exceeding 35 allochthonous plant species in scientific literature, 24 of which were identified in the *Draft Management Plan* of the protected area (Xunta de Galicia, 2013).

In addition to urban pressure, other major anthropogenic disturbances have occurred for the last 50 years, triggering processes that have increased instability of the system and visibly altered the extant habitats. On an annual basis, a

Figure 2: Location of the A Frouxeira coastal lagoon and the natural protected area in the suburban area of Ferrol, showing built areas and settlements.



manual aperture of a canal was historically performed by the local residents (especially farmers who had their grassland plots seasonally flooded) when opening did not occur naturally. However, the earliest event with long-term effects was industrial sand mining in the 1960s, followed by small-scale extraction. The resulting canal in the central part changed water circulation, weakening the whole sand dune system. Dunes were restored in 1984 through a cooperative effort between the municipality and an environmental NGO, closing the new canal. Later on, two disasters had an indirect effect on the lagoon that changed the course of its history. In 1992 when the tanker Aegean Sea caused an oil spill in a nearby area, the foredune (in addition to several other coastal areas) was protected with a sand barrier in order to prevent the habitat from being polluted. A similar accident occurred again in 2002, with the Prestige oil spill, although with a much higher environmental impact. A barrier of sand big bags was placed in the natural outlet of the lagoon (Figure 3). However, it was during the removal of the barrier in 2003 that the geological substrate in the outlet (that acts as a bottom barrier which regulates the lagoon water base level and inflow of seawater) was excavated and damaged (Figure 1b).

Following this event a succession of seasonal floodings of the surrounding built area occurred in 2011, 2012 and 2013, apparently due to the changes in the whole wetland system, triggering political and social conflict. Some of the stakeholders took irreconcilable positions and these were not homogeneous within each family of stakeholders, leading to a multiple-front controversy. At the governmental level, the European Union, the national, regional and the local governments hold various stances as the result of their different responsibilities in environmental management, resource management, economic development or urban planning. Also, environmental NGOs and community based organizations are no strangers to division and conflict, since different interests interplay and dissenting understanding of the problem can be found. Proposals for action range from strict implementation of environmental regulation to flexible solutions which allow limited human intervention. This led to a social conflict in which alliances and disputes between either very different or similar families of stakeholders became widespread. Every player has taken a stance and all are waiting for a key actor (the regional government) to make its move.

The regional government of Galicia, Xunta de Galicia, has the legitimacy and responsibility as well as the technical and financial capacity to become the leading institution in this situation. It not only has the capacity to design, implement and monitor policy development, but also to collect data, produce information, and involve all stakeholders. However, due to conflicting responsibilities and in particular, regional and urban planning versus environmental planning and management, the regional government may end up in controversies. This paradox is also found at other levels of administration. For example, the national government is responsible for delineating the boundary of state oceanic and terrestrial waters, and this has been done in the area without taking into account the variable water level of this coastal lagoon. In addition, at the lowest level, the municipality elaborates land use plans and zoning, however it still operates with a plan elaborated in 1994 (Deputación Provincial da Coruña, 1994) when the environmental protection of the lagoon was just underway. Thus, urban planning is neither taking into consideration both the extensive transformation in the last twenty years in terms of urbanism and economic change nor the environmental values and protection in place.

2. Methodology

Various actions have been taken to mitigate impacts caused by past human disturbances in the dune system or to respond to seasonal floods on the shore of the lagoon. But, since integrated action has neither been planned nor implemented thus far, other development actions are entering into conflict with the goals of ecological restoration and adding vulnerability, concurrently increasing the level of risk of some residents and environmental pressure over the habitats.

2.1 Actions to protect the dune system from marine pollution

When various oil spill disasters occurred in the adjacent coastal area, sand and sand big-bag barriers were placed on the seashore to protect the lagoon from being polluted. However, the use of heavy machinery to mechanically remove the sand barrier in 2003 damaged the bottom rock crust of the outlet, which acts as a water base-level regulator. This led to deeper discharges of the water in the

Figure 3: Water canal in the outlet connecting the lagoon and the open sea.



lagoon (Xunta de Galicia, 2013) and the loss of environmental quality as wetland during seasonal conditions of low-water. Use of heavy machinery in the protected area further intensified existing disputes and questioned the need to intervene in the natural process of freshwater charge and discharge amongst the stakeholders.

2.2 Actions to restore the dune system and protect the habitats

The damages caused by industrial (particularly the opening of a new canal in the central part of the dune system) and small-scale sand mining were partially corrected. This non-natural aperture was eventually closed after a restoration process, helping to stabilize the processes of erosion and sand deposition in the northern area of the lagoon and favouring the return to intermittent circulation through the long-established eastern natural canal. Furthermore, 23 informal residential cabins built over the easternmost part of the dune system and an adjacent restaurant that brought many visitors to the vulnerable area were demolished in 1996 and 2007 respectively. The dunes were restored using native species of vegetation (Figure 4). This managed retreat of the built area followed by environmental restoration led to a reduction in human vulnerability to windstorms and coastal flooding, and ultimately became turning points in the local perception of the limits to urban

growth. In the 1990s a set of conservation schemes with national and international scopes (see above, section 2) started to be adopted to appropriately manage the complex of habitats. To complete these, the process of design and elaboration of a management plan of the site has commenced recently, and is expected to be completed throughout 2015.

2.3 Disturbances in the canal and the emerging hazard

These actions have been particularly controversial, because not only is their impact on the habitats uncertain but they have also undoubtedly interfered in the functioning of the lagoon system. The manual – and spatially limited – opening of the sand bar to limit the exposure of meadows to floods on the shore of the lagoon, traditionally performed by local farmers during the high-water season, has been followed over time by mechanical opening with heavy machinery to prevent new housing units and infrastructure on the shore of the lagoon from flooding. Evidences of damage in the rock crust of the outlet have been identified, disrupting the water base level of the lagoon (Xunta de Galicia, 2013) and the sand inflow-outflow balance and dynamics. Mismanagement during the flooding events in the last years, together with poor communication of the limits of the kind of operations that can be performed

in a protected area and the mechanical opening of the sand bar to facilitate the discharge of the lagoon water, polarized the positions of stakeholders regarding the environmental protection of the site. While some residents occupied the city hall during the winter holidays in 2011-2012 to protest against government inaction to resolve flood issues, other actors (not only environmental NGOs, but also residents) lobbied against all potential interventions.

2.4 Disturbances on the shore of the lagoon and rising vulnerability

The construction of a foreshore way in the eastern part of the lagoon (Figure 5a) invading the ecotone of riparian forest between the lagoon and adjacent uplands (Figure 6), and of boardwalks accessing the centre of the beach from the south, invading the grey dunes and the whole dune system in two locations (Figure 5b), are increasing the pressure over some critical habitats, if we particularly take into account the small size of the protected area. Both accesses have been designed for recreation since they are an extension of two respective car parks, substantially increasing accessibility. Despite the demolition of private informal developments over public land that had reduced human vulnerability along the coastline, this infrastructure has had a contrary effect by attracting fresh interest in the shoreline of the lagoon and the dunes from visitors and by consolidating rights of way for housing units on the lagoon shore. Thus, the location of the jurisdictional boundary between public and private land has been a key factor both to reduce and increase exposure to lagoon and coastal flooding. Had this boundary delineation considered the seasonal water oscillation and incorporated the lagoon into the coastal system, it is probable that suburban developments would not have occurred on the lagoon shore, and the limits of the protected area would have been more in harmony with ecological processes.

Processes of development, restoration, planning or management have predominantly been top-down, even in times of conflict, with a disregard for facilitating dialogue and negotiations among all the stakeholders, that could be particularly useful to allow exchange of knowledge and learning from other points of view. This weakness is explained

Figure 4: Restored area after the demolition of buildings that invaded public land.



Figure 5: Foreshore way in the eastern part (a) and boardwalks in the central area (b) of the lagoon.



by the feeble participatory approach of political processes in Spain at large which scores higher on state capacity than on civil society (Sissenich, 2010), essentially based on selective consultation, one-way stakeholder-to-government interaction, rather than allowing an all-actor holistic interaction, and weak political involvement of societal actors (Lancaster & Beck-Lewis, 1986). The process of elaboration of the environmental management plan of the protected area has been initiated by the regional government with open consultation to all stakeholders in 2014 (Xunta de Galicia, 2013), marking a turning point in the formal knowledge available to

the public about the existing environmental values.

Research to understand the social conflict was made through interview methods (reports currently in print). Several difficulties arose during field work. Some interviewees were reluctant to participate because the interviewers were identified as possible supporters of the regional government position, or at least as having a natural inclination for a certain position instead of being neutral. An environmental NGO lodged complaints with the European Commission in 2010 and 2012 against Spain, as a member state of the EU, for

the actions to discharge the lagoon and the impacts caused to bird species in the area protected by EU law (ADEGA, 2012), while the residents on the lagoon shore, who saw their properties flooded, filed both a lawsuit (El Pais, 2012) and a complaint to the regional ombudsman (La Voz de Galicia, 2012) against the regional government for its inaction during the 2012 floods.

3. Results

Despite the fact that environmental and social conflicts are still ongoing (and may even continue beyond any kind of court decision regarding governmental actions and the environmental management plan) some results can be identified.

Figure 6: Riparian forest in contact with farmland.



In the course of time, wider consensus has been achieved regarding the need to protect the site. Perhaps this was helped by the increased awareness of the environmental values of the wetland resulting from the multiple controversies about the management of the site brought by the various emerging threats. However there is no consensus about its boundary limits or about the land uses compatible with conservation, especially since some stakeholders consider that there should not be limits to recreation on the beach or to fishing, nor to urban development in built-up areas. Some components of the conflict should be clarified and eventually resolved through the environmental management plan.

No consensus has been achieved regarding the human-made aperture of the sand bar to facilitate the discharge of the lagoon water when there is flooding on a section of the built-up area, and the enclosing paved and unpaved eastern foreshore during the high-water season. However, there is consensus that heavy machinery cannot be improperly used. The most difficult consensus to reach might be regarding the eventual relocation of houses and infrastructure located on the eastern shore of the lagoon, as well as regarding the use of the beach in summer time. Expanding economic interests result from the growth of tourism, increasing both the pressure on habitats and the number of stakeholders supporting recreational use.

Moreover, some of the underlying factors may increase the complexity of the problem. The process of suburbanization and encroachment on the lagoon (Figure 7) continues and may intensify with future economic recovery. Pressure over the resources and ecosystem services are expected to increase, since the current urban plan of the village of Valdoviño allows for the intensification of urban density up to the shore of the lagoon. The abandonment of farming has increased the pressure to change zoning from farming land to residential land or, as a transient alternative, to planted forest with non-native species, such as *Eucalyptus sp.* and *Pinus sp.* Despite the fact that wastewater management is working properly on the eastern side, diffuse pollution carried by runoff and by small water courses to the lagoon might increase with higher urban density. Waste water from the urban section on the shore of the lagoon is collected in a water pumping station located by the shore. Its failure may drive untreated wastewater into the lagoon, particularly during flooding events. Human pressure may lead some of the endangered species to extinction in the area, particularly those living in the dune habitat, where the improvement in accessibility brought a larger number of visitors and increased difficulties to enforce the law and make compatible conservation and recreation. Finally, since plans to eradicate invasive plant species have not been implemented yet (the draft plan for the management of exotic species at the regional scale was made public in late 2012, and the Draft Wetland Management

Figure 7: Encroachment of the eastern side of the natural protected area (the lagoon is in the background).



Plan focuses on the prioritization of five species), these species will continue to colonize the protected area.

Human interventions have gradually increased the instability of the system and reduced the quality of the ecosystem services provided. However, restoration of the central section of the dune system and protection against oils spills has had an evident positive effect. The removal of built infrastructure for visitors on the beach and sand dunes allowed limited restoration with native vegetation and did affect the liveliness of the tourism business. On the whole, environmental protection led to a reduction (although not avoidance) of the degradation process, and an increased awareness of the environmental values of the site. Nevertheless other actions that seem to support sustainable development might have a counter effect, such as the issuing of the blue flag to the beach within the natural protected area, certifying the required quality standards for recreation but multiplying the number of visitors to the beach and supporting the development of infrastructure such as car parks, a lifeguard base and a roundabout in adjacent areas.

4. Discussion

The environmental conflict shifted to social controversy, disclosing a multiple

lack of integrated governance of both the ecosystem and disaster risk (Sudmeier-Rieux et al., in press). First, there has been a weak vertical cooperation amongst the regional and local governments, inhibiting the coordination of land use plans with environmental management. Secondly, there has been a poor horizontal sectoral cooperation between the various departments of the regional government, particularly the urban planning and environmental management authorities, which might act as a second level of control of the likely land use conflicts. Third, there has been limited communication between the national and regional authorities in the delineation of the jurisdictional boundary between public and private land. The current zoning does not consider the seasonal oscillation of the lagoon water level and the delineation of the protected area. Furthermore, public participation has been weak, which led, on the one hand, to limited understanding of the interests and perceptions of stakeholders by the government, and on the other, to low levels of transparency and limited access to key information that would facilitate better understanding of the environmental processes amongst all actors. Altogether, these failings highlight the absence of political priorities that should guide environmental and disaster

risk policy making, and governance at large.

Inclusive and cooperative governance involves higher levels of participation and, ultimately, co-decision-making, empowering lesser represented civil society groups and balancing competing interests. Some actions taken in the past either did not fully understand the complexity of environmental and social components and processes, or decisions were taken in response to the interest of more influential groups, without consideration of environmental values or of other stakeholders' interests. This is demonstrated by acts such as the mining of sand from the sand dunes, the construction of the eastern foreshore way, the development of infrastructure and car parks within or next to the protected area, the removal of sand big bag barriers, the application for the blue flag and the controversial mechanical opening of the outlet.

Interactions amongst administrations – while responding to their specific political responsibilities – to reach a policy decision constantly follows a path of formal, regulated exchange of information but framed by sectoral scope and constraints. This does not allow for dialogue and appropriate accounting of cross-cutting issues. Essential information is generated, held and appropriated by the government, but is not easily accessible to all stakeholders, including local governments and civil society groups, and, if available, is frequently fragmented. Such an approach does not facilitate two basic types of knowledge (local and expert knowledge) to be contrasted or conflated. Thus, multi-stakeholder platforms would help knowledge exchange and dialogue as a basis for decision making and become an instrument for the timely management of critical situations, such as during seasonal flooding events, instead of relying just on bureaucratic processes. Other important decisions remain to be made, such as the

removal of the intrusive sand in the lagoon bed, removal of invasive species, the restoration of the damaged bottom rock crust in the outlet, or the pattern of urban development of the village of Valdoviño. Accordingly, improved instruments for environmental and risk governance are required. Reactive measures have worked in the past as in the case of the restoration of the central dune system. However, there is an urgent need for proactive measures, especially now, with climate-related weather variability triggering still uncertain effects at the local scale. This would also enforce improved capacity to anticipate social conflicts and save financial resources.

Seasonal flooding of a section of the built up area on the lagoon shore turned out to be a visible indicator of the poor understanding of the functioning of a multi-stable natural system and of the disruption of the ecosystem services provided to mitigate floods. To achieve the goals of risk reduction, habitat conservation and lessening social conflict, deeper societal consensus on the environmental values should be reached. Particularly, it should be recognized that the system has been perturbed by past human interventions, that floods are one component of this current unstable system, and that the models of recreation and urban development being implemented are increasing the vulnerability and challenging the environmental services provided by the wetland system.

5. Conclusion

The two key lessons learned include the understanding that weak governance has led to increased social complexity and conflict, helped by the environmental complexity of a very dynamic physical environment with multiple habitats, a lagoon with multiple stable states alternating by variations of water and salinity levels, and an active sand dune system. Social complexity requires better governance and innovative modes of

governance. Social and environmental evaluation can be conceived not just as a measure of performance or accomplishment of goals, but as an opportunity to share data, information, knowledge (and conflate local and scientific knowledge), as well as an avenue to become aware of other stakeholders' interests, goals and points of view. Early positions of participants in evaluation usually change and adapt as the result of exchange and dialogue. In this case, evaluation should not be understood as examination of governmental actions but as an assessment of the mechanisms and of the roles of all players, and serve to re-evaluate goals and inform policy making (Fra.Paleo, in press).

Research has to contribute not only to a better understanding of the environmental but also the social processes to properly address the multiple risks from natural hazards (lagoon and coastal flooding, windstorms) and from the loss of biodiversity. It implies monitoring the water cycle, the evolution of the canal, the changes of the sand coverage in the lagoon bed, the evolution of the sand dune system, and the state and diversity of plant and animal species. Without doubt it is necessary to study these issues with the perspective of human-driven and natural environmental change, because Holocene marine transgression has driven the formation of coastal lagoons in the region, including A Frouxeira. This dynamic process, the effects of global environmental change and human interventions at the local scale are interfering with each other in still unknown ways. Social and political processes should also be better understood to monitor the variation and types of vulnerability, evaluating the role of underlying factors in decision making, such as the interests and influence of all stakeholders, their interactions, as well as the impact of economic transition and urban processes in place in the surrounding area.

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Chapter 14

Contribution of protected areas in mitigation against potential impacts of climate change and livelihoods in the Albany Thicket, South Africa

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Abstract

The reality of global climate change and the risks it poses to various communities and ecosystems is increasingly being felt in Africa. One of the greatest risks of global climate change is desertification of semi-arid areas. In anticipation of potential desertification of the extensive degraded areas in South Africa, from 2007 up to 2013 the Department of Environmental Affairs undertook a land restoration project in the semi-arid Albany Thicket of the Eastern Cape. The objective of this project included increasing vegetation cover in areas that have been over-utilized through domestic herbivory, thus improving the potential for water infiltration, reducing soil erosion potential, increasing carbon sequestration and ultimately providing parallel opportunities for diversification of land use options. The project was undertaken in the semi-arid parts of South Africa in three protected areas, namely the Fish River Nature Reserve, Baviaanskloof Nature Reserve and Addo Elephant National Park, with rainfall averages of 466 mm, 211 mm, and 281 mm per annum, respectively. All targeted sites in the protected areas fall within the Albany Thicket Biome, comprising a biota of high conservation value. The implementation of this project incorporated a transdisciplinary approach that recognizes the complexity and the inter-connectedness of ecological, social and economic systems, in order to ensure the effectiveness of individual protected areas within a broader network. Restoration of degraded lands allowed

increase in plant biomass and thus carbon sequestration, improved water infiltration and retention. A natural return of representative plant species composition suite for this vegetation is expected to be achieved in 30 to 50 years after initial restoration activities. The sale of carbon credits could potentially fund further restoration initiatives. Ultimately, restoration will provide an improved flow of key ecosystem services, namely water base flows, forage for wildlife and livestock as well as those services associated with biodiversity, namely honey production. Importantly, the restoration will also reduce the risk of climate change impacts such as increased temperatures and greater frequencies of droughts. It is essential, therefore, to upscale this successful pilot project across other areas experiencing similar conditions and threats. In so doing, options of sustainable land use will be increased, and the community's climate change resilience will be strengthened.

1. Introduction

The southern parts of the Eastern Cape region (ca 33°S, 25°E) of South Africa have been extensively used for agricultural purposes for more than 150 years. This region is dominated by the Albany Thicket Biome of subtropical affinity, and is a centre of high endemism (Novellie et al., 1996). The vegetation has mesic and xeric forms (associated with wetter (>400 mm/yr) and drier climatic conditions, respectively) (Vlok

et al., 2003). In its untransformed state, xeric thicket has an almost complete cover of tall (3-4 m) evergreen dense woody and succulent species, and has a much higher biomass than would be expected under semiarid conditions (Lechmere-Oertel, 2004; Mills et al., 2005; Lechmere-Oertel et al., 2005). Much of the biomass comprises the succulent shrub *Portulacaria afra*, known locally as spekboom (Acocks, 1953; Vlok et al., 2003). The distribution of this vegetation is dependent on a complex of interrelated factors (Everard, 1987), especially soil, frost and fire (Vlok et al., 2003). Currently, these thickets are commercially used for pastoralism (mainly goats) and game farming (Kerley et al., 1995). Ecotourism has increased substantially over the past two decades (Geach, 1997; Boshoff et al., 1998), and has been shown to be highly profitable, relative to other land uses (Sims-Castley, 2002). There is also limited bark collection (La Cock and Briers, 1992) with extensive wood collection in areas close to human settlements (Briers and Powell, 1996).

The Albany Thicket supports an exceptionally high diversity and abundance of large browsing mammals such as elephants (*Loxodonta africana*), black rhinoceros (*Diceros bicornis*), as well as about 40 species of medium- and small-sized mammals (Skead, 1987; Kerley et al., 1999). Despite this long association with indigenous herbivores, (Midgley, 1991; Kerley et al., 1995) the Albany Thicket is not resilient to intensive

goat pastoralism (Stuart-Hill, 1992). Sustained heavy browsing transforms it from a dense closed-canopy shrubland into open community isolated trees, in a matrix of ephemeral herbs (Hoffman and Cowling, 1990; Moolman and Cowling, 1994; Lechmere-Oertel et al., 2005). This transformation is associated with a reduction of species diversity (Moolman and Cowling, 1994; Johnson et al., 1999; Lechmere-Oertel, 2004), soil quality (Mills and Fey, 2004) and soil carbon stocks (Mills et al., 2005). Ultimately the degraded thicket loses its functionality (Lechmere-Oertel et al., 2008; Sigwela et al., 2009; Cowling and Mills, 2011) and becomes desertified. These desertified thickets can no longer support the suite of herbivores associated with its intact state.

The Albany Thicket will be subjected to higher temperatures and more erratic rainfall as a consequence of anthropogenic climate change (Alam and Rabbani, 2007). This will exacerbate droughts and soil erosion, making restoration even more important for maintaining ecosystem services. As a consequence, without mitigation, degradation in the Albany Thicket will have a negative impact on the livelihoods of pastoralists, and will lead to reduced opportunities for ecotourism (Kerley and Boshoff, 1997). Furthermore,

owing to topsoil erosion, drainage systems will have reduced base flows which will cause the rapid siltation of dams. In the absence of livestock browsing, degraded thicket does not restore spontaneously (Stuart-Hill and Danckwerts, 1988; Lechmere-Oertel et al., 2005; Sigwela et al., 2009). Therefore, without human intervention, these negative impacts of Albany Thicket degradation will persist.

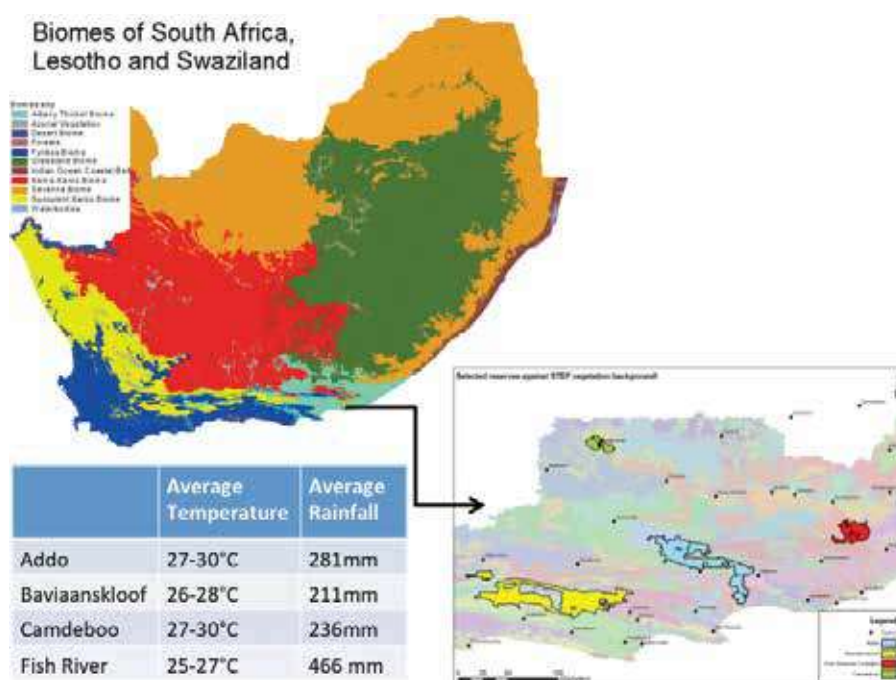
Land degradation poses a threat to ecosystem stability and may also negatively affect human livelihoods. This challenge occurs against the backdrop that the South African government targets the country's natural resource base as a key foundation for development plans and strategies. Therefore the degradation of Albany Thicket may not only be an ecological problem but may hamper the developmental initiatives of the country. These threats may be more pronounced in the face of global climate change. One of the strategies incorporated in the South African government's National Development Plan (NDP) is to provide the basis of a vibrant and wealth-generating ecotourism industry. Ecotourism is recognized as one of the land-use options that can play a major role in promoting development and community upliftment (Kerley et al., 1995). However, in degraded

Albany Thicket this form of land use is severely constrained, owing to reduced potential to support the fauna attractive to tourists.

The NDP also recognizes rural development as a key development challenge for the country. Improvement of agricultural operations is one of the key strategies of rural development. These initiatives are, however, difficult to implement in these degraded areas as the natural capital is reduced (Lechmere-Oertel et al., 2005). Moreover, reduction in plant productivity in degraded Albany Thicket also leads to reduced livestock stocking capacity (Stuart-Hill and Aucamp, 1993). The transformation of Albany Thicket does not only negatively affect agricultural productivity, but also reduces the availability of wood, fruit and medicines for local communities, with a potential financial loss of approximately US\$ 150 per annum per household (Cocks and Wiersum, 2003).

Moreover, the South African government has identified the Eastern Cape, which is the second largest province in South Africa and the third largest in terms of its total population, as one of the provinces most in need of socio-economic development. Considering these government objectives and that degraded Albany Thicket negatively impacts ecosystem functioning and human livelihoods, the Natural Resource Management Program (NRM) of the Department of Environmental Affairs initiated a Subtropical Thicket Restoration Project. This project adopted a multi-disciplinary approach and was implemented in three protected areas of the Eastern Cape, namely Baviaanskloof Nature Reserve, Addo Elephant National Park and Fish River Nature Reserve (Figure 1). Since the project was implemented in protected areas, the key partners in the implementation were South African National Parks and the Eastern Cape Parks and Tourism. The objective of this project was to do action research to determine the potential of the restoration of Albany Thicket in these three protected areas and to use this experiential learning to expand restoration projects to production landscapes.

Figure 1: Location of the protected areas where restoration has been implemented.



2. Methodology

Portulacaria afra (spekboom), a succulent tree dominant in the xeric Albany Thicket, was used as an ecosystem engineer for the return of all ecosystem functioning. The motivation for selecting this plant species was that *P. afra* can naturally reproduce vegetatively (Swart and Hobson, 1994) and can regenerate easily through planting its cuttings (Table 1).

2.1 Selection of study sites

Protected areas were selected as appropriate sites to pioneer the project. The rationale for selecting protected areas was that this long term project needed to be implemented in areas where land-use options will not change in the long term or in perpetuity. Within each protected area, large degraded areas of Albany Thicket of xeric affinity (Spekboomveld and Spekboom Thicket) that were historically dominated by succulent tree/shrub, spekboom, were identified. To determine the appropriate and suitable areas for rehabilitation within each protected area, a GIS-based site selection method was used. The process followed is described in the following stages

Although about 9,000 hectares (90 km²) were selected as the project implementation area, the current implementation is in 696 hectares in Addo, 204 hectares in Baviaanskloof Nature Reserve and 526 hectares in Fish River Nature Reserve. This selected area is very small in relation to the extent of degradation in the Albany Thicket, but was found to be sufficient as this project was intended as a pioneering restoration programme in this area. However, of the 16,942 km² of Albany Thicket, 46% of it has been heavily degraded and 36% moderately degraded (Lloyd et al., 2002).

2.2 Consultation with stakeholders

Although this project was initiated in protected areas, its intention was to 'kick-start' a large-scale restoration initiative, including on private lands. To this end, a community consultation was undertaken through the PRESENCE network¹. The motivation for this initiative was that restoration of the degraded areas should be seen as a priority to

Table 1: Method of selecting areas suitable for restoration

Stage	Action	Purpose
1.	Vegetation mapping	To identify maximum percentage to which transformed areas can be planted with spekboom
2.	Digitizing of high resolution aerial photography	Production of 1:5000 transformation field map
3.	Exclusion of areas unsuitable for restoration e.g. areas with a slope greater than 30°, buffers to water bodies, and riparian areas or areas with standing water.	Production of a suitability map for restoration
4.	Selection of severely transformed suitable vegetation	Project implementation map

achieve optimally sustainable rural livelihoods and to keep people 'living on the landscape'. There was however a bias in consultations favouring areas surrounding the Baviaanskloof Nature Reserve. This was due to limited human and financial resources, therefore assessments were not done in other areas. To increase the public awareness of this restoration programme, various articles were presented in *The Farmers Weekly* (a weekly journal distributed to farmers in South Africa). Moreover, presentations were made in various farmers' meetings. In the Fish River Nature Reserve area, awareness research initiatives were undertaken through the Rhodes University. Farmers were interviewed using structured interview schedules and questionnaires.

Considering that the South African National Parks, the Eastern Cape Parks and Tourism Agency were part of the project, it was not necessary to have further consultations with them. A further consultation was undertaken with local communities by the implementing agents. These were undertaken on the basis of sourcing people for restoration activities.

2.3 Activities undertaken on site

The restoration activities started in 2007 up to 2013. These activities included 1) Drilling of soil to a depth of 20 cm with a soil auger; and 2) Planting of Spekboom (*P. afra*) cuttings of 20 mm in diameter into the drilled holes.

2.4 Main factors

In view of the fact that the planted cuttings are still young, the outcomes of the restoration activities were inferred from

reviews of published and existing data.

The key questions asked in this project were

- Can the planting of spekboom cuttings assist in returning plant cover in degraded thickets?
- Can the planted cuttings (i.e. resultant plant cover) assist in reducing water runoff, thus increasing water infiltration and, as a consequence, reduce the impacts of drought?

Canopy cover

Mills and Cowling (2006) and van der Vyver et al. (2013) compared the above-ground biomass of *P. afra* and soil carbon accumulation potential in restored areas up to the past 27 (Figures 2 and 3) and 50 years respectively. The growth rates that are observed in these blocks give insights on the potential long-term growth rates that are possible in the current project. The detailed methodology of this assessment can be obtained from the cited authors.

P. afra as a nurse plant

On the same sites, van der Vyver (2013) identified plant species that have established themselves subsequent to restoration through spekboom. Detailed methodology can be obtained from the cited literature.

Water infiltration

Van Luijk et al. (2013) determined the potential impact of canopy cover on the soil response to rainfall by quantifying the differences in infiltration rate and rewetting patterns. The detailed methodology for this can be obtained from the cited literature.

¹ www.earthcollective.net/initiatives/presence

Figure 2: Restoration blocks in the private land (K5, K7, K13, K27 are plots planted with one genotype. K27R is a plot planted with a different genotype).

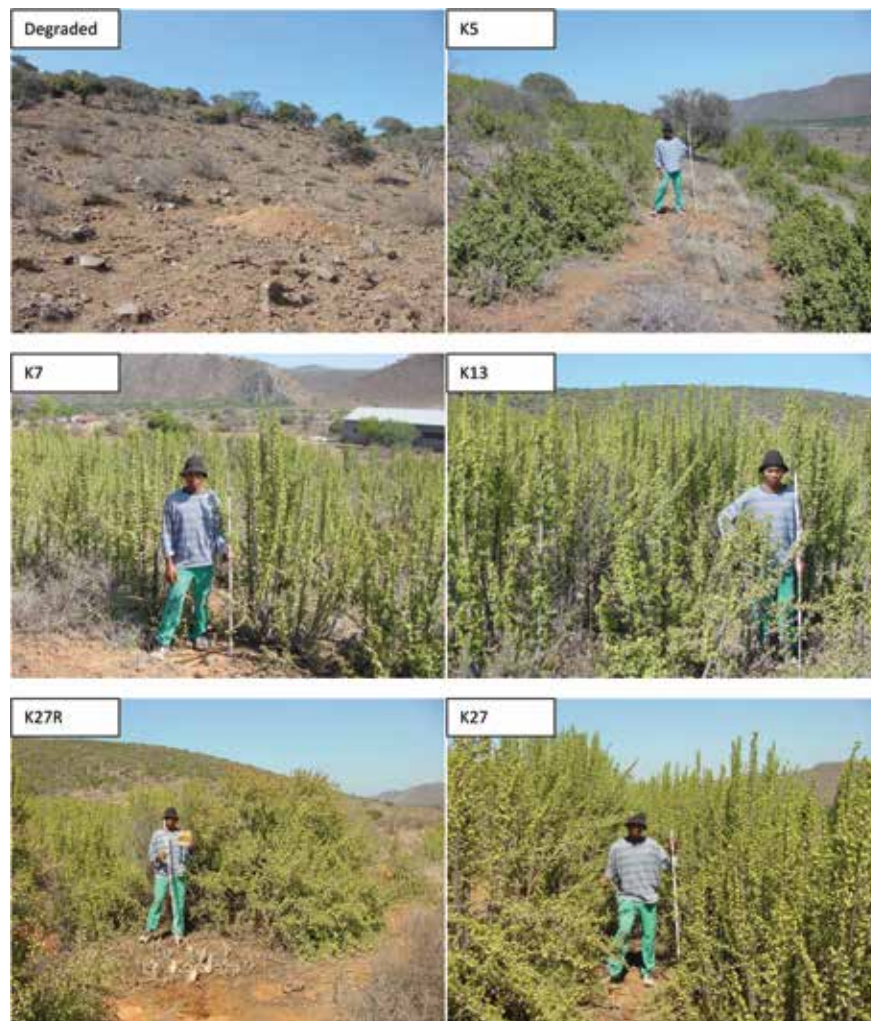
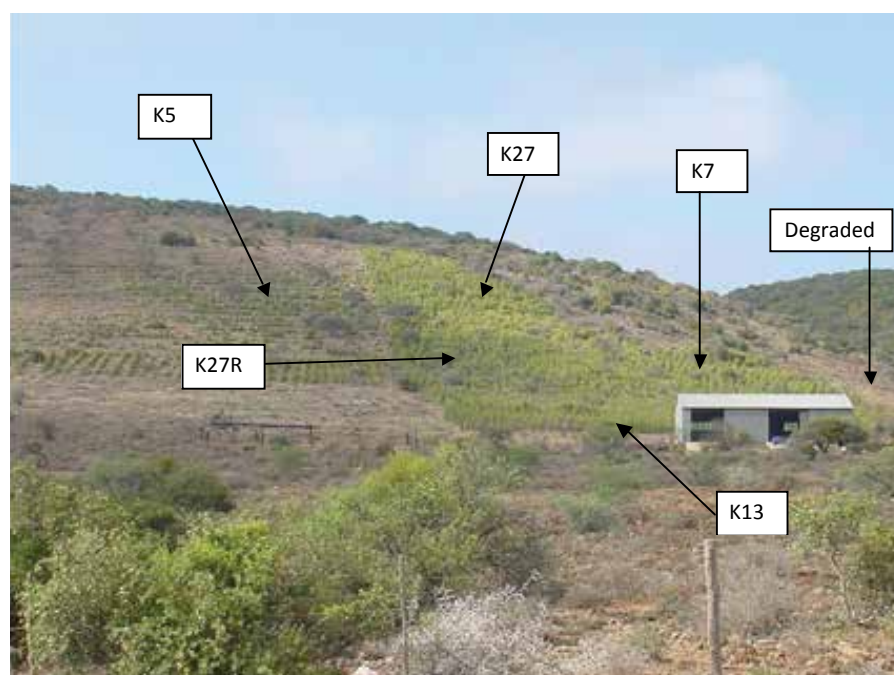


Figure 3: Overview of all planted areas.



Socio-economic impact

The impact of the project to the society was quantified by determining the number of people employed in the project and the amount of money spent in salaries of those employed persons. The work opportunities of the project were calculated as Full Time Equivalent (FTE), which is the equivalent of one person working full-time in the project (8 hrs/day multiplied by 5 days/week multiplied by 52 weeks/year).

3. Expected project outcomes

3.1 Increase in vegetation cover

Mills and Cowling (2006) discovered that a block planted with *P. afra* in the 27 years increased aboveground carbon (taking the transformed block as a baseline) by 3.5 kg C/m² (including *P. afra*, litter, and ephemeral plants) at an average rate of 0.13 ± 0.02 kg C/m² yr⁻¹. The calculated average rate of carbon sequestration over 27 years is 0.42 ± 0.08 kg C m⁻² yr⁻¹. Van der Vyver et al. (2013) identified that as the restored stands mature in age (up to 50 years), the soil carbon stocks increase threefold where from 35 to 50 years soil carbon increased from 71.4±24 t C ha⁻¹ to 167.9±20 t C ha⁻¹. These outcomes are expected to be observed in the current project.

3.2 Increase in plant species diversity

Van der Vyver et al. (2013) identified recruits of 13 species (detailed in this citation), dominated by canopy species, in spekboom-restored sites.

3.3 Improvement of water infiltration rates

Van Luijk et al. (2013) observed that infiltration rates beneath spekboom canopy varied between 26.1 and 28.7 mm h⁻¹ while infiltration rates in the degraded state varied between 0.04 and 0.25 mm h⁻¹, (115 and 650 times lower than in the intact state).

Maximum volumetric soil moisture content (at saturation) that van Luijk et al. (2013) observed, was 51±5% beneath spekboom canopy while in degraded sites it was 37±3%. The soil moisture (as measured using the capacitance probes) mirrored infiltration rates, where higher soil moisture content was recorded over the whole soil profile beneath spekboom canopy than in degraded sites (Figure 4). In dry spells the topsoil in degraded sites dried out rapidly and little water was stored in deeper layers.

There was higher soil moisture for longer periods in soils under spekboom canopy as displayed in Figure 5.

3.4 Socio-economic outcomes

The project recruited previously unemployed workers from the local community. From 2008 till 2013 the 'full time equivalent' jobs created were 3,754. In view of the fact that the programme employed no more than one member from each family, this means the project supported 3,754 families within the five year period. During this five year period, income for these families (in terms of salaries for workers) amounted to US\$ 404,950.

4. Discussion

Although the canopy cover of the currently restored areas could not be determined, the outcomes observed by Mills and Cowling (2006) could be used to infer the long-term impact of the restoration activities in these protected areas. The growth rates observed in the Kroomport restored thicket is high for a semi-arid region. This high rate of primary productivity can be attributed to the physiology of the *P. afra* plant. It has high tolerance to drought due to its ability to shift from a C3 photosynthetic pathway (used when oxygen is in abundance) to a CAM pathway (used when carbon dioxide is in abundance) (Ting and Hanscom, 1977). This therefore makes *P. afra* the most suitable plant for restoration of the Albany Thicket, which has arid environmental conditions. This high rate of primary production may be attributable to the high rate of carbon sequestration (Mills and Cowling, 2006). Using *P. afra* in this project can therefore be concluded to be effective and sustainable as the plant growth will be ensured. Furthermore, the ability of this plant to regenerate vegetatively from cuttings makes it cost effective to use *P. afra* for restoration activities.

Using the research done in the Kroomport area, the restoration project undertaken in Baviaanskloof, Addo Elephant National Park and Fish River Reserve can demonstrate a case for rehabilitation of degraded Albany Thicket of the Eastern Cape across the rainfall gradient. The carbon sequestration rates demonstrated by Mills and Cowling (2006) and van der Vyver (2013) can be attributed to soil fertility as leaf litter accumulation will

Figure 4: Depth-time plots of the soil moisture in the soil profile of degraded thicket (top) versus beneath canopy (bottom) that van Luijk et al. (2013) identified in the Baviaanskloof, South Africa.

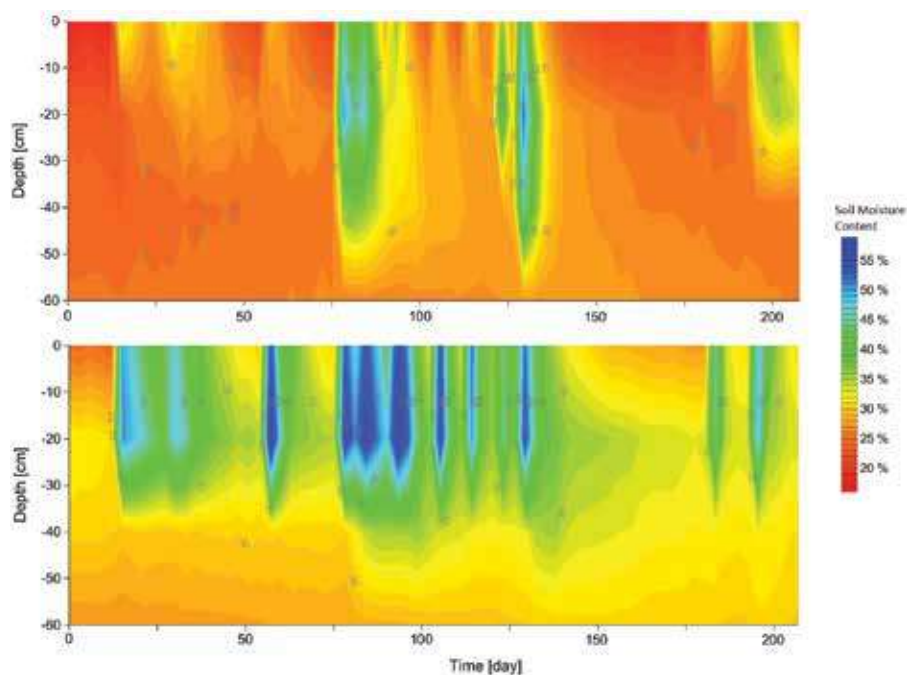
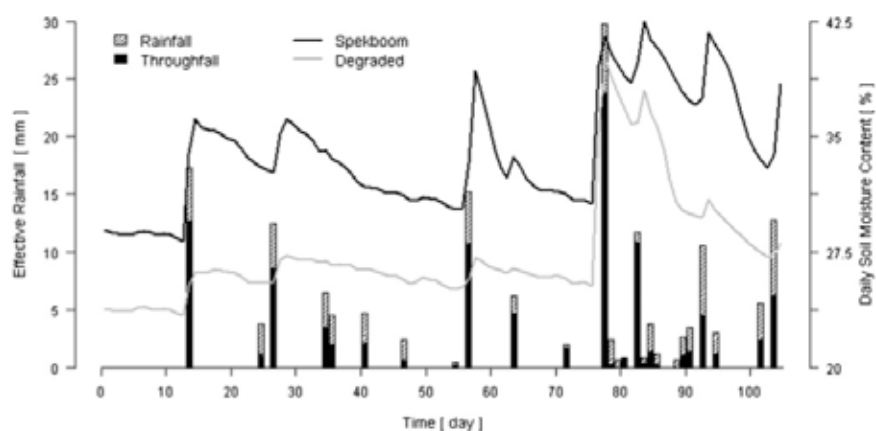


Figure 5: Soil moisture measured in relation to rainfall dynamics recorded by van Luijk et al. (2013). Note the rate at which soil moisture decreases after the rain event.



contribute to the restoration of topsoil. The observations of Van der Vyver et al. (2013) were based on a 50 year restoration. Considering that the current project is implemented in protected areas, the land use is not expected to change in the near future. Therefore, the soil carbon accumulation is expected to increase beyond the thresholds identified by van der Vyver et al. (2013). The rate of carbon sequestration observed by Mills and Cowling (2006) is fast for a semi-arid region. These protected areas can therefore act as long term carbon sinks, which will ultimately contribute to mitigating climate

change, whose effects are already felt in the region.

The work of Van der Vyver et al. (2013) suggests that *P. afra* can act as a nurse plant for recruiting additional species on restored landscapes. The recruitment of these plant communities is attributed to the spekboom's ability to act as an ecosystem engineer. Therefore, although in the current project, only *P. afra* was used for restoration activities, it is not expected that the ultimate outcome of the restoration activities will lead to a monoculture. This is important considering that the objectives of the protected areas in which the project

is implemented include improvement of biodiversity in degraded areas.

The throughfall² recorded beneath the canopy environment in the Albany Thicket (van Luijk et al., 2013) is lower than international values of Amazonian rainforest (Cuartas et al., 2007), temperate forests (Herbst et al., 2008), coniferous forests (Johnson, 1990) and beneath individual trees of the northern hemisphere Mediterranean woodlands (Pereira et al., 2009). The extreme accumulation of soil organic carbon in thicket can be attributed to the low rates of throughfall as well as constraints that moisture has on microbial activity. The results of Van Luijk et al. (2013) indicate a clear impact of restoration of degraded thicket on soil properties and associated hydrological processes. It is expected that in the under-cover environments of restored thicket, due to soil aggregate stability combined with higher organic content (Mills and Fey, 2004), crust formation will be minimal, which explains the infiltration rates observed in undercanopy environments (van Luijk et al. 2013). High infiltration rates will improve the retention of soil moisture, and reduce the amount of runoff, which would otherwise increase soil erosion. The restoration activities are therefore not only contributing plant growth in degraded areas, but also assisting in the reduction of runoff. Since soil erosion will be minimized, water quality in rivers will be increased. Also, considering that *P. afra* is a drought resistant plant, restoration in these protected areas will facilitate the availability of animal forage even during drought periods. Considering that canopy cover facilitates water infiltration rates and thus soil water retention, restoration in these protected areas will contribute significantly to the provision of ecosystem services such as provision of cleaner water. Also, winter flows in downstream rivers and water availability to downstream communities will be increased. Overall, this is contributing to communities' and ecosystems' resilience in the face of climate change and recurrent droughts.

South Africa has high poverty levels. The fact that the restoration of these protected

areas could contribute significantly towards employment demonstrates that protected areas should not be viewed in isolation, but rather can benefit societies. Some people employed in this project further developed their management and business skills. Some labour employed in this project were previously farm labourers who lost their jobs when, due to high levels of land degradation, the farming enterprise was unsustainable. Therefore, although protected areas have a core mandate, these protected areas could contribute to mitigating poverty of local communities.

As has been outlined in the introduction, intact thicket provides multiple benefits. These include harvesting of plant products used for domestic consumption and sale harvesting of medicinal plants, collection of firewood, sustainable use of livestock, bee keeping, game farming and nature-based tourism activities. These benefits cannot be derived from degraded thickets. This means, restoration of degraded thickets can assist in the improvement of human livelihoods and have a potential of diversified land use options. Furthermore, although the restored thickets may not reach the exact status in terms of biodiversity elements as intact thicket, the return of biodiversity elements will improve the ecosystem functioning of previously degraded areas to be similar to that of intact areas. Moreover, restoration of these degraded thickets may potentially contribute to the abundance of useful planted species (such as *P. afra*) where they occur in greater abundance than they would occur naturally. In such cases restored areas could potentially provide more benefits than the original thicket.

5. Conclusion

This project has demonstrated that protected areas can contribute to disaster risk reduction. The surrounding areas are highly prone to soil erosion and drought events. However, due to the land use practice inside the protected areas, these conserved areas act as sinks for water resources and centres for build-up of soil resources. These protected areas ameliorate the impact of water scarcity to surrounding areas by their high water holding capacity and gradually releasing water, thus potentially buffering the effects of extended dry spells. This is very important in areas of low rainfall such as

the south Eastern Cape of South Africa, where Albany Thicket is dominant. The downstream communities and urban centres such as Port Elizabeth are highly dependent on water resources harvested in the Albany Thicket catchments.

Furthermore, this project has shown that the protected areas of the south Eastern Cape, South Africa can assist in mitigating climate change. Carbon sequestration is one of the dominant forms of a mitigation strategy. The carbon sequestration rate in these protected areas has been shown to rival that of rainforests (Mills and Cowling, 2006) although its rainfall is far less than that in rainforests.

The need to integrate the management of protected areas to societal dynamics has also been highlighted. The protected areas can be catalysts of economic activities in regions where they occur and can assist in reviving the rural economy. Therefore, they should not be viewed in isolation but their management should be in relation to surrounding landscapes and surrounding context.

Additionally, the project has shown that given sufficient time, *P. afra* can sequester large amounts of carbon dioxide thus opening opportunities for national and international corporates seeking green credit. However, sequestration rate will vary according to climate, planting density, herbivore intensity and soil type. This would provide a parallel income generating option of selling carbon credits to international markets. The implication for protected areas is that they may therefore diversify their income generating streams and not focus solely on tourism revenue.

South African National Parks together with the Eastern Cape Parks and Tourism have used this restoration project as a basis of rehabilitating their degraded areas. Their respective management plans have now placed land rehabilitation at a higher focus. These protected areas can then provide a platform for learning lessons of the rehabilitation of Albany Thicket even on private lands.

Acknowledgements

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² Throughfall: the amount of rain that is not intercepted by plant canopy and falls through to the under-canopy environment

provided by the Natural Resources Management Program of the Department of Environmental Affairs. The South African National Parks and the Eastern Cape Parks and Tourism Agency are sincerely thanked for permitting the project to be implemented in their protected areas.

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Chapter 15

Initiatives to combat landslides, floods and effects of climate change in Mt Elgon Region

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Abstract

Mt Elgon is an important trans-boundary ecosystem that strides the Kenya – Uganda border. The ecosystem is a vital water catchment area and hosts over 400 species of plants, 300 bird species and a number of wild animals including the African elephant (*Loxodonta Africana Africana*). In the recent past, Mt Elgon ecosystem has experienced unprecedented human induced degradation in form of deforestation and poor land use practices. As a result, disastrous landslides on mountain slopes and floods in lowland areas are frequent and intense. In addition, mountain cracks¹ are evident, widespread and appear to be a real threat to the livelihoods of neighbouring communities. Consequently, human lives have been lost, property destroyed and thousands of people displaced. High human population pressure and increased demand for agricultural land have exacerbated the situation.

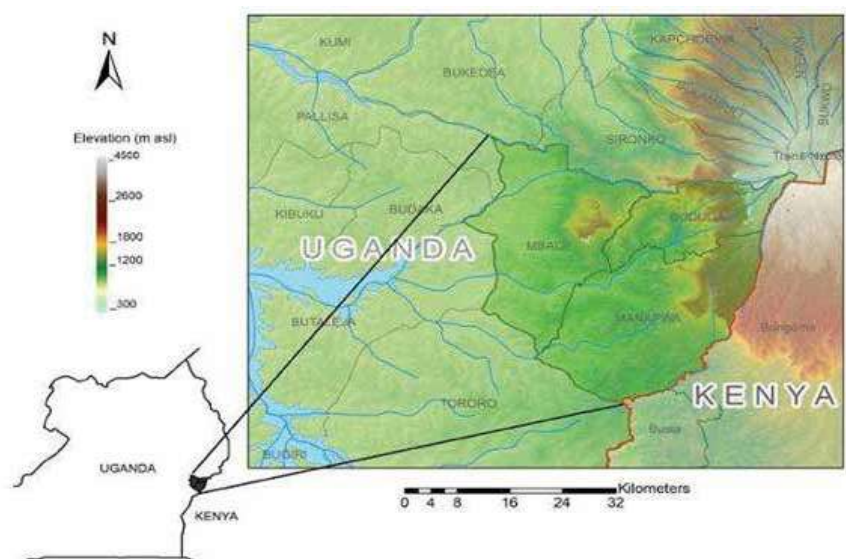
However, recent studies provide unequivocal evidence that although Mt Elgon is naturally prone to landslides due to the nature of soils, steep slopes and heavy rainfall, the degraded areas outside Mt Elgon National Park are more vulnerable to disasters than areas within the protected area. It is therefore critical to strengthen the management of Mt Elgon National Park

for reducing occurrences of landslides. Past and current conservation projects from agencies like IUCN, UNDP and Lake Victoria Basin Commission (LVBC) that have supported the Uganda Wildlife Authority (UWA) and Local Governments to implement mitigation and adaptation interventions which contribute to the restoration of degraded areas and improve the resilience of Mt Elgon National Park against landslides. These innovations have generated lessons that could be of great value to implement integrated approaches for conservation, disaster mitigation and climate change adaptation. This paper provides an overview of these initiatives and lessons learnt.

1. Introduction

Mt Elgon trans-boundary ecosystem is an important water catchment that serves Lake Kyoga, Lake Turkana and Lake Victoria as well as supports the livelihoods of neighbouring local communities. The vegetation of Mt Elgon reflects the altitudinal controlled zoned belts commonly associated with large and high mountain massifs. The vegetation communities are comprised of mixed montane forest up to an elevation of 2500 m, bamboo and low canopy montane forests from 2500 m to 3000 m and moorland above 3500 m above sea level.

Figure 1: Map of Mt Elgon region showing Bududa and Manafwa Districts.



¹ Mountain cracks are some of the observable early warning signs of pending landslides (GOK, 2004; Fomo & Padegimas, 2012; Shoaei, 2013).

Source: Adapted from TACC, 2014.

This report covers Mt Elgon ecosystem as an entity, however, much emphasis is put on Manafwa and Bududa Districts, located on the south-western slopes of Mt Elgon, Eastern Uganda because this part has experienced more frequent and intense landslides in the recent past than other areas. The two districts extend from 0°59'N, 34°17'E to 1°04'N, 34°25'E (Figure 1). The area is situated on the mid-slopes between 1800-2600 metres above sea level and is characterised by more rainfall (1500-2000mm per annum than the lower slopes or the summit (UWA, 2000). There are two distinct rainy seasons in the months of March–May and August–October.

The geomorphology of the area is heavily controlled by the volcanism (Davies, 1952; Knapen *et al.*, 2006; NEMA, 2010). Mt Elgon is a solitary volcano considered to be one of the oldest in East Africa (Scott, 1994), rising to the height of about 4321m above sea level. The mean maximum and minimum temperature are 23°C and 15°C respectively (Mugagga *et al.*, 2012).

The area is divided into Mt Elgon National Park (the upper zone comprising area above 2200m above sea level) and the lower slopes are farmland. Majority of people in the area depend on crop farming for livelihoods, typically Arabic coffee (cash crop), bananas (staple food) and maize. Beans, yams, onion and cabbages are grown in the lower slopes. Crops are grown on steep slopes that range from 36° to 58° (Mugagga *et al.*, 2012) as high population pressure (600-1000 people/square km and land scarcity have forced people to settle on and cultivate steep slopes (Kitutu, 2004) without proper soil and water conservation measures. This has led to soil erosion, soil infertility and poor crop yields forcing people to clear more forests to create new farmland. The loss of forest cover and degradation of land have accentuated the development of cracks on mountain slopes stretching over 40 km and intensification of landslides. Furthermore, the frequent landslides have degraded farmlands and the overall environment, caused death, destroyed homes, damaged infrastructure such as roads and bridges and displaced many people (Kitutu, 2010; NEMA, 2010). Residents of lowlands have not been spared. The earth material from landslide

sites ends up in the water systems leading to siltation and damming of certain sections of rivers (upstream). When water accumulates and breaks the dams, it floods lowland areas, destroying crops, houses, property, displacing people and sometimes causing death. Studies carried out in Mt Elgon have attributed the cause of landslides to removal of tree cover, exploitation of steep slopes for agriculture, human settlement as well as land degradation among others; (Kitutu, 2004; NEMA, 2010; Mugagga *et al.*, 2012; GOU, 2013). Most of the landslides have occurred at the bottom of a 2200 m altitude scarp and studies show that there is a decrease in the safety factor which is a measure of slope stability through root decay by 30% to 60% on such slopes (NEMA, 2010). Similarly, the soil properties, steepness of the slope and status of the forest cover determine the stability of the area and frequency of the slope failure hence landslides (Kitutu, 2010). Therefore, it can be observed that the occurrence of landslides inside Mt Elgon National Park, which has extensive tree cover, is less than on neighbouring farmlands despite the topographic and soil properties being similar.

Furthermore, analysis of the magnitude of destruction reveals that effects of landslides and floods on livelihoods have worsened in the past decade (NEMA, 2010; Formo & Padejimas, 2012; Juventine, 2012; Kitutu, 2010;). The toll on human life is large (Kitutu, 2004) and the situation is likely to worsen as time goes on due to reoccurring disasters. The intensification of disasters in the area has coincided with human induced degradation of some sections of Mt Elgon National Park as a result of encroachment and deforestation. To minimise the effects of disasters on neighbouring communities and the integrity of Mt Elgon National Park, ecosystem based initiatives were implemented to improve the livelihoods, coping mechanisms and to restore degraded protected areas.

MERECAP was designed and implemented by IUCN in 2005 for a period of four years. It was funded by the Government of Norway and Sweden, which committed US \$ 5.8 million towards the implementation of interventions aimed at securing a productive ecosystem that is able to

sustain the livelihood of neighbouring communities and resilient to the effects of climate change. The mid-term review which was carried out in April 2008 refocused resources and efforts towards communities living adjacent to the national parks and forest reserves because they incur conservation costs and at the same time have a key role to play in the protection of ecosystem and restoration of degraded areas. The key result areas of MERECAP were centred on equitable benefit sharing, strengthening institutional framework for trans-boundary ecosystem management and linking livelihood improvement to climate change mitigation and adaptation.

The Territorial Approach to Climate Change (TACC) project was implemented in the Mbale region of Uganda from July 2010 to 31st December 2013 by the United Nations Development Program (UNDP). It was funded by the Danish Embassy, the United Kingdom based Department for International Development (DFID) and UNDP. Technical and Development Support was provided by the Welsh Government. The project intention was to provide a coordinated mitigation and adaptation plan to increase resilience to climate change and reduce emissions for three districts of Bududa, Manafwa and Mbale in the Mt Elgon region. This initiative was one of the ten pilot projects for the UNDP-UNEP Global Initiative, “Down to Earth” Territorial Approach to Climate Change.

The EBA project in Mt Elgon was initiated in Sanzara Parish which is located in the rain shadow at the foothill of Mt Elgon; in the lower region of Kapchorwa District. The lack of clean and safe drinking water, drought and seasonal floods are some of the key challenges faced by the parish. Sanzara is prone to flooding and is a depository for soil erosion and landslides from steep slopes of Mt Elgon. EBA initiatives were focused on River Sippi which originates from Mt Elgon National Park and is a major source of water for the Sanzara community. UNEP in partnership with UNDP and IUCN, with funding from the Government of Germany implemented EBA to address water stress as one of the ways to provide incentives and mobilise local communities to recognise and appreciate the value of R. Sippi as well as

taking positive steps to restore and protect the river banks.

Evaluation of the projects has generated key lessons that may guide approaches and practices to conservation and disaster risk reduction.

2. Methodology

Scientific baseline studies were carried out to establish causes of landslides and benchmark information on which monitoring and evaluation of ecosystem based adaptation and territorial approach to climate change initiatives would be based, in the Mt Elgon area. The studies involved the use of aerial photographs of 1:24,000 scale taken in 1962 as well as Land Sat MS and Spot imagery taken on 2nd September 1995 and 17th February 2006 in order to understand land use and land cover changes (Mugagga *et al.*, 2012). Field and household surveys, using participatory rural appraisal (PRA) tools such as focused community groups and pair wise ranking were carried out to understand local people's perception on their vulnerability and initiatives.

Based on the results of baseline studies, representatives of beneficiaries (local communities) and technical staff from the targeted districts and lead agencies like the National Forestry Authority (NFA) and UWA were involved in the identification and implementation of initiatives that were considered to be environmentally friendly, pro-poor, holistic and broad in scope (trans-boundary in nature and in addressing root causes of disasters, issues of vulnerability as well as effects of climate change). The key projects were Mt Elgon Regional Ecosystem Programme (MERECP), Territorial Approach to Climate Change (TACC) and Ecosystem Based Adaptation Approach (EBA). The projects produced quarterly and annual progress reports that acted as a critical source of information that enriched this paper.

International and national consultants were hired to evaluate the projects. The experts reviewed the project documents, interviewed national and regional focal persons, heads of implementing institution and field officers. They conducted face – to – face interviews with project management team as well as focused group discussion with beneficiary community based organisations (CBO). They also carried

out field observations. Consultants' reports (MERECP, 2011; TACC, 2014) were reviewed to establish the impact of ecosystem based approaches on disaster risk reduction and draw lessons from the implementation of initiatives. The consultants' reports acted as a source of data on the performance of initiatives.

3. Results

3.1 Scientific Baseline Studies

The results from the scientific baseline studies indicated that landslides were not new to people living on marginal and steep slopes of Mt Elgon especially in Bududa District. According to the residents, the number of people who lost their lives as a result of landslides was higher than the official records (Figure 2). For instance, the official records indicated that in 1970, sixty people were killed by landslides in Bududa, while residents put the death toll to 100 people. In addition, landslides had displaced more than 10,000 people (Juventine, 2012) which had a significant impact on the national resources for resettlement and rehabilitation efforts. The most destructive landslides occurred in March 2010, which claimed more than 440 lives, destroyed vast area of farmland and claimed over 700 livestock, destroyed homesteads and caused floods in lowlands.

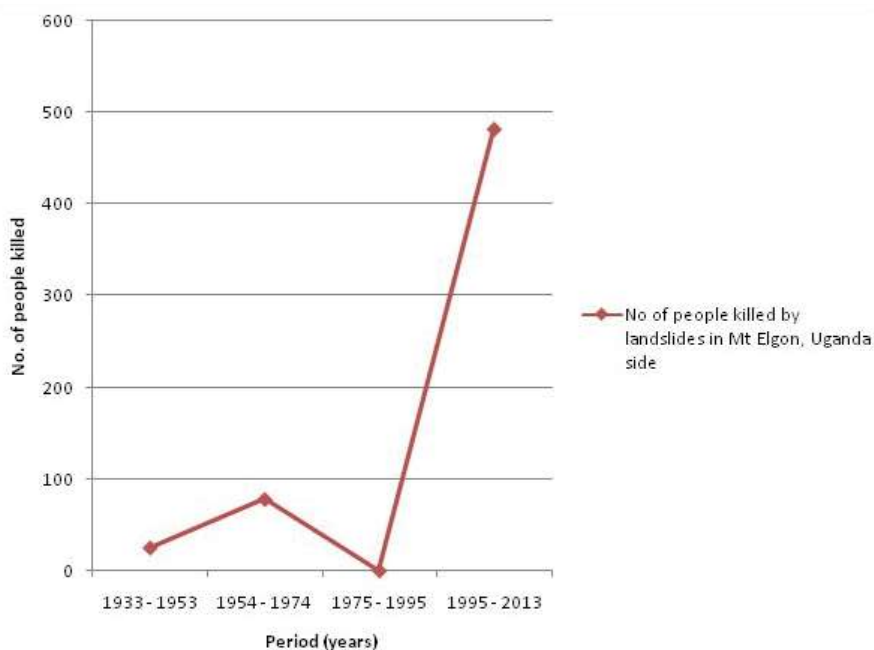
Results showed that most of the landslides have occurred in the farmland areas, which have experienced heavy deforestation rather than within the Mt Elgon National Park, which has significant forest cover (Figures 3 and 4). Most of the landslides surveyed (13 out of 14 sites) 92.9% occurred during a spell of torrential rainfall. Whenever landslides occurred, lowlands would experience floods

Cracks covering a distance of more than 40 km were observed in Mt Elgon ecosystem especially in the districts of Bududa, Manafwa and Mbale (Figure 5). Most of the cracks were found on farmland where the forest cover was not significant. However, due to limited financial resources, expertise and time, it was not possible to determine the extent and magnitude of these cracks, assess the levels of vulnerability and to identify suitable interventions to prevent further cracking of the mountain.

3.2 Disaster Risk Reduction Initiatives

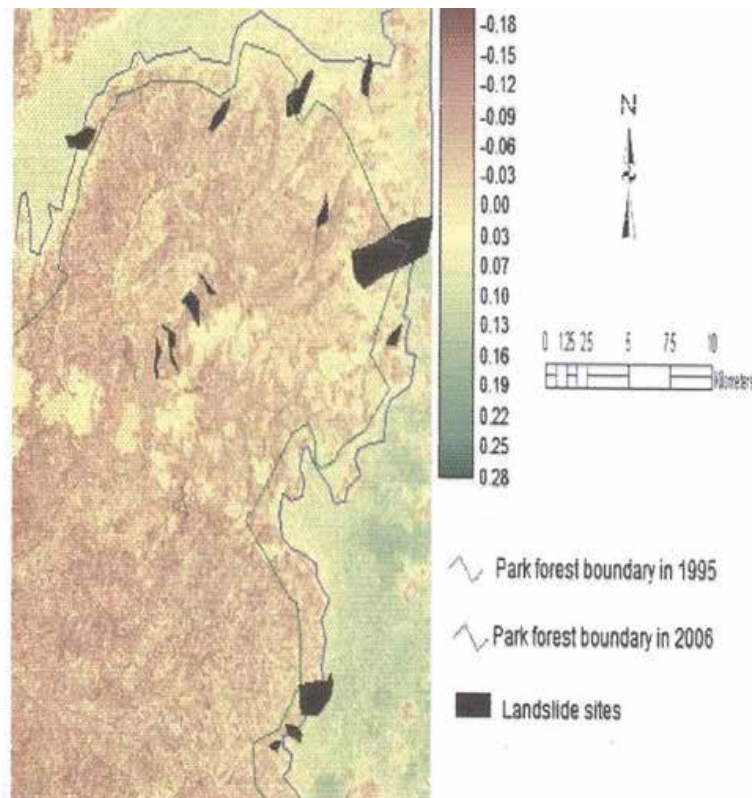
The interventions that were designed based on the findings of the baseline studies conducted prior to the implementation of EBA, MERECP and TACC go beyond the traditional efforts of relief and reconstruction. They aim to address environmental problems, improve resilience and reduce vulnerability to future

Figure 2: Number of people killed by landslides in Mt Elgon, Uganda side.



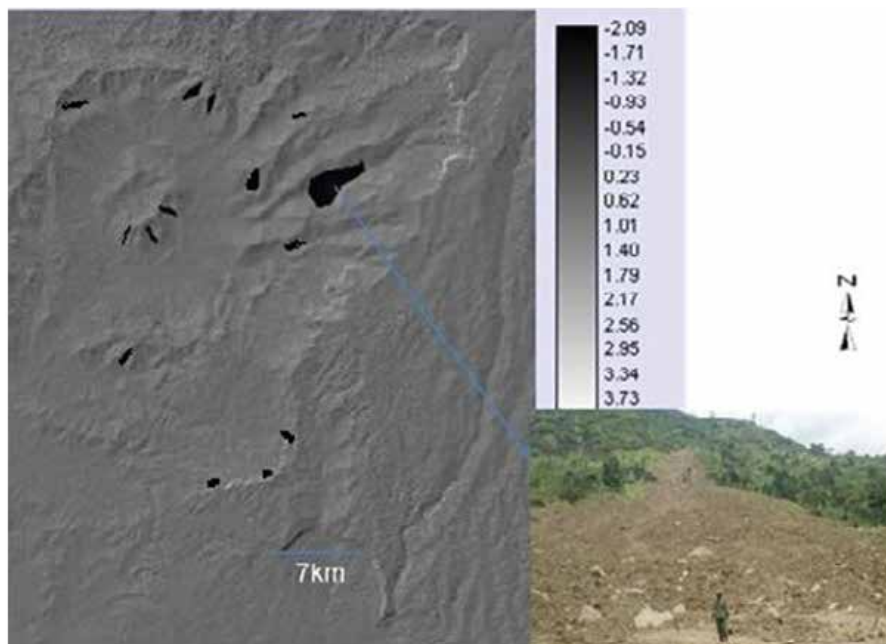
Source: Adapted from NEMA, 2010; Kitutu, 2010.

Figure 3: NDVI image of landslide sites on farmland areas.



Source: Adapted from Mugagga et al., 2012.

Figure 4: Image of Landslides on concave hillside. Inset: a photo of Nametsi landslide in Bududa District where more than 350 lives were lost.



Source: Adapted from Mugagga et al (2012).

landslides, floods and other disaster that may occur due to climate change. The main outputs from these initiatives are described below:

Community Revolving Funds (CRFs)
 MERECP supported Community Based Organisations (CBO) to manage CRF as a livelihood (household income) improvement program for CBO members living adjacent protected areas to invest in environmentally friendly income generating activities. In total twenty CBOs (10 in Kenya and 10 in Uganda) were each given US \$ 10,000 as seed money to be managed by beneficiaries as revolving funds. CRFs targeted rural people with limited access to bank services that were affecting or affected by the existence of protected areas. The implementation of this intervention put into consideration the needs of different gender by ensuring that men, women and the youth were fully involved in the management of CBOs. The evaluation showed that repayment was below 85% and most of the enterprises initiated with CRFs were still in the incubation period.

Forest Plantations for Livelihoods
 Although a total of 7,882 ha were mapped for establishment of *Eucalyptus grandis*² forest plantation, 1200ha (600ha in Uganda and 600ha in Kenya) were planted. The end term evaluation of the intervention revealed that, the set targets (Figure 6) were not achieved due to delays in disbursement of funds. About 32% of the planned acreage for establishing forest plantations was planted.

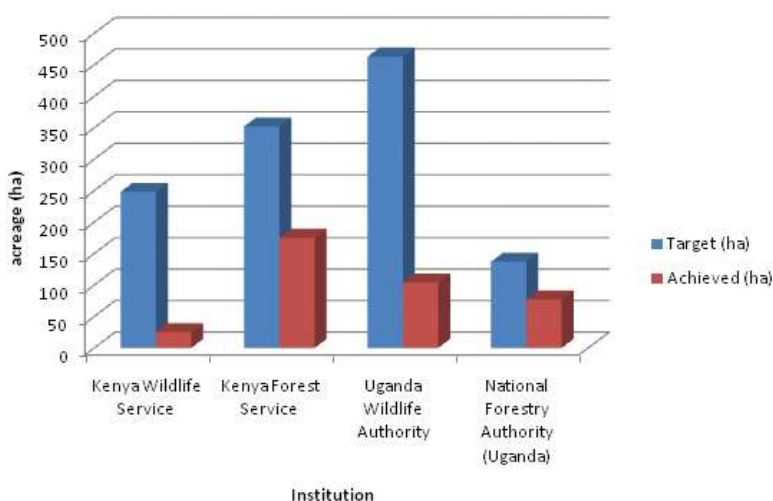
Forest Restoration and Carbon Sequestration
 Good performance was registered in forest restoration and carbon sequestration where more than 83% of the planned areas for restoration were planted with indigenous tree seedlings (Figure 7). Forests within Mt Elgon National Park which had been seriously degraded before MERECP was initiated were starting to recover, giving a chance for improved carbon sequestration.

² *Eucalyptus grandis* species which is exotic but more or less widely grown in Uganda was selected because it is fast growing and provides quick wood products. A twenty metre wide strip of *Eucalyptus* plantation was established on the edge of Mt Elgon National Park to act as live boundary mark as well as a source of fuel wood for household use.

Figure 5: Mountain crack as a warning sign of potential landslide on mountain slopes where tree cover has been cleared.

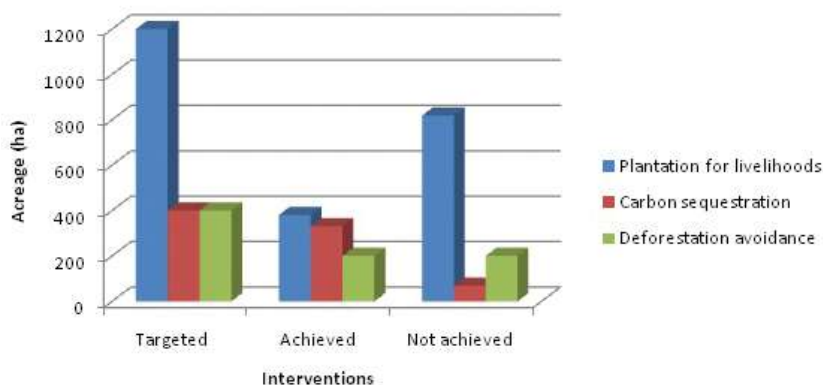


Figure 6: Implementation of Livelihood Forest Plantation by institutions.



Source: Adapted from MERECP End-term review report (2011).

Figure 7: Performance of MERECP according to three key interventions.



Source: Adapted from MERECP, 2011.

Some parts of the fully recovered forest ecosystem had started to shield the farmlands on the low slopes of Mt Elgon against the effects of heavy rainfall and fast water runoffs which were contributing to the occurrence of landslides in the area. In addition, the forest cover was expected to significantly contribute to carbon sequestration. Local people had the opportunity to earn carbon money from trees planted in restored areas.

Deforestation Avoidance

A total of 400 ha of Mt Elgon National Park which was still under intact natural forest cover and undisturbed park boundary (Figure 8) was identified, mapped and targeted for payment under deforestation avoidance model. Uganda effected these payments, and two CBOs (Kapchebut Elgon Farmers Association and Tengwen Kwigate Bee Keeping Association in Sebei region) benefited from the deforestation intervention. Each CBO received financial support worth US\$ 7,000 as an incentive to protect the integrity of Mt Elgon National Park. The basis for the payments was the long history of collaboration with these communities in the conservation of Mt Elgon National Park.

Territorial Approach to Climate Change

A total of 25,441 people (10,176 women & 15,265 men) from 1,824 households benefited from the UNDP-Global Environment Facility (GEF) - Small Grant Support program. Through this initiative, 270 acres of trees, 1.5 acres of grafted fruit trees and 17 acres of coffee were planted. Likewise, farmers were provided with 50 bee hives to harvest and sell honey. 25 households were supported with improved cattle for income to improve livelihoods. 13 vulnerable households were supported with biogas systems for lighting and cooking while waste from the system was used to improve soil fertility. To address problem of fuel wood for cooking among rural communities, selected households were provided with improved cook stoves. The ECOTRUST³ supported 62 farmers who benefited from UNDP-GEF Small Grant to qualify for payment

³ ECOTRUST is a non-profit environmental conservation organisation that was established in Uganda in 1999 to support financing of natural resources and biodiversity conservation (Carter, 2009)

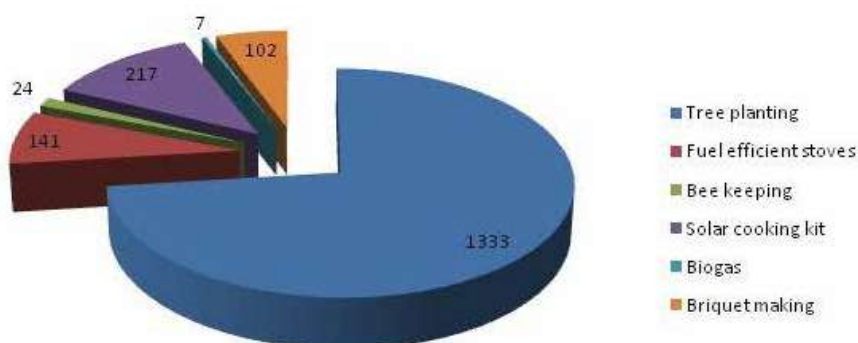
Figure 8: A section of Mt Elgon National Park with clear boundary line and well protected. The neighbouring local communities benefited from deforestation avoidance scheme because of their active role in maintaining its integrity.



from carbon under voluntary carbon trade scheme. Most of beneficiaries used small grants to plant trees for carbon sequestration and household income. Majority of the trees planted were indigenous (196,076 tree seedlings), followed by coffee trees (99,324 tree seedlings) and fruit trees (3,400 tree seedlings) as indicated in Figure 9.

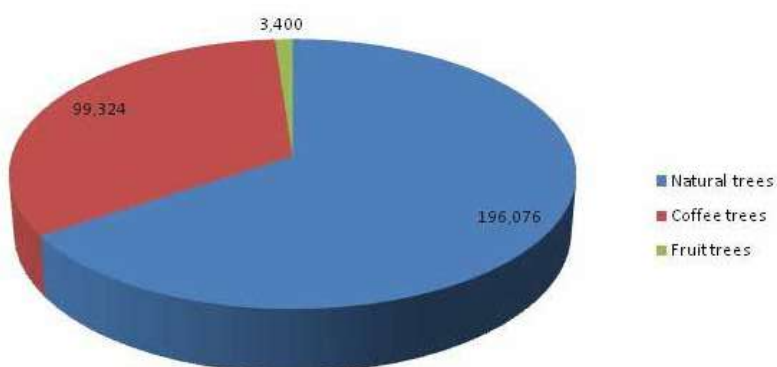
Integrated Territorial Climate Plan 2014-2029 that guide stakeholders in the region for responding to disasters, reducing disaster risk and managing disasters was developed. TACC also supported the process to form a strong regional framework to coordinate and implement initiatives that build resilience to the effects of climate change. A Regional Climate Change Forum (RCCF) was formed to coordinate and share information on issues of environmental management and climate change. In addition, farmers were supported to plant about 196,076 natural trees, coffee seedlings and fruit trees (Figure 10).

Figure 9: Number of beneficiaries (households) of TACC small grants.



Source: TACC (2014).

Figure 10: Number of tree seedlings planted by TACC Small Grant beneficiaries.



Source: TACC (2014).

Ecosystem Based Adaptation (EBA) Approach

It was established that prolonged drought spells used to force residents to cultivate along the river banks, thus encouraging the siltation of the river and compromising water quality and availability. UNEP in partnership with UNDP, IUCN, Kapchorwa District Water Department and local communities received funds from the Government of Germany that was used to implement EBA to tap and distribute water from River Sippi (as a key ecosystem service of Mt Elgon forest) to the residents through a gravitational flow scheme. The project enhanced the resilience and adaptive capacities of more than 1,000 households by securing reliable supply of water for production/irrigation and domestic use. The parties, promoted catchment area restoration and management in order to sustain the river flow through river bank management, tree planting to restore the entire degraded landscape that supports river Sippi as well as soil and water conservation.

4. Discussion

Results from studies and baseline surveys carried out prior to the implementation of disaster risk reduction and climate change initiatives provided critical information with regards to the magnitude of disasters,

needs of the people, levels of vulnerability and potential interventions to improve people's resilience to disasters, reduce the risks and mitigation of effects of disasters. The importance of linking ecosystem goods and services with livelihoods (poverty reduction) and ecosystem conservation was highlighted in the implementation of MERECP initiatives. The challenge of disasters was handled in a broad sense using a regional (trans-boundary) and ecosystem based approach.

By using a trans-boundary ecosystem approach, it was possible for MERECP to involve local communities living on the slopes of Mt Elgon in both Kenya and Uganda in controlling deforestation and encroachment of Mt Elgon protected areas which were responsible for land degradation, vulnerability of the ecosystem and a driving factor for landslides and floods. Mt Elgon Trans-boundary District Implementation Teams worked hard to mobilise local people and monitor disaster risk reduction interventions. The teams were coordinated by the management of Mt Elgon National Park, with support from MERECP Program Management Unit of Lake Victoria Basin Commission. However, the major limitation to disaster risk reduction efforts in Uganda was lack of formal early warning systems to alert victims on landslides and floods.

The need and value for a platform to coordinate and plan climate change initiatives is presented by TACC. The formulation of an integrated territorial climate plan (ITCP) for Mbale Region in Uganda through a consultative process that involved many stakeholders at local, regional and national level played a key role in sensitising decision makers and local communities on the potential threats posed by disasters and the effect of climate change. The platform and ITCP are now key tools for stakeholders in Mbale Region for integrating climate change into development plans. This is possible because ITCP is well linked to the National Development Plan and Climate Change Policy which empowers district local governments to take appropriate mitigation and adaptation actions to reduce the effects of climate change. It was also important to handle disaster risks and the effects of climate change as

integral part of regional and national plans and strategies. The role of small grants in providing a range of benefits such as improvement of household income and funding of income generating adaptation and mitigation projects to communities living adjacent Mt Elgon National Park is also emphasised by TACC. The need for training and mentoring of CBO leaders in leadership and management skills is also highlighted in MERECP. Capacity building was a trigger factor for the empowerment of CBOs to manage micro credit and saving schemes in the rural setup. At initial stages, it was vital to provide significant technical support and monitoring to the management of CRFs in order to keep beneficiaries focused on environmental management, climate change adaptation and disaster risk reduction. Otherwise, there was temptation of CBOs spending financial resources on ventures that give high and fast returns but which may not necessarily be environmentally friendly. However, like CRFs, for small grants to be meaningful and worthwhile to the poor rural communities they should be given out as conditional funds meant for implementation of disaster risk reduction initiatives, adaptation and mitigation of the effects of climate change.

Delays in disbursement of funds due to government bureaucratic procedures was responsible for the failure of MERECP to meet set targets of forest plantation for livelihoods as local people could not get tree seedlings for planting in time to catch up with rainy season.

The need for active participation of local people in planning, management and implementation of disaster risk reduction is highlighted by EBA. Implementation of a gravity flow water scheme, which was addressing a pressing need of Sanzara people contributed to the success of project. The involvement of beneficiaries in all stages of project implementation was a major factor that enabled residents to understand, recognise and appreciate the River Sippi catchment. This motivated them to engage in the restoration and management of the entire river catchment. The replication of EBA approach calls for identification of appropriate and vital ecosystem good or service that provides a suitable entry point for local people and other stakeholders to participate in

ecosystem management and livelihood improvement. In the case of Sanzara village, it was water resource from River Sippi that acted as an important entry point and incentive for engaging downstream and upstream residents in the conservation of the River Sippi micro catchment. Kapchorwa District Local Government supported the community initiative by offering US \$ 20,000 as contribution towards the extension of the gravity flow water scheme to cover other villages that had been left out, after realising the benefits of the project. By realising the value and the need to restore the integrity of the river system, the entire River Sippi catchment would be sustainably managed for the long term benefit of all stakeholders.

Building on the success and lessons learnt from existing initiatives, IUCN Eastern and Southern African Regional Office in collaboration with partners like USAID and African Collaborative Centre for Earth System Science (ACCESS) recently introduced a project that seeks to improve the understanding of science on climate change and demonstrates social and ecological resilience in hotspots of Mt Elgon. On the Ugandan side, River Suam and River Manafwa catchment areas were identified as hotspots. The project aims at assisting people to acquire knowledge on climate change adaptation from local to regional levels and use evidence and lessons from adaptation approaches to inform policies across sectors. Although the implementation of this project is still in its initiation (incubation) stages, its design, management and impacts will contribute towards the replication of the existing initiatives.

5. Conclusion

The importance of Mt Elgon National Park's forest cover lies in its ability to prevent mass movements of soils and rocks. Mt Elgon ecosystem scenario demonstrates that a secure protected area plays a vital role in disaster risk reduction and contributes to the improvement of people's livelihoods and resilience to the effects of climate change. One of the important lessons learnt from Mt Elgon initiatives is that it is vital to link protected area conservation, disaster risk reduction and climate change initiatives to the livelihoods and aspirations of the local people, especially if the beneficiaries are

to give overwhelming support, ownership and implement DRR and climate change programs. In other words, the responses to disasters should go beyond the traditional humanitarian assistance and emergency management to addressing the underlying causes of disasters, ecosystem management and reducing the vulnerability of people's lives and livelihoods, especially if the affected people are to be safeguarded against future disasters. Projects that involve various institutions (government, NGOs, CBOs and private sector) at all levels provide opportunities for synergies development and possibilities of sustainability and replication of successful initiatives. Mainstreaming DRR and climate change in national and regional planning process across sectors enhances coordination and sustainability of mitigation and adaptation programs.

It is also important to identify protected area goods and services that form important entry points for EBA initiatives around which local people and other stakeholders can work together to reduce risks of disasters, effects of climate change and improve protected area ecosystems. Looking at the bigger picture is essential because it allows policy makers, partners and local communities to take a broad and holistic approach to tackle the challenges of disasters, climate change and ecosystem conservation. However,

considering the high level of illiteracy and poverty in communities residing around protected areas in the developing world (Uganda inclusive), investing in capacity building is vital in empowering institutions and local people to effectively and efficiently deal with issues of climate change and disasters. Local community involvement in the implementation of community-natural resource based projects is highly essential because they are the ones who are most affected by disasters and their activities impact on the stability factor of ecosystems. The use of already existing CBOs with alternative sources of funding in implementing DRR provides opportunities for dealing with existing community groups to champion ecosystem conservation at grass-root level.

Although carbon money is an essential incentive for local people to participate in ecosystem restoration and reforestation, the existing mechanisms for carbon trade are not well understood and unaffordable to the majority of rural people in developing countries. Land fragmentation and small scale landholding by many people around Mt Elgon ecosystem make clean development mechanism projects that involves hectic certification and marketing of carbon credits unsuitable. The pilot project of TACC in collaboration with ECOTRUST has proved that voluntary carbon trade at small scale based on small

landholding can work in rural areas.

Finally, the current mountain cracks in Mt Elgon ecosystem still pose a threat to the livelihoods of mountainous people. It is necessary to carry out a scientific study on the extent and magnitude of these cracks, assess the level of vulnerability and identify suitable interventions to prevent further cracking of the mountain and make it safe for neighbouring communities.

Acknowledgement

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Chapter 16

Hurricane Katrina, the role of US National Parks on the northern Gulf of Mexico and post storm wetland restoration

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Abstract

Hurricane Katrina approached the northern Gulf of Mexico coast on 28 August 2005, making landfall as a category 3 storm, with sustained winds of 205 km/hr in southeastern Louisiana. It then moved up across the Mississippi coast, causing catastrophic damage to the coastal communities of both states, inflicting an estimated US\$ 81 billion in damages and causing 1,836 deaths.

Tropical low weather systems in the form of tropical storms and hurricanes are frequent to this coast. Large metropolitan areas as well as small coastal communities are periodically at risk from disastrous impacts from hurricanes, mostly in the form of storm surge. Two major landscape features of the northern Gulf of Mexico coast, one being mainland coastal marshes and swamps, and the second being offshore barrier islands, act as risk reduction measures from hurricanes to populated areas. The two United States (US) National Parks along the coast played a key role in the protection of the coastal communities, despite being directly impacted by Hurricane Katrina. Jean Lafitte National Historic Park and Preserve (JELA NHPP) south of New Orleans and Gulf Islands National Seashore (GUIS-MS) south of the Mississippi coastal mainland provided protection through their wetlands and barrier islands. Coastal marshes, swamps and barrier islands can reduce storm surge from roughly 5 cm/km to 1m/4 km, depending upon the topography, bathymetry and the plant community type. Together with storm surge attenuation, the parks protect engineered hurricane

protection levees (which border the park and metropolitan New Orleans), as well as coastal communities of Mississippi without hurricane protection levees, thereby providing a multiple defence system against hurricanes.

Restoration of wetlands in Jean Lafitte National Historic Park and Preserve is essential for this National Park Service (NPS) unit to continue to provide a disaster risk reduction function. Restoration of the Mississippi Gulf of Mexico islands at Gulf Islands National Seashore will further contribute to disaster risk reduction efforts, including the attenuation of storm surges. The US Congress has authorized and allocated funds to conduct restoration of the Gulf Islands, primarily closing Camille Cut, as well as restoration work on other islands for a cost of over US\$ 400 million. This sum, plus the cost of restoration for Jean Lafitte NHPP estimated at over US\$ 50 million, is minor compared to the economic losses in damages caused by Hurricane Katrina alone.

1. Introduction

On 28 August 2005, Hurricane Katrina approached the northern Gulf of Mexico coast threatening the states of Louisiana and Mississippi as a category 5 storm on the Saffir-Simpson hurricane scale (Saffir, 1973; Simpson, 1974) with sustained winds of 282 km/hr and gusts of 310 km/hr and reaching a diameter of 668 km at her peak. First landfall as a category 3 storm occurred in Plaquemines Parish near Buras, between New Orleans and

the mouth of the Mississippi River, before Katrina moved out across Lake Borgne and into the state of Mississippi. New Orleans flooded and almost everything within several hundred metres of the beach in Mississippi was destroyed, especially from Waveland to Biloxi. The storm surge ranged from 7 metres to 8.5 metres along a 32 km stretch of the Mississippi coast, the highest ever recorded in the USA, with waters reaching as far as 19 km from the beach¹. Total loss of life was 1,836 people, including 1,557 in Louisiana. Following the storm, these communities, which have tourism driven economies, faced long roads to recovery. Hurricane Katrina still ranks as the costliest storm in US history, causing over US\$ 81 billion in damages (Knabb *et al.*, 2005).

Jean Lafitte National Historic Park and Preserve (JELA NHPP), south of New Orleans and Gulf Islands National Seashore (GUIS-MS) which lies south of the Mississippi coastal mainland (Figures 1 and 2) provide protection through both their wetlands and the offshore barrier islands. Based on storm attenuation research in recent years for both coastal marshes and swamps and for barrier islands, coupled with studies post Hurricane Katrina, there is strong evidence that these ecosystems play a role in the protection of populated coastal communities.

¹ www.nhc.noaa.gov

The two parks have also undergone extensive degradation from human activities as well as natural hazards over the years. Jean Lafitte NHPP is a complex of marshes including rare floating marsh (flotant), swamps and bottomland forests, which are directly adjacent to the Mississippi River west bank urban areas of metropolitan New Orleans. This park unit, historically explored for the extraction of petroleum products prior to becoming a National Park, is crisscrossed with abandoned oil exploration access canals. These canals contribute to increased salt water intrusion, which in turn leads to changes in the plant community, contributes to shoreline erosion and eventually wetland loss. Exotic plant species are also degrading habitats within the park.

Gulf Islands National Seashore in coastal Mississippi, which is the longest national seashore in the USA, is a barrier island chain formed from the east to west due to transportation of sands and other sediments along the north Gulf of Mexico coast. Six islands are part of the National Seashore in Mississippi (Cat, West Ship, East Ship, Horn, Sand and Petit Bois). These islands shelter the mainland of the state of Mississippi, stretching 129 km from the state line with Louisiana to the state line with Alabama. Gulf Islands National Seashore is an IUCN Category V protected area (protected landscape/seascape). The islands lay from 10 km (Horn Island) to as much as 19 km (West Ship Island) south of the Mississippi mainland. Horn and Petit Bois Islands are designated wilderness areas by the US Congress.

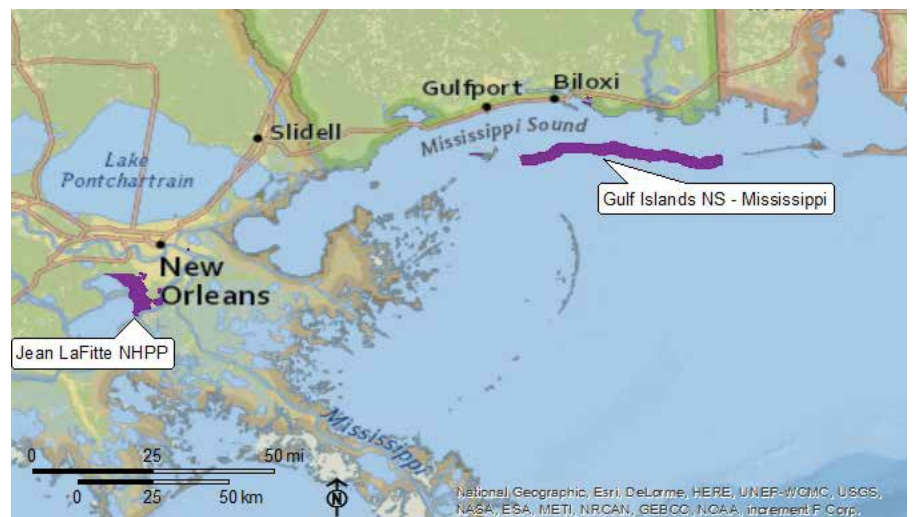
Numerous endangered species inhabit the islands, which are also home to nesting sea turtles, shore birds and a stopover for neotropical migratory birds. The islands house diverse wetland assemblages that provide a resting area for neotropical migrant birds. Islands are a critical component of the local tourist economy and they also provide protection to the mainland from hurricanes.

Gulf Island National Seashore islands have suffered a severe loss of sediments from the disruption of the long shore east to west transport system through the dredging of navigation channels for the shipping industry. Navigation channels

Figure 1: Location of Jean Lafitte National Historic Park and Preserve and Gulf Islands National Seashore on the northern Gulf of Mexico coast.



Figure 2: Jean Lafitte NHPP and Gulf Islands National Seashore.



have been maintained between Cat and West Ship islands, and between Sand and Petit Bois islands, to provide for the ports of Gulfport and Pascagoula, Mississippi, respectively. Sediments can no longer move westward, settling into the shipping channels instead of reaching the next island in the chain. As a result, island erosion has increased, new deposition of sands has decreased and hurricanes have dramatically changed their morphology.

Damages from Hurricane Katrina were the greatest on the Mississippi mainland for 32 km along the stretch bordered by West and East Ship Islands. Storm surge waters travelled as far as 19 km inland, destroying most structures for the first

100 metres from the beach. Further to the east and along the shoreline where Horn, Sand and Petit Bois lay, damages were considerably less. This is in part due to the distance from the maximum winds and surge, but these islands are also closer to the mainland shore and could be providing greater surge attenuation and therefore protection.

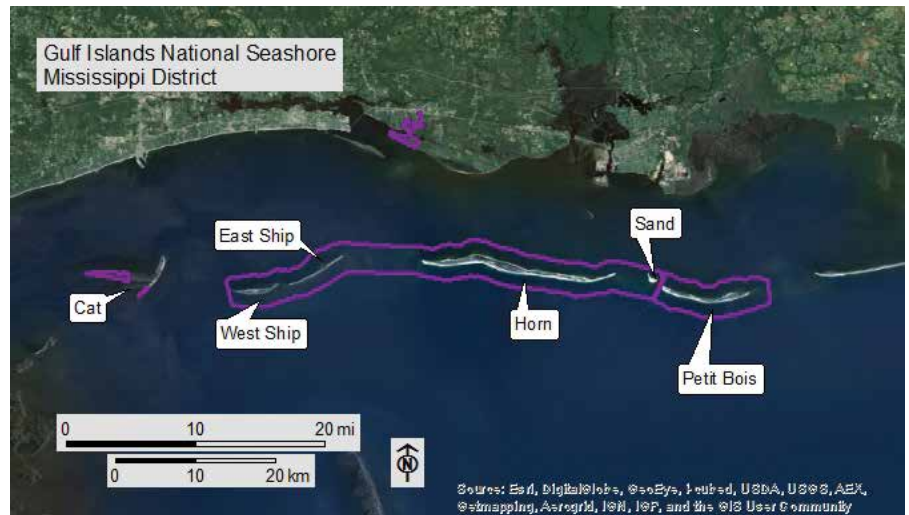
One major reason for barrier island restoration is to enhance the barrier that will reduce storm surge from hurricanes. Gulf Islands National Seashore provides protection to the mainland of the state of Mississippi by reducing wave heights and storm surge heights. Loss of these barrier islands could result in wave heights

as much as 1.25 metres greater at the mainland beaches. In addition to sea level rise, which is threatening to submerge the islands, interruptions of long shore sediment transport from navigation channel dredging is limiting the ability of the islands to migrate and rebuild. Reestablishing sediment transport processes will contribute greatly to island restoration and extend the islands' lives (Byrnes *et al.*, 2012).

The US Congress directed the Army Corps of Engineers, a branch of the US Army made up mostly of civilian engineers whose job is to investigate, develop and maintain the nation's water and related environmental resources, to reconnect the two halves of Ship Island, which was divided into West and East Ship Islands after being breached by Hurricane Camille in 1969 (Figure 3). Known as Camille Cut, the breach has grown to nearly 11 km wide. Hurricane Katrina contributed tremendously to Camille Cut widening, nearly doubling it from 6 km. US Congress authorized and appropriated nearly US\$ 500 million to the restoration of the seashore's barrier islands, including the closing of Camille Cut. This will be done by connecting the eastern edge of West Ship and the western edge of East Ship Islands using dredged sand. This work should begin early in 2015.

Marine intertidal beaches are considered wetlands by the National Park Service, following the classification system of Cowardin *et al.* (1979). From the mean high spring tide to the mean low spring tide, these areas of ocean beaches are wetlands. Much of the land which will be buried by the project is marine intertidal wetlands on both West Ship and East Ship Islands. Executive Order 11990 - Protection of Wetlands (42 Fed. Reg. 26961) signed by President Jimmy Carter in 1976 states that there can be no net loss of wetlands on federally managed lands. Approximately 14 ha of marine intertidal wetlands will be buried due to placement of sands, however 37 ha of new marine intertidal wetlands will exist at the completion of the project for a net gain of 23 ha (NPS, 2013).

Figure 3: Gulf Islands National Seashore.



2. Methodology

2.1 Restoring Wetlands in Jean Lafitte NHPP

Wetland restoration at Jean Lafitte NHPP includes canal reclamation (backfilling), use of dredged material for marsh nourishment, the removal and control of

exotic plant species, planting of desired species and Mississippi River water and sediment diversions. Oil exploration and navigation canals dug prior to the property becoming a National Park unit, crisscross the Barataria Preserve of the park south of New Orleans and west of the Mississippi River (Figure 4). These canals directly

Figure 4: JELA NHPP Barataria Preserve.

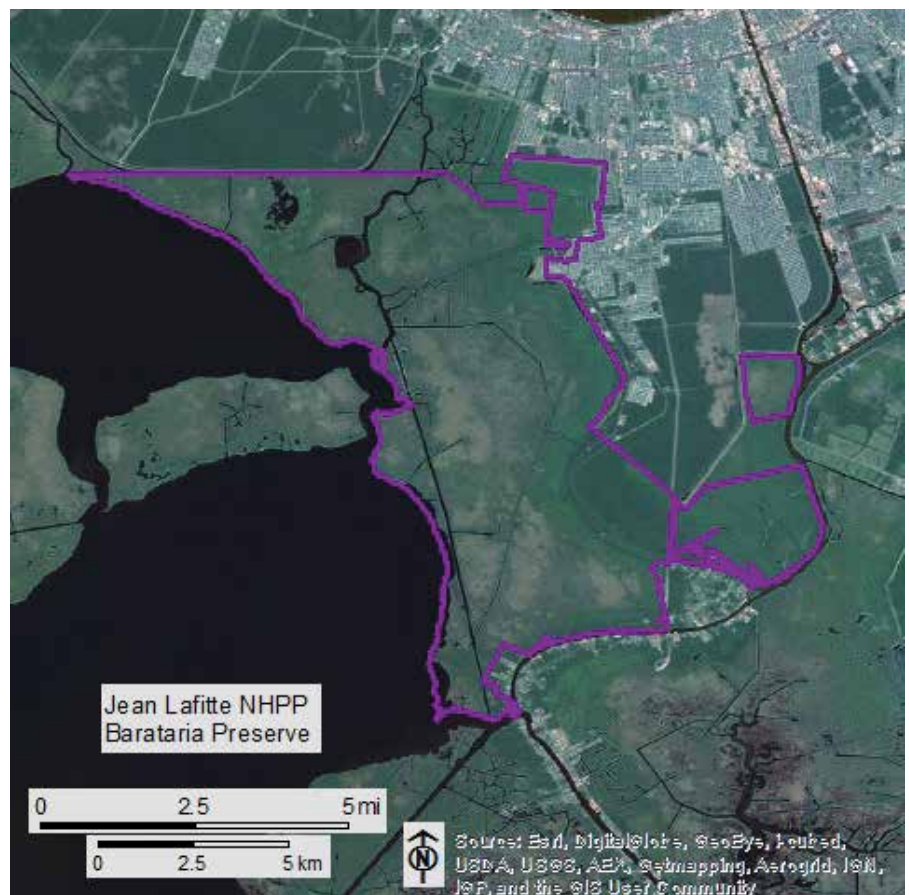


Figure 5: Dredge material spoil banks covered in trees in the background are a stark contrast to the area in the foreground where the spoil banks have been bulldozed into the canal.



Figure 6: Spray dredge distributing sediments to sides of a canal.



cause the loss of wetlands by converting land to open water, create uplands from the piling of dredged sediments along the canals, disrupt the natural hydrology, and create habitat for exotic species.

Spoil banks that were created from previous canal dredging actions are being

lowered and pushed back into the canals in what are called backfilling events. This helps to restore the normal hydrology and keep the marsh healthy and less stressed (Figure 5). Filling the canals still unrestored will cost roughly over US\$ 50 million. When funding or opportunities are available Jean Lafitte NHPP continues to work on the

backfilling of canals. So far, 8 km of canals have been backfilled at a cost of US\$ 12,000 per 0.5 ha. Using heavy equipment such as excavators mounted on marsh buggies, tree covered spoil banks are pushed into canals, partially filling them. Target elevation for the restored land is similar to the surrounding marsh, resulting in a similar, or often the same marsh plant community. Hydrologic barriers are removed, water flow is no longer restricted and an exchange of fresh and salt water can take place. Consequently, sediments within the water can move into the marsh, nourishing the marsh and adding to the vertical soil accretion. Landscape that supports woody exotic vegetation is removed to prevent repeated colonization of unwanted species through returning the soil elevation to a level that will support a herbaceous marsh plant community.

Periodic dredging of canals at Jean Lafitte NHPP is occasionally required for navigation purposes. The Bayou Signette Waterway, which runs the length of the western border of the preserve, is congressionally legislated to remain open and usable for commercial fishing vessels or other business related navigation. The use of thin-layered spray dredging is desired (Figure 6) because the light layer of dredged material does not smother existing vegetation while still raising the soil elevation, unlike thicker applications of more traditional dredged material placements that often kill an existing plant community. These dredges collect the material, mix it with ambient water and spray the slurry on to the marsh surface (Ford *et al.*, 1999). The thickness of the applied slurry can vary from very light with a depth of only a couple of centimetres, which would primarily nourish the marsh with fresh sediments and light nutrient loads, or applied to the marsh surface at depths of up to and around 30 cm. If done as a thin layer, the marsh receives a mixture of water and sediments that nourishes the plant community. Thicker applications would be desired if there is a strong vertical elevation deficit due to high soil subsidence rates. Subsidence rates in coastal Louisiana average over 10 cm per year, and can be much higher in the Barataria Basin. Subsidence in coastal Louisiana is similar to that in other major river deltas. One major cause is the downwarping of tectonic plates due to the

weight of sediments near the Mississippi River's mouth. Also, these sediments are relatively young in geological terms, being laid down in the past 7,000 years. Therefore, these sediments are still dewatering, degassing and settling at a rate greater than more stable non-deltaic land forms.

Vegetative plantings also help to restore and preserve the marsh and swamp ecosystems. In some areas that have been degraded, bald cypress (*Taxodium distichum*) stems are being planted using volunteers from non-profit conservation groups. Vegetative planting of small seedlings is carried out using polyvinyl chloride (PVC) trunk protectors to prevent herbivores from consuming the newly planted trees (Figure 7). The protectors are split down one side, so as the tree grows and the trunk enlargens the protectors split as well.

Chinese tallow (*Sapium sebiferum*), an exotic species, is being treated with herbicides by the National Parks Service (NPS) Exotic Plant Management Teams. Floating aquatic exotic species, such as water hyacinth (*Eichhornia crassipes*) are being physically removed from waterways. Other species, such as giant salvinia (*Salvinia molesta*), are being treated with weevils that attack and kill the plants. The state of Louisiana has constructed river diversions, water control structures that allow controlled flows from the Mississippi River into various basins of the delta. The Davis Pond diversion, upstream from New Orleans, releases fresh river water into the Barataria Basin which strongly influences salinities and sediment loads into the Barataria Preserve.

2.2 Gulf Islands National Seashore – Mississippi

Restoration of Ship Island will take place using dredged material. A project is currently under planning to place roughly 17 million cubic metres of sand, at a cost of an estimated US\$ 368 million, to fill Camille Cut in order to attach the west end of East Ship Island and the east of West Ship Island, creating a restored Ship Island.

Storm surge attenuation was modelled by the US Army Corps of Engineers to determine the effectiveness of barrier island restoration. In order to simulate the barrier island restoration scenario in the integrated

Figure 7: Bald cypress seedlings with PVC trunk protectors.



coastal storm modelling system, an ADvanced CIRCulation model (ADCIRC), which is a two-dimensional, depth-integrated, barotropic time-dependent long wave, hydrodynamic circulation model was modified to include the restoration template for Camille Cut and borrow site data. A full-plane STWAVE (STeady State spectral WAVE), an easy-to-apply, flexible, robust model for nearshore wind-wave growth and propagation domain, was then created by interpolation from the restored ADCIRC mesh scenario (US Army Corps of Engineers, 2014).

3. Results

3.1 Jean Lafitte NHPP

Canal backfilling removed the hydrology barrier present from the dredged material spoil banks, as well as partially filling in canals long unused for oil exploration or production extraction. Using heavy equipment, old spoil banks were pushed into the canals. Trees were knocked down and the final elevation was similar to that of the surrounding marsh. This allowed for natural flows of water and for the mixing and equilibration of fresh and brackish waters.

Using vegetative plantings, deepwater bald cypress (*Taxodium distichum*) communities are being restored. Survival rates tend to be close to 100% when using the

protectors versus most not surviving without (Meyers *et al.*, 1995).

Giant salvinia (*Salvinia molesta*), also known as kariba weed, Chinese tallow (*Sapium sebiferum*), water hyacinth, (*Eichhornia crassipes*) and Cuban bulrush (*Oxycaryum cubense* (Poepp. & Kunth) Lye) are some of the more problematic plants in the park. Treatment of Chinese tallow trees using herbicides applied directly to the trunks of individuals is resulting in stands of the trees dying. National Park Service Exotic Plant Management Team staff conducts this programme. Giant salvinia (*Salvinia molesta*), a large floating fern, has successfully been controlled through the use of an introduced weevil (*Cyrtobagous salviniae*). The weevil attacks only the giant salvinia, leaving other plants undisturbed. Water hyacinth is mostly controlled through mechanical removal using harvesters that scoop up the plants and stockpile them in upland areas to kill them. This method is highly successful (Table 1).

The Davis Pond Mississippi River Diversion directs fresh river water into the upper part of Barataria Basin and the preserve. Salinities in the upper Barataria Basin can change from 2-3 mg/l to near zero.

3.2 Gulf Islands National Seashore – Mississippi

The filling in of Camille Cut, reconnecting

Table 1: Exotic plant species, control measures and relative success.

Scientific Name	Common Name	Control Measure	Relative Success
<i>Salvinia molesta</i>	Giant Salvinia/Kariba Weed	Weevils <i>Cyrtobagous salviniae</i>	Highly successful
<i>Sapium sebiferum</i>	Chinese Tallow	Herbicides directly applied to lower trunk	Highly successful
<i>Eichhornia crassipes</i>	Water Hyacinth	Mechanical removal	Temporarily highly successful
<i>Oxycaryum cubense</i>	Cuban Bulrush	Mechanical removal	Unknown

West and East Ship Islands back into a single island is still in the planning stage. It is hoped that Ship Island will provide protection for the coastal Mississippi mainland. Modelling suggests that wave height will be reduced in the lee of the island and surge height from major storms at the mainland beach will be reduced by as much as 1.25 metres.

4. Discussion

4.1 Jean Lafitte NHPP

Oil exploration and production canals are conduits for salt water from the coast, and increase the amount of salt water intrusion, which in turns stresses the more freshwater plant communities and in some cases accelerates wetland loss. Canal backfilling is an effective method of reversing some of the negative influences of the canals. Thousands of miles of canals have been dug throughout coastal Louisiana, including several miles within Jean Lafitte NHPP. Digging canals converts healthy marsh directly into open water, thus immediately resulting in wetland loss. Further, the marsh immediately adjacent to the canals is buried under the discarded spoil material, resulting in the filling in of wetlands. Lastly, the spoil banks, which are now upland plant communities, act as hydrologic barriers to limit overland flows and reducing the mixing of fresher water with saltier water, which is trapped behind the spoil banks in the marsh interior. Elevated salinity levels stress the marsh plant community leading to degradation of the marsh. While restoration of the canals is a significant achievement, further funding of this restoration is not guaranteed at this time, but is desired.

Controlling exotic plants are a challenge throughout the National Park Service, including in Jean Lafitte NHPP, where the park's staff from Natural Resources are attempting to control several species.

Control of *Salvinia molesta* has been very successful through the use of weevils. However, even though populations are reduced, continuous controls must be applied because this floating fern has a very high growth rate. Chinese tallow, an invader with deep roots, high seed production and the ability to outcompete most other tree species, remains a problem and constant pressure to reduce the populations is required. Chinese tallow seeds remain viable for a long time in the seed bank. Seeds are easily spread by birds who selectively eat them, then deposit them widely in their faeces. Mechanical removal of water hyacinth is highly effective, but like other exotic plant species, it has a high growth rate and can quickly recolonize the waterways. Constant pressure on the population is required to keep the species suppressed. Removal of unwanted exotic plant species provides the opportunity for desired species to thrive, such as bald cypress which are long lived and storm tolerant. The bald cypress swamps play a strong role in the protection of the hurricane levee system that borders the park and the adjacent human communities.

River diversions have been built along the Mississippi River in Louisiana to help replace some of the lost function of periodic pulses of fresh water, historically delivered during periods of high water, into the coastal wetlands. Prior to the building of the river control levees, the river would flood its banks during high water, bringing sediment rich water into the wetlands that would flush salt water out, nourish, and provide vertical soil accretion to the wetlands. Located 24 km up the river from New Orleans, the Davis Pond diversion which is a 300 cm³ per second discharge structure, delivers river water and sediments to the upper Barataria Basin, including the Barataria Preserve

of Jean Lafitte NHPP. Such fresh water inputs limit salt water intrusion, helping to protect the floating marsh (flotant) and the bald cypress swamps on the north end of the preserve. Poirrier *et al.* (2010) report that abundant fresh water and nutrient input into the preserve resulted in a robust growth response from submerged aquatic vegetation (SAV).

In areas with sufficient soil elevation for tree establishment, the deep water swamp community is being expanded. Mainland wetlands, including marshes and swamps, can attenuate hurricane storm surge (Costanza *et al.*, 2008). Marshes can decrease storm surge heights from 4.7 cm/km (LA Coast 2050, 1998) to as much as 1 m/4 km (Wamsleya *et al.*, 2010). Storm surge attenuation is based on geomorphology of the land, coastal bathymetry, and a storm's intensity, speed and track (Wamsleya *et al.*, 2010). The marshes and swamps of Jean Lafitte NHPP provide direct storm surge risk reduction for the New Orleans metropolitan town of Marrero, a small community on the west bank of the Mississippi River. The bald cypress swamp grows near the base of the levee on one side while homes and businesses are located immediately on the opposite side of the levee, creating a very strong gradient between the natural and developed landscape. This juxtaposition of human dwellings and the natural environment does not allow for much space to buffer storm surges. Therefore, bald cypress are critical to storm surge attenuation before the surges can impact the hurricane protection levees.

Through the use of river diversions, canal backfilling, swamp tree species planting, and the beneficial use of dredged materials, the marsh and swamp ecosystem is restored to provide better risk reduction than the degraded

landscape. This risk reduction extends to all of the communities on New Orleans' metropolitan west bank area. A healthy swamp ecosystem can also contribute to protecting hurricane protection levees (Mashriqui *et al.*, 2006; Wamsleya *et al.*, 2010). During Hurricane Katrina, levees with swamps bordering them did not fail, while those open to the surge sustained damages including breaching.

4.2 Gulf Islands National Seashore – Mississippi

Offshore barrier Islands have long been reported to provide risk reduction from storm surges (Day *et al.*, 2007). Modelling by Suhayda (1997) shows that barrier islands contribute to storm surge attenuation, but do not remove it completely. Benefits would include annual hurricane and storm damage risk reduction of US\$ 20 million to mainland Mississippi, US\$ 470,000 in average annual recreation benefits, and US\$ 43 million in average annual fishery losses avoided. Modelling by the US Army Corps of Engineers (USACE, 2014) shows that restoration of Ship Island will decrease wave heights significantly on the leeward side of the island by between 0.2 and 1.25 metres compared to existing conditions and will reduce storm surge heights on the mainland.

5. Conclusion

Hurricane Katrina severely affected the states of Louisiana and Mississippi, and the wider northern Gulf of Mexico. It inflicted an estimated US\$ 81 billion worth of damages and caused 1,836 deaths. Analyses of impacts from Hurricane Katrina clearly show that coastal marshes, swamps and barrier islands of the northern Gulf of Mexico coast provide a valuable

service in disaster risk reduction. Marshes and swamps can significantly reduce storm surge depending upon the topography, bathymetry and the habitat type. Barrier islands also provide this service, depending upon their size and position to the coast.

Given the role these ecosystems play in providing risk reduction from natural disasters, there is a strong and urgent need to continue restoration. However, restoration of swamps in Jean Lafitte National Historic Park and Preserve is challenging as funding for planned projects has not yet been obtained, for the most part. Without additional restoration, this National Park Service (NPS) unit will not be able to provide adequate disaster risk reduction in the form of storm surge attenuation and the protection of the hurricane protection levees that border both the park and metropolitan New Orleans. Estimated at roughly US\$ 50 million, backfilling of old oil exploration and production canals would contribute greatly to the restoration of the marsh and swamp ecosystem. Some restoration will be likely in the near future funded as mitigation for other projects impacting wetlands. That potential funding will not fully cover the estimated cost of all planned restoration. Additional plantings of bald cypress swamps will take place as money, often in the form of grants, is obtained. Restoration of the ecosystem through the removal of exotic plants is mostly funded through the budgets of the National Park Service. The current economy of the United States, coupled with the need to restore other major coastal bays, deltas and estuaries make it difficult to obtain other funding from the government. Other outside sources,

including donations and grants from private entities is necessary if this restoration work is to be completely accomplished.

Restoration of the Mississippi Gulf of Mexico islands at Gulf Islands National Seashore will also contribute to disaster risk reduction and the attenuation of storm surge. The US Congress has authorized and allocated funds to carry out restoration of the Gulf Islands, primarily closing Camille Cut, as well as restoration work on other islands for a price of over US\$ 400 million. This cost, plus the estimated cost of restoration projects for Jean Lafitte NHPP is minor compared to the economic losses in damages caused by Hurricane Katrina alone.

Natural resource land managers who face risk from hurricane storm surge should work to restore marshes and swamps adjacent to human settlements. Natural landscapes contribute greatly to reducing disaster risk reduction from storms. Restoration of natural processes, such as hydrology, salinity regimes and sediment transport not only are much less expensive than post disaster repairs, but also can improve the ability of these systems to repair themselves. These restoration efforts though expensive must be completed before another major hurricane, like Katrina, inflicts more devastation on Gulf of Mexico communities.

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Chapter 17

Building Resilience in Hoi An city, Viet Nam through the Cham Islands Marine Protected Area

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Abstract

In 2009, Hoi An officially declared its vision to become an eco-city by 2030, in the form of Hoi An eco-city strategy (UBND Hoi An, 2009). As part of this eco-city strategy, Hoi An has launched over forty different projects. A significant programme towards resilience-building in Hoi An is the development of the Cham Islands Marine Protected Area (MPA), as well as the Biosphere Reserve. Establishment of the MPA and Biosphere Reserve aims to build long-term resilience in the face of climate change and extreme weather events. The protection and sustainable management of natural resources increases the capacity of the environment to cope with natural hazards and also decreases human vulnerability. This paper aims to describe how Hoi An came to support actions for mitigating climate change impacts and reducing disaster risk through the MPA establishment and management, as well as the biosphere reserve criteria adoption process. The case study will focus on what the benefits have been, the challenges local people face, as well as lessons learnt from past experiences.

1. Introduction

Hoi An city is located in the Vu Gia – Thu Bon estuary (Figure 1), which empties into the Pacific Ocean. Its economy is based on its natural resources, such as fisheries, agriculture and tourism, all of which are severely affected by disasters and climate change impacts (Trinh, 2011b). The most significant stresses the city faces include

natural hazards such as floods, typhoons, saline intrusion, coastal/riverbank erosion, and environmental and natural resource degradation. Regular floods during the rainy season incapacitate the city as people are unable to move around on the streets, buy food at the market or work. As a consequence, Hoi An's tourism and agricultural industries shut down and

electrical and power generation come to a halt. Furthermore, typhoons destroy crops, buildings, homes, schools, bridges, and infrastructure, and frequently endanger people's lives. Saline intrusion is also a concern and has steadily been increasing, particularly during the summer dry season, when the river flow is low. This saltwater intrusion is found in shallow groundwater

Figure 1: The Quang Nam Province Thu Bon river where Hoi An city is located downstream and the Cham Islands on the coastal straight from the river estuary.



and in open wells, especially those from areas near the river mouth and along the coast. Hoi An has already had to move its drinking water supply station further inland twice in the last ten years (see Hoi An Biosphere Reserve Map, Figure 2) because of saline intrusion. Climate change projections indicate that by 2020 up to 2,700 hectares (ha) of the land area will be affected by saline intrusion if no preventive action is taken. This is 50% of the entire city area. Lastly, coastal and riverbank erosion is a serious hazard threatening Hoi An. Since 2009 the city has lost 8 kilometres (km) of beach coastline to erosion resulting from storm waves hitting deforested coastal areas that were once protected by mangrove forests. Additionally, erosion along the Hoi An riverbanks causes the loss of valuable arable soil and threatens homes located along the river.

In the face of such challenges, Hoi An's work on the marine protected area, as well as the biosphere reserve concept have laid the foundation for its resilience-building work. The Cham Islands Marine Protected Area (MPA) was created for conservation of marine resources and biodiversity, as well as local livelihood improvement. There are about 2,500 people living on the Cham Islands. More than 80% of the islands' population is reliant on fishing and other marine resources, which include

coral, fish, lobster, squid, abalone and sea cucumber. According to recent research conducted by the Nha Trang Institute of Oceanography, the Cham Islands host 277 coral species, 270 reef fish species, 76 seaweed species, 5 sea grass species, 4 lobster species, 97 mollusks, and 11 species of echinoderms (Long, 2008). In addition to the natural beauty, the Cham Islands have an abundance of traditional/local knowledge and customs, archaeological heritage, forest resources and medicinal plant resources (Tuan, *et al.*, 2004, Minh, 2005).

Cham Islands MPA was established under a decision of the Provincial People's Committee of Quang Nam (Province) on 20 December 2005. The Cham Islands MPA project was implemented from October 2003 to September 2006, with the long-term objectives of (i) protecting natural resources and cultural and historical values of Cham archipelago, and (ii) using sustainable natural resources as well as cultural and historical values of Cham Islands to stimulate socio-economic development (Trinh, 2006). In 2009, Hoi An was recognized by UNESCO as a World Biosphere Reserve, because of the city's unique relationship with the estuary, and its reliance on local mangrove, sea grass, and coral reef habitats. People in this area have always lived in harmony with nature and implemented sustainable livelihood

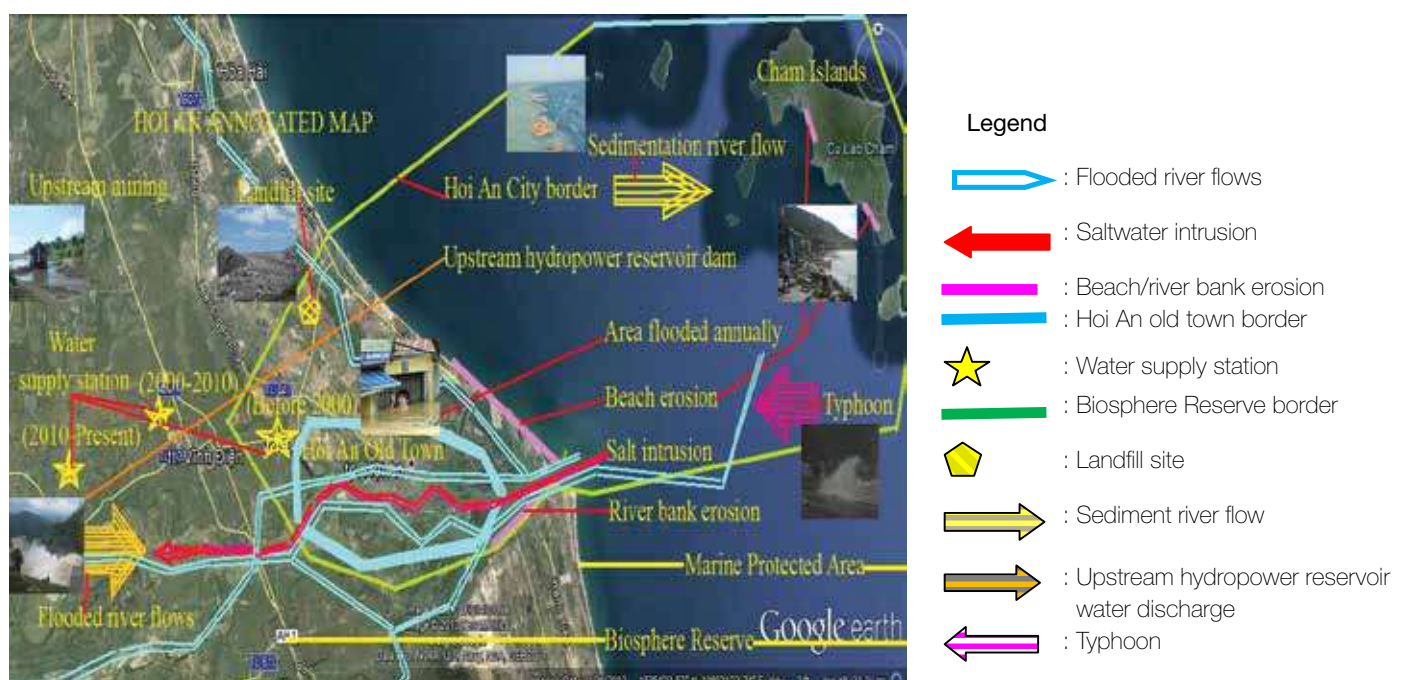
practices. In order to hold the UNESCO World Biosphere Reserve certificate, Hoi An city had to adopt its criteria which included requirements on ecological and biodiversity conservation together with environment friendly economic development (Trinh, 2013).

The Hoi An Biosphere Reserve Map clearly shows the borders of the Hoi An Old Town, the Hoi An Biosphere Reserve, together with the Marine Protected Area as the core zone inside. The flooded river flows and upstream hydropower reservoir water discharge gradually impact the downstream area, especially the Hoi An Old Town, while typhoons occur from the ocean during the rainy season. On the contrary, saltwater intrusion severely affects during the dry season. Moreover, sediment river flows, river bank and beach erosion are found more often here in Hoi An.

2. Methodology

The research focuses on the process of establishment and management of the Cham Islands MPA and Biosphere Reserve. It is based on systematic analysis of qualitative and quantitative data from research activities, which have been conducted since 2003 until 2013. Research data include both primary source information collected by experimental activities, observations, participation, and questionnaire and in depth interview and

Figure 2: Hoi An Biosphere Reserve Map (Trinh, 2013).



secondary reviews from reports, scientific articles, statistical yearbooks, monitoring databases and previous studies. In particular, some research tools, which are applicable to local circumstances, have been used. DPSIR (Driving forces, Pressures, State of the environment, Impacts, Responses) logical framework (Bach, 2002) was used for gathering information amongst community workshop participants. The workshops focused on the issues of natural resources and environment protection as well as social economic development in the Cham Islands MPA and Biosphere Reserve, including, of course, causes and possible solutions. Simultaneously, a SWOT (Strength, Weakness, Opportunity, Threats) matrix was also applied for analysing Cham Islands communities' strengths, weaknesses, opportunities and challenges related to marine resources and environment conservation and management (Trinh, 2008a).

3. Results

Overall, the establishment of Cham Islands Marine Protected Area and Biosphere Reserve aims to build long-term resilience in the face of climate change and extreme weather events. The protection and sustainable management of natural resources increases the capacity of the environment to cope with natural hazards and also decreases human vulnerability (Trinh, 2013). Indeed, healthy ecosystems easily meet people's needs for food and water, and protect them from hazards, through flood regulation and coastal protection against storms and erosion (Trinh, 2011a). The logical framework and priority actions for the Hoi An city resilient building work are described in Table 1.

3.1 MPA establishment and management

Zoning plan development

The Cham Islands MPA of 235 km² is divided into different zones, which respectively prioritize strictly protected (1.26 km²), ecological restoration (2.25 km²), controlled tourism development (1.39 km²), community development (1.39 km²), protected forestry (15.5 km²), reasonable fishing (94.58 km²), and buffer (120.02 km²) zones (Trinh, 2006). Each zone has its own characteristics and is managed according to different requirements to meet the needs of the ecosystem health and the local community benefits. (Figure 3).

Establishment of regulatory mechanism

The MPA management regulations demonstrate the commitment of local people to protect and use natural

resources in a way that ensures preservation for future residents. The regulations were discussed and proposed by the local community, for review and approval by the state agencies. The approved regulations document is the legal platform to protect natural resources in the community. Their enforcement is the responsibility of the entire community (Trinh, 2006).

MPA Co-management plan development

The MPA management plan was developed using the co-management model, which promotes the participation of the state and of the local community (Trinh, 2008a). The MPA Co-management plan approach is based on six target resources, which are coral reefs, sea grass beds, beaches, lobsters, land crabs and limpets. Based on analysis of the status of these

Figure 3: The Cham Islands Marine Protected Area (Trinh, 2006).

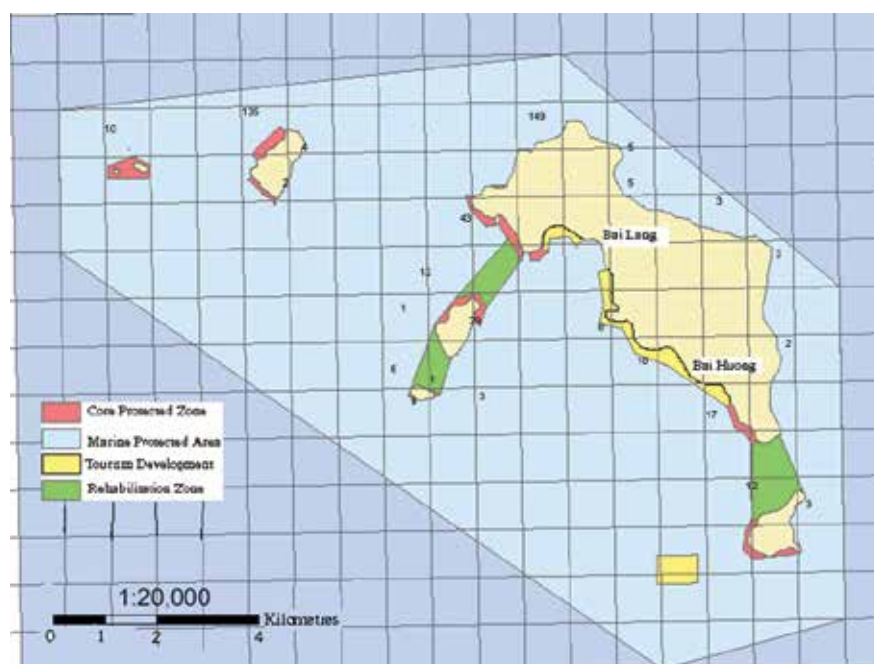


Table 1: The Hoi An city resilient building work.

Goal	Thematic issues	Priority solutions
Climate change mitigation and disaster risk reduction	MPA establishment and management	Zoning plan development Establishment of regulatory mechanism MPA Co-management plan development Monitoring and enforcement programme
	Biosphere Reserve criteria adoption	Community based livelihood development and impact assessment Community based ecotourism homestay programme Community participation in recovery and sustainable exploitation of Cham Islands land crabs (<i>Gecarcoidea lalandii</i>) Mangrove forests recovery

six target resources, a series of solutions was developed to ensure their protection. A five year financial plan was proposed to support these activities, which were funded through state budgets, entrance visiting fees, technical and monetary NGO supports, with a local community implementation role (Trinh, 2008b).

Monitoring and enforcement programme

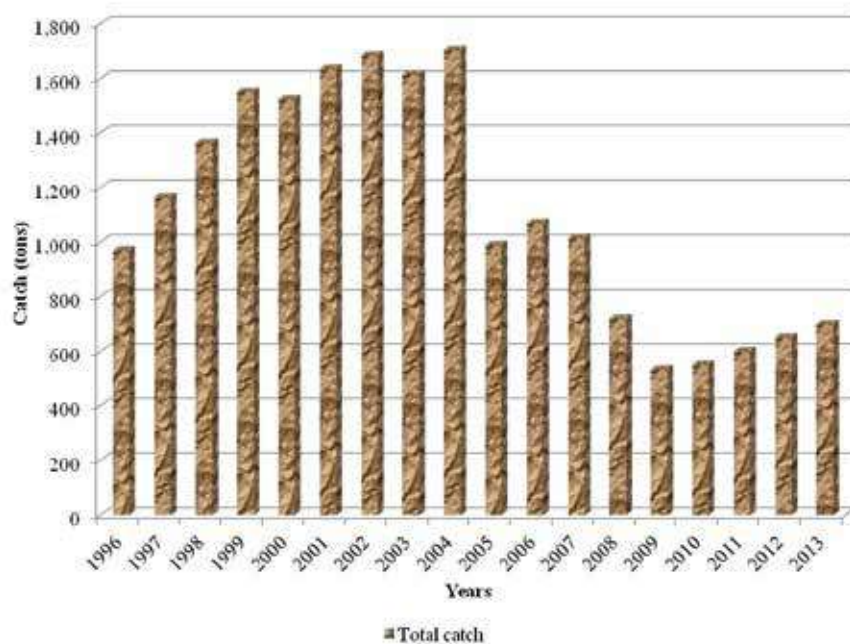
The co-management approach has required fishing activities to be changed to follow the ecological aspect, which has proven effective in seasonal, zone, fishing gear, and size regulation for fish caught. (Figure 4).

Average fish catch was increasing annually from 1999 until 2004 with an average of 1,467 tonnes per year. However, the total fish catch was reduced gradually from 2004 to 2013 to an average yield of 865 tonnes per year, corresponding to the time when the Cham Islands MPA applied the fishing regulations. The Cham total fish catch and fish catch composition have changed gradually since the Cham Islands MPA was established up to today. During the period from 1998 to 2004, fish catch revenue is recorded as increasing steadily from 10 billion dong (\$5 million USD) to 21 billion dong (\$10.5 million USD) per year. However, for the period 2005 to 2013, the Cham Islands fishing grounds have been controlled through conservation, so that the fish catch and revenue dropped significantly to 8 billion dong (\$4 million USD) in 2005, and has since been increasing gradually to 15 billion dong (\$7.5 million USD) per year (Trinh, 2013).

The Cham Islands MPA is also a core zone of the Hoi An Biosphere Reserve, which plays a very important role for resilience of the communities and their recovery after a disaster, through ecosystem services and goods, and livelihood diversification, as well as for awareness-raising about the role of nature for human well-being, especially in the face of climate change.

The establishment of Cham Islands MPA has contributed to expanding the protection area of the fisheries resources of Quang Nam Province. As of 2013, the total Quang Nam Province coastal area is around 3,000 km², in which there are 552 km² reserved for protection, accounting for 17% of total coastal area (Trinh, 2014). This protected area percentage was relatively

Figure 4: Trend in fish catch in years (Trinh, 2008a).



low compared with the expected rate (30%) but it shows a very good effort in the locality as a beginning. In the future, if the MPA models are replicated to six coastal districts/cities in Quang Nam Province, the conservation and protection of coastal resources will be expanded further and will be good for sustainable fisheries development. We hope also to expand the MPA/Biosphere Reserve model to the entire river basin.

3.2 Biosphere Reserve criteria adoption

Community based livelihood development and impact assessment

People in these local communities depend heavily on natural and environmental resources to meet their basic needs. Policies to preserve the local environment are more successful when people have a stake in the protection and use of natural resources, and receive benefits in return (Brown & Trinh, 2008). Activities in the Cham Islands sought to identify, build and develop alternative livelihoods such as home stays, local tour guide services, fish sauce, drying fish, forest tea product processing (Trinh, 2010b).

Community based ecotourism homestay programme

The community-based ecotourism home stay programme has provided job opportunities and improved life

standards for local people. The number of tourists that visit Cham Islands has increased dramatically since it was named a Biosphere Reserve site. In 2008, it welcomed 16,000 visitors, while in 2013 a record-setting 195,000 people visited the Islands (Figure 5) (Trinh, 2013). Increased tourism has contributed to local economic development. The community-based ecotourism home stay programme is a model suitable for the Cham Islands MPA because it allows promoting socio-economic development, and providing opportunities for local income generation. This programme ensures that local people reap the benefits of tourism directly, instead of outside tour operators.

Community participation in sustainable exploitation of Cham Islands land crabs

The land crab (*Gecarcoidea lalandii*) is one of the important marine resources that has historically contributed to the livelihoods of local people (Damholt, 2006). Nowadays, land crab has become a popular tourist product, and as a result it is facing a high risk of becoming overexploited (Anh & Hieu, 2011). To conserve and ensure sustainable exploitation of this resource, Cham Islands communities proposed a common guideline, which supports local people to form a land crab group that issued and approved regulations governing the use of this resource (Figure 6). This has allowed local people to buy-in to

Figure 5: Trend in number of tourists in years (Trinh, 2013).

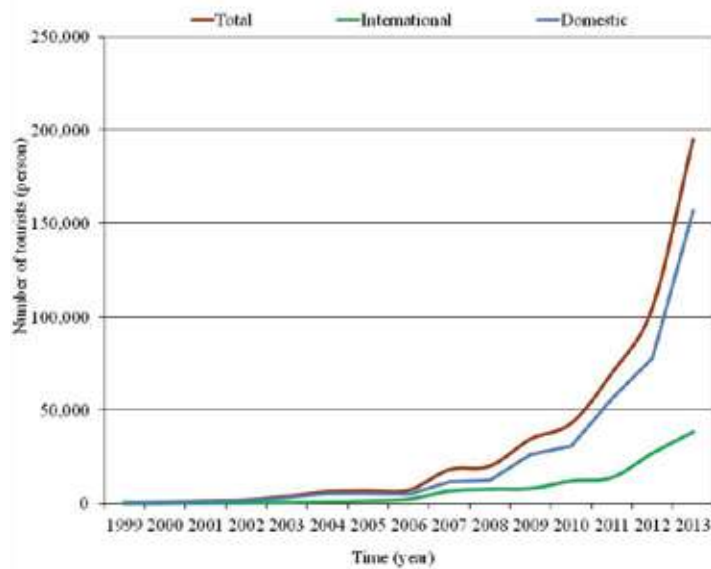


Figure 6: Local participants determining if the land crab carapace meets regulation. An ecological label will be pasted on all qualifying land crabs (*Gecarcoidea lalandii*).



Figure 7: Land crabs (*Gecarcoidea lalandii*) that have been harvested and gone through the labelling process that are ready for sale.



a conservation ethic, which has in fact increased the price of land crabs and their income (Damholt, 2006). To ensure participants are in compliance with the agreement, the collected land crabs must be labelled before they can be sold to customers (Trinh, 2010a), (Figure 7). In 2013, the total number of land crabs collected was 7,500, representing 25% of the amount that was collected previously. Thus, the measure allows conserving 75% of the land crab population, in comparison to previous years (Thao & Trinh, 2013) (Figure 8).

Mangrove forests recovery

As a first step to protect against coastal and riverbank erosion, Hoi An has developed some mangrove reforestation projects at the mouth of the river and along the banks of the river (Figure 9). The mangrove forests of Nypa Palm (*Nypa fruticans* Wurm) have been replanted gradually for the last 14 years from 2000 until now. More than 39 ha of Nypa Palm were recovered by local people and projects which are supported by Hoi An city and NGO activities (Table 2) (Trinh, 2014).

Mangrove forests, particularly Nypa Palm (*Nypa fruticans* Wurm), Tall-stilt Mangrove (*Rhizophora apiculata* Bl), Black Mangrove (*Bruguiera gymnorrhiza* (L.) Lamk), Golden Leather Fern (*Acrostichum aureum* L.) are expected to act as buffers against floods, high tides and extreme climatic events such as storms, typhoons and tsunamis (Dai, 2006). In addition, Hoi An has also built several small dykes and sea walls with the intent to combine green and grey infrastructures for disaster prevention.

By adopting the Biosphere Reserve criteria, Hoi An has increased and strengthened the concern and capacity on environmental and natural resources management at an ecosystem level, from inland to coastal areas and the whole river estuary. Alternative environment friendly livelihoods based on home stay, labelled land crabs, and replanted mangrove forests have gradually not only improved local people's quality of life but also contributed to building resilience of the city in the function of disaster risk reduction and climate change adaptation (Trinh, 2013, 2014).

Table 2: Trend in Nypa Palm area (Trinh, 2014).

Year	1990	1994	1996	1998	2000	2002	2006	2008	2010	2012
Area (ha)	150	99.86	92.04	91.79	54.40	54.89	57.68	58.02	84.69	89.54

Figure 8: Trend in land crabs (*Gecarcoidea lalandii*) harvested versus permitted catch limit (Trinh, 2013).

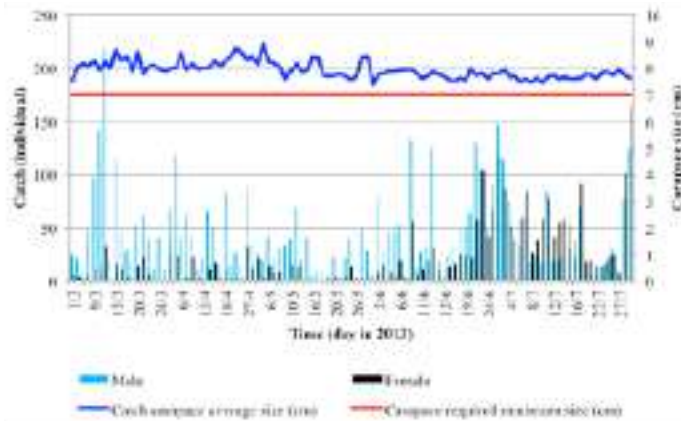


Figure 9: Hoi An Nypa Palm (*Nypa fruticans* Wurmb) forests along the river estuary.



In the past ten years, the number of visitors to Hoi An has grown from several hundred thousand tourists in 2004 to more than one million in 2009, around 1.5 million in 2012 and to 1.6 million in 2013. Twelve new kinds of livelihoods have been created by the increased tourism, which has increased local island residents' annual income from 12 million dong (\$600 USD) in 2005 to 24 million dong (\$1,200 USD) in 2013. The improved income and living standards resulting from ecotourism have encouraged local residents to participate in the island's natural resource protection (Trinh, 2014).

4. Discussion

The establishment of Cham Islands Marine Protected Area, as well as the Biosphere

Reserve constitutes efforts for resilience building, in order to become an eco-city by 2030. The Marine Protected Area allows Hoi An to regulate fishing activities and pollution to protect species and marine resources. The Biosphere Reserve has supported the development of eco-tourism models to diversify local income sources, proving that environmental protection can also be compatible with economic growth.

The total area of coral reefs around the Cham Islands is 311.2 ha. Most of the coral reefs are widely distributed in the shallow waters of the islands and 6 ha of submerged rocky reefs were found in the deep waters (25-40m), so the Cham Islands MPA can play a very important role for the reduction of slow

onset hazards such as erosion, sea level rise, saline intrusion, as well as acting as a buffer against natural hazards of storms, typhoons, and floods. The MPA establishment and management contributed to improving stakeholder and local community awareness raising. This allowed them to understand the ecological values of the marine resource and appreciate how to use such resources in a sustainable way. By adopting the MPA regulations and developing alternative livelihoods, local people's income and livelihood have been improved gradually, allowing them to cope with and quickly recover from extreme events such as floods and typhoons (Trinh, 2012, 2011b). Healthy coral reefs and coastal ecosystems also act as a barrier against storm surges and contribute to slowing down erosion of the coast, making Hoi An city less vulnerable to these threats (Trinh, 2011a). By supporting sustainable development, human well-being and human security, the MPA is an effective solution for disaster risk management (Trinh, 2010b), economic development, and long-term climate change adaptation in the Cham Islands.

However, in the long-term, the health of the Cham Islands marine ecological system will be strongly dependent on the quality of sea water, which will be influenced by sediment concentration, as well as fresh water from the Vu Gia-Thu Bon River. Therefore, the longer-term Cham Islands MPA management plan should not be limited only to the MPA site, but must be expanded into coastal areas, where the integrated coastal zone management (ICM) concept is needed (Trinh, 2009). Moreover, Hoi An's resilience depends on the health of the entire Vu Gia-Thu Bon River basin. In the future, it is very important to establish a Vu Gia-Thu Bon River Basin organization to serve as a space for upstream and downstream stakeholders to meet, establish a dialogue, and negotiate integrated basin management strategies (Thang & Trinh, 2013). Potential issues to address collaboratively include:

coordinated planning and regulation for the entire river basin, to manage deforestation, dam releases, agricultural practices, fishing, and riverbank and coastal development.

5. Conclusions

Through the process of the Cham Islands Marine Protected Area establishment and management, as well as biosphere reserve criteria adoption in Hoi An city, Quang Nam Province, there have been many lessons learnt on building a resilience model for mitigating climate change and reducing disaster risk. All the actions identified aim to improve human livelihood and security, in a context of high vulnerability to disaster risks. Protecting ecosystems, sharing natural resources and diversifying livelihoods are key to strengthening the resilience of the Cham Islands communities, in the face of climate change. Resilient ecosystems not only increase societal resilience, but a process of healthy ecosystem management and development planning that fundamentally

involves interested and affected populations enhances better governance and coping strategies for climate change and recurrent disasters. The shared responsibilities and interests of the state, community, and stakeholders have been identified, in order to ensure the model is successful. Further, the methods, tools and techniques involving communities to achieve consensus have been determined and tested. Marine resource management in the Cham Islands not only includes power-sharing between the government and people, but also the sharing of responsibilities and interests to preserve natural resources.

The Cham Islands MPA has supported community participation and alternative livelihood development locally. By using the co-management method, the Cham Islands MPA communities have been able to apply the ecological approach to environmental and natural resources management. This has demonstrated the communities' daily consensus on

functional zone planning, regulations building, MPA management plan as well as government approval. The Cham Islands MPA has helped to support local people in diversifying into alternative livelihoods, in reducing natural resource exploitation, while ensuring standard of living and income improvement.

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Chapter 18

Integration of Climate Change and Disaster Risk Strategies into Local Natural Resources Management in Viet Nam

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Entrance view of the Phong Nha – Ke Bang National Park

Abstract

The social, political and economic expectations pertaining to Protected Areas (PAs), as well as their more widely recognized importance in providing safeguarding and ecosystem services, leads to enormous conservation pressures on these designated areas. These pressures are magnified by risks resulting from changing climate. This paper explores the extent to which disaster risk reduction and climate change adaptation strategies have been embraced within socio-economic development and nature conservation planning, with specific focus on adoption of policies for PA planning. The UNESCO Natural World Heritage Site Region Phong Nha – Ke Bang in Central Viet Nam has been used as an example for analysis at the PA level. It was shown that there is, as yet, little recognition of strategies and policies in place at the meso-level for integrated natural resources management at the micro (PA)-level. Efforts should focus on awareness raising, specifically with local/sub-national authorities, on the role of PAs in reducing disasters. Considering strategies and policy frameworks already in place, as well as analysing the lessons learnt from the deficiencies and commitment levels of locally-involved stakeholders, may help to further advance sustainable and integrated management approaches.



1. Introduction

The act of establishing a Protected Area (PA); whether it includes land, sea or littoral areas; fundamentally implies recognition of the natural, ecological and sometimes also cultural values of these areas. Protected natural environments and ecosystems however are not acknowledged only for the benefits they may bring for nature and biodiversity. The conservation concept is more and more contested by expectations on PAs to function as natural income-producing resources. PAs are increasingly turning into 'means for human ends', where the socio-economic values of modernity are imposed on natural environments, rather than them being considered as 'ends' in themselves. In Viet Nam, reported cases of anthropogenic disturbances, such as concrete constructions within or through parks, are increasing. Arguments can be made for and against improving public accessibility and such infrastructure will increase the income of private and public actors. There seems to be little recognition of the value of awareness raising, enjoyment of the natural environment, local benefit-sharing or re-investments into conservation. As well, environmental challenges such as climate change and natural hazards put further pressures on PAs and on the ecosystem services they provide.

Viet Nam is considered as one of the most bio-diverse countries in the world (UNDP 2010). Around 7.6% of its terrestrial land is declared as protected areas (GoV, 2012a). Situated in the monsoon-belt, Viet Nam is also considered among the countries most prone to changes in climate and to the occurrence of natural hazards in the South-East Asian region (ISPONRE, 2009; Worldbank, 2011). The country features a coastline that is 3,200 km long, and is increasingly exposed to more intense floods and storms (Worldbank, 2011). Besides sea-level rise and a projected increase in annual average surface temperature, Viet Nam is likely to experience inter-seasonal and inter-annual changes in weather conditions, leading to more severe weather events, like droughts, cold and heat wave extremes. Such changes are expected to have wide effects on agricultural production and, generally, on the socio-economic development of the country as well as on peoples' livelihoods.

Yet, research institutions also point out the difficulty to predict impacts, as calculations of climate models and predictions remain uncertain, and will likely differ from one region to another due to the varied climatic conditions in Viet Nam (Worldbank, 2011; ISPONRE, 2009).

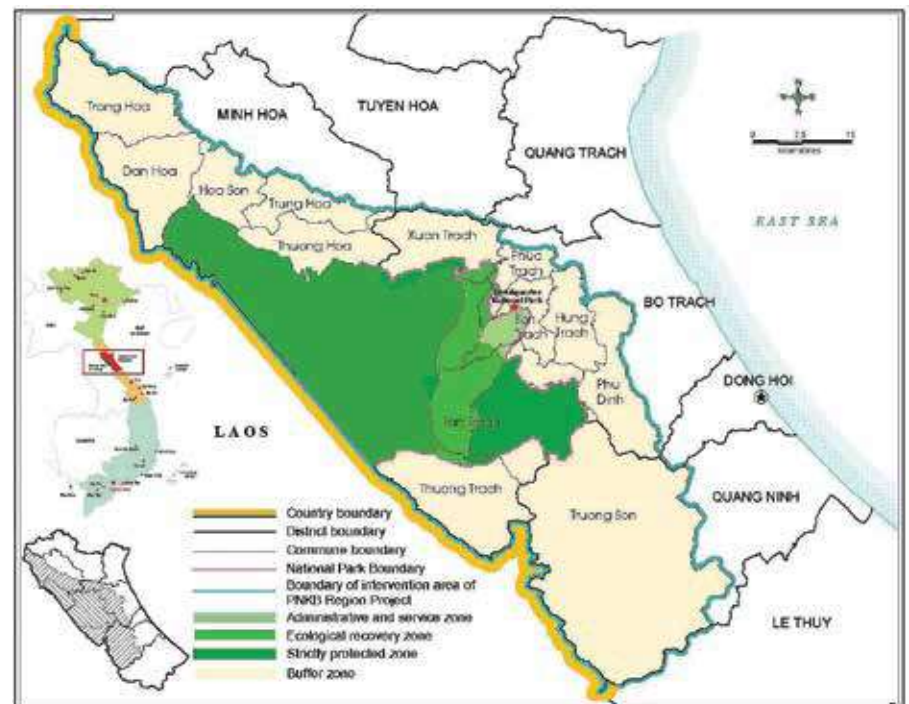
Viet Nam has made great advances in the past decade in mitigating adverse effects of climate change and impacts from natural hazards. These advances include the development of long-term strategic policies through mainstreaming policies. Political commitment has been demonstrated since the early 1990s when Viet Nam ratified the United Nations Framework Convention on Climate Change (UNFCCC). Yet, deficiencies in human capacity, lack of experience in (long-term) climate change adaptation options and alternatives, lack of clear and detailed strategies, as well as missing funds and climatic data, are posing additional challenges. According to the Danish Institute for International Studies (DIIS, 2013), Viet Nam was the single largest recipient of international climate adaptation funds in 2010. Although this corresponds to less than 0.1% of Viet Nam's GDP, it nonetheless signifies the urgency and need for 'climate investment'

and adaptation in Viet Nam. US\$ 240 million of international and bilateral donor funding have been allocated for the implementation of the recent Support Programme to Respond to Climate Change (Priambodo *et al.*, 2013) which addresses both adaptation and mitigation needs.

Disaster risk reduction (DRR) has been an issue for Viet Nam for a longer time, and mechanisms to reduce risks have been put in place to at least some extent in many of the affected areas in the country (DIIS, 2013). Climate change is gaining more importance on the political agenda, but links to natural hazards and to disaster risk reduction are still weak. Based on the case of the Phong Nha – Ke Bang National Park region¹ in Central Viet Nam, this paper will discuss policy responses and links made to natural hazards in more detail.

The Phong Nha – Ke Bang (PNKB) National Park (NP) was recognized as a World Natural Heritage Site in 2003 for its unique geology and geomorphological features. It covers a total area of 125,000 ha, and is bordered by Lao PDR to the west and a buffer zone of 225,000 ha to the eastern side (Figure 1). Around 65,000 people live in its buffer zone, and a few hundred ethnic

Figure 1: Map of the Phong Nha – Ke Bang National Park and its surrounding buffer zone.



¹ 'Region' refers to the National Park and buffer zone area.

Table 1: Geographic and socio-economic brief facts for the Phong Nha – Ke Bang Region.

Phong Nha – Ke Bang National Park (PNKB NP)	
Administration and service zone	3,411 ha
Ecological rehabilitation zone	19,619 ha
Strictly protected zone	100,296 ha
Total NP area	123,326 ha
National Park population (incl. Internal buffer zone)	~350 (Van Kieu and Arem ethnic minorities)
• 33 species listed in international and national red data book	
Buffer Zone Area	
Internal buffer zone area	200 ha (village area)
External buffer zone area	225,000 ha
Buffer zone population	~65,000
Agriculture	<ul style="list-style-type: none"> • The total agricultural area covers around 5,721 ha, about 0.5 ha per household, plus a significant swidden area. Only 1,255 ha are irrigated in the buffer zone communes. The shortage of land for local communities leads to increasing encroachment on forest land, slash-and-burn cultivation and, generally, to forest degradation. Unused land (which refers both to barren forest land as well as to fallow and swidden land) amounts to around 14,000-16,000 ha. • Main food crops: rice, maize, cassava, sweet potato, peanuts, vegetables • Livestock and poultry breeding
Average rainfall (Quang Binh Province) per year	1,600-2,000mm (with around 80-93% amount of rainfall concentrated in the rainy season)
Average annual temperature	24-25°C
GDP per capita in the region	<ul style="list-style-type: none"> • In 2010: 530 US\$ • In 2015 (projected): 1,120 US\$

Fröde & Tuan (2011); PNKB NPMB (2013); PPC QB (2012); Wode (2012)

minority people live within the borders of the Park. PNKB includes important watershed areas and is an important income source for non-timber forest products for those people living adjacent to the Park border. It furthermore holds historical and cultural relics and landscape with a high value for the local population. Resource ownership of the Park, including the NP area and the World Heritage Property, lies with the National Park Management Board (NPMB) and thereby with the national government². The land of the NP is managed as Special-Use-Forest (SUF) land and is protected under Vietnamese forest law. The NPMB, with a provincial status similar to that of a provincial line department, is responsible for (managing) the protection of these resources.

PNKB is located in the Central Vietnamese Province of Quang Binh, which possesses

² Resource ownership of the buffer zone lies within the respective Communes/Districts, and finally, likewise within the Provincial People's Committee (PPC) and the government.

a climate characterized by a dry season, lasting from March to August, and a wet season, from September to March, with heavier precipitation and increased likelihood of storms from September to November. With changes in climate, the extent to which Quang Binh is already affected by storm surges, inundations of low-lying areas, flash floods as well as by heat waves and forest fires is likely to increase further, due to more regular and more intense occurrences of typhoons and an increase in mean temperatures and heavier precipitation patterns (Worldbank, 2010).

The PNKB region is already exposed to a number of these challenges. Each year, for example, floods in September/October bring a halt to tourism activities. Extreme outliers further cause negative impacts on habitats and damage to infrastructure for tourism. Extreme weather events already negatively affect socio-economic development in the PNKB region, with severe consequences and further pressures for local populations (poverty, land and infrastructure damage, human

health) as well as for the flora and fauna of the Park region. Table 1 summarizes some key facts about the National Park region.

The designated Park areas as well as its designated buffer zone are extensively connected. The buffer zone is an area (land or water) close to the National Park border, which has the effect of 'preventing or mitigating harmful impacts towards special use forest [i.e. the National Park]' (PPC QB, 2007). As well as natural hazards, illegal poaching, hunting and logging exert great pressures on the Park and its resources. As buffer zone resources are further depleted and population pressures increase, so the pressures on the resources of the Phong Nha – Ke Bang National Park will become more intense.

Legal frameworks moreover set the basis for National Park management responsibilities and involvement in coordination of buffer zone activities (in particular provincial Decisions 18 and 36 as well as the national Decree 117). This includes the appraisal of development and

investment projects, the involvement of local communities in the management of SUFs, or strategic planning in cooperation with local government and relevant agencies in order to safeguard the natural landscapes of the Pong Nha – Ke Bang National Park (PPC QB, 2007).

To date, not much can be said about the implications of emerging climate-related policies and programmes on the ground, as structures and funding might not be fully clarified yet; similarly for the implications of locally-driven factors and decisions assumed at the sub-national levels (see also DIIS, 2013). Furthermore, it is interesting to note that responses and studies have largely neglected the specific role that PAs (specifically of terrestrial/inland PAs) (can) take in climate change adaptation (CCA) and for the adaptive response patterns of local populations near protective areas.

Given the exposure to natural hazards and to the increasing challenges arising from climate change for the Phong Nha – Ke Bang region, this study examines current national policy responses to climate change in Viet Nam. Subsequently, implementation of responses to reduce vulnerability to natural hazards for local populations will be analysed for the case of the Phong Nha – Ke Bang National Park as well as for its surrounding buffer zone. Specific questions include: To what extent are climate change and disaster risk strategies and policies taken into account at the national and provincial/local level? Which of these strategies and policies particularly address challenges that arise for the management of the PNKB NP and for the populations living adjacent to the Park? What measures have been undertaken so far to reduce disaster risks both at the sub-national and at the Park level (PNKB)? What are the critical thresholds for implementation? What recommendations can be made for the integration of CCA and DDR into national-level policy-making? What possible role does PNKB, and PAs in general, play for the recognition of CCA and DDR in Viet Nam?

Delineating emerging strategies and policy frameworks in the first place, as well as analysing the lessons learnt from deficiencies, and from current commitments at meso- and micro-levels, could help to further advance systematic

consideration of sustainable and integrated natural resources management approaches.

It is important to note that this analysis includes terrestrial PAs only. Marine Protected Areas are governed by different public authorities and their management is guided by a different set of Policies, Laws and Regulations (PLRs).

2. Policy, strategic and institutional responses for CCA and DRR

To provide context for a subsequent analysis on actual impacts of PLRs to date, this section introduces the reader to the national, provincial and protected area policy framework relating to DRR and CCA. Current coping mechanisms for natural hazards, and their integration into a climate change adaptation agenda, are explained.

2.1 National Level

Viet Nam has a long history of struggling with natural hazards, but has also made progress in reducing their negative impacts. This includes the allocation of responsibilities to governing institutions, and the setting up and implementation of PLRs in order to reduce impact and promote precautionary measures. The Ministry of Natural Resources and Environment (MoNRE) as well as the Ministry of Agriculture and Rural Development (MARD) are the designated lead agencies for climate response activities, with technical support from the Department of Hydro-Meteorology and Climate Change and the National Hydro-Meteorology Agency. MARD focuses on climate response interventions in the agricultural sector, and is also responsible for the management of terrestrial SUF

designated areas, including most National Parks in the country. Additional Ministries also support climate change actions, such as the Ministry for Planning and Investment (for funding mobilization and allocation), the Ministry of Education and Training (for climate change education) and the Ministry of Information and Communication (for awareness raising) (DIIS, 2013). MARD is also the lead agency for responses to natural hazards.

In 2011, the Prime Minister approved the National Strategy on Climate Change (GoV, 2011). Institutional structures related to its implementation are largely based on already existing structures related to disaster risk prevention (mostly to storm and flood support) – as far as these exist at the sub-national level. Additional PLRs, which have been mainstreamed or which are newly established to increase resilience to climate change and disaster risks, have also been put in place. Table 2 provides a comprehensive overview of the relevant PLRs related to disaster risk reduction and climate change.

2.2 Quang Binh Province

Climate change has been recognized (albeit to a small extent) as one of the future challenges for Quang Binh in the Socio-Economic Development Plan until 2020 (PPC, 2008). Despite this, and similar to the national level post-disaster action, the Province of Quang Binh has been re-active to the damage and devastation which followed from natural hazards. In 2010, an extreme flooding event severely affected six out of seven Districts in the Province. It had serious impacts on the livelihood of the

Forest fires in the Northern buffer zone of PNKB



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Table 2: Selected PLRs relating to disaster risk reduction and climate change in forest areas in Viet Nam.

Time Period	PLRs
-2020	National Environmental Protection towards 2020, with a Vision towards 2030
-2020	Strategy to manage systems of SUFs, marine reserves and wetland areas towards 2020, with a vision towards 2030
-2020	Master Plan of the National Natural Resources and Environmental Observation Network
2013-2020	Decision 2623/QĐ-TTg, Approval of scheme 'urban development of Viet Nam' responding to climate change in the period
2013	Law on Natural Disaster Prevention and Control
2012-2020	National Action Plan on climate change for the period
2012	Decision 24/2012/QĐ-TTg on investment policy for development of special use forests in 2011-2020
2012	Decision 1216/QĐ-TTg on the National Strategy on Environment Protection to 2020, with Visions to 2030
2012	National Green Growth Strategy
2011-2020	Forest Protection and Development Plan
2011	Decision 2139/QĐ-TTg on the National Strategy on Climate Change
2011	Decision 1410/QĐ-TTg on the 3rd period policy matrix (2011) of the Support Programme-Responses to Climate change
2011	Integrated Disaster Risk Management Plan
2010	Decree 117 /2010/ND-CP on special use forest organization and management
2010	Decree 99/2010/ND-CP Policy on payment for forest environment services
2009	Law on Royalties
2009	Dispatch No.3815/BTNMT-KTTVBĐKH on the Guidance Framework for the Development of Action Plan to Respond to Climate Change (in order to guide the ministries, sectors and local authorities to develop their action plans to respond to climate change)
2008-2020	Decision No. 2730/QĐ-BNN-KHCN on an Action Plan Framework for Adaptation to Climate Change in the Agriculture and Rural Development Sector
2008	Decision No. 158/2008/QĐ-TTg on the National Target Program to respond to climate change and National Steering Committee 2008
2007	Decision No. 172/2007/QĐ-TTg on the National Strategy for Natural Disaster Prevention, Response and Mitigation to 2020
2006-2020	Forestry Development Strategy
2005	Law on Protection of the Environment
2004	Law on Forest Protection and Development

local population. The Provincial People's Committee (PPC) responded with the enactment of five new Decisions. These Decisions were instrumental in the establishment of the Integrated Disaster Risk Management Plan until 2020. The Plan aims to identify priority issues as well as to provide detailed assessments on disaster risk management. This has included cost-effectiveness, encouraged community participation and integrated risk management into planning. Furthermore, the formulation of an Action Plan Framework for Climate Change Adaptation and Mitigation has been initiated. This Framework lists priority projects for response to climate change and sea level rise for the period 2011-2015 and orientation to 2020 (Table 3). These plans and initiatives are designed to strengthen precautionary measures and responses to climate hazards within all jurisdictional levels, mainly through the Flood & Storm Control and Search & Rescue Committees – SCFSC & SR. Such measures also

include raising awareness amongst the community, providing training in disaster management for commune leaders and Red Cross staff, information sharing on mitigation and on the provision of additional funding for infrastructural measures (DIIS, 2013). Coordination of activities takes place under a provincially-steered Flood & Storm Control and Search & Rescue (FSC & SR) Committee, which provides guidelines for communities and mobilizes resources at local level institutions.

2.3 Phong Nha – Ke Bang National Park Region

Currently, management and planning of the Phong Nha – Ke Bang National Park are guided by three major documents: the Operational Management Plan 2013-2020 (OMP), the Strategic Management Plan 2013-2025 (SMP) as well as by the Communication Strategy 2013-2020. All these plans point to climate change (already) being a major threat to natural resources. Named impacts of climate

change include shifts in weather patterns, increased risks of droughts, fires and other natural hazards relevant to the area (OMP). The SMP is slightly more specific and highlights the effects climate change could bring for the World Heritage Site (WHS) title, such as increased forest fires, floods, wind storms and changes in species composition. Accordingly, adaptive management is set as a key priority to guide responses, including the introduction of 'climate monitoring' which would involve the setting up of weather stations and a natural disaster database in the National Park. Furthermore, capacity building among management staff on coping strategies as well as understanding potentials of WHS to withstand negative effects are also key priorities in the plan. Approval is currently under way of the so-called Buffer Zone Development Plan (BZDP), a conservation-oriented socio-economic development plan solely for the buffer zone area of the PNKB NP. In its initial draft, the BZDP, which is supposed

to harmonize sustainable economic development and biodiversity conservation, did not take much account of climate change impacts on the area and further actions which would potentially take precautionary steps for adverse effects (Fröde & Tuan, 2011). Resulting from this, the Phong Nha – Ke Bang Region Project, a cooperation project between the PPC of Quang Binh, the German Development Bank (KfW) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), prompted the initiation of a study which examined and recommended potential actions to make the BZDP ‘climate proof’ (Fröde and Tuan, 2011).

3. Results: policy, strategic and institutional responses for CCA and DRR at national, provincial and park level

3.1 National level

Despite important PRLs (Table 2) in place, the Worldbank (2011) outlined some institutional and policy gaps existing on the national level concerning climate resilience and disaster reduction. Their study has shown that responses generally still remain passive, meaning that measures are only taken when damage has already taken place, and that there is a lack of coordination in responses and a lack of systematic awareness raising activities on risks from climate hazards. Likewise, enforcement of laws and regulations

need to be more stringent. There is still a lack of harmonized coordination and planning among Ministries and sectors. Improvements in the enforcement of laws are needed, for example, concerning the enforcement of fines for activities that are counter to environmental policies, and there is limited recognition of climate hazards within local socio-economic development plans (Worldbank, 2011). The disregard, or only sporadic consideration, of such integration, however, is partially owing to an unclear absorption of climate adaptation costs (DIIS, 2013).

While the PLRs reflect the importance of climate and disaster resilience building, there is very little indication on the meaning of PAs for disaster mitigation, nor about the integration of PAs into disaster/climate response planning. Needs are expressed to ‘design and implement programs on protecting and managing available natural forests, preventive forests, SUFs, and production forests’ (GoV, 2011). But, in fact, there is hardly any detailed mention of SUFs with reference to climate hazard mitigations or safeguard measures which would need to be taken within the PLRs listed in Table 2. An exception may be Decision 24, released in 2012, on investment policies for the development of SUFs. This Decision included a demand for forest fire prevention measures (GoV, 2012b). Broader regulations may be

mentioned in other regulations or policies in regard to forest areas in general, and are also valid for SUFs. For instance, the Law on Forest Protection and Development (GoV,2004) declares that ‘forest owners must adopt plans on forest fire prevention and fighting; when planting new concentrated forests, they must design and build firebreak boundaries, canals, watchtowers, signboards and information systems according to law provisions on fire prevention and fighting’.

3.2 Quang Binh Province/ PNKB Buffer Zone

There has been recognition of the urgent need to respond to climate hazards and disaster risks, and to take precautionary measures in order to reduce the impacts on socio-economic development and the environment. However, no specific actions have taken place which indicate a visible change to the former constrained action-taking to date. In the scope of the DIIS (2013, 23) survey, the Vice-Head of the Department of Natural Resources and Environment (DoNRE), who led the development of the Action Plan Framework for Climate Change Adaptation and Mitigation, ‘did not appear to expect that the plan would lead to significant changes in overall development trends, but basically hoped it would generate access to some funding (presumably international) for sea and river dyke construction in the future’.

Table 3: Summary of annex of the Provincial Decision 3073 on the issuance of an Action Plan as a response to climate change and sea level rise (SLR).

Objective	Measures/ Outputs			
	Study/Report	Construction measure	Awareness raising	Other measures
Water resources (mostly dams)	8	5	1	
Social security	5	2	2	1 (medicine distributed)
Capacity building			1	3 (equipment), 1 CB measure
Infrastructure	3	4		
Environmental protection	3	1		
Forestry (largely mangrove, coastal afforestation)	1	3		
Energy		2	1	
Natural Disaster Risk Management	2			1 (information system/ database)
Awareness raising	2			
Fishery	1	1		
Integrated coastal management	2			
Agriculture	1			
Biodiversity	1			
Coastal ecosystems	1			
Land-use planning	1			
Marine ecology	1			

Eroding river bed in the PNKB buffer zone



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3.3. Phong Nha – Ke Bang National Park Region

The assessment of the climate study conducted in the PNKB region in late 2011 covered a range of aspects. The study outlined climate risks (Table 4), analysed risks posed by climate change on the implementation of the BZDP and delineated adaptation needs. Moreover, recommendations on risk reduction and opportunities which could be further capitalized on have been made. Fröde and Le Anh Tuan (2011) delineated four major challenges for the PNKB Region likely to result from a changing climate, namely:

- 1) higher frequency, and more intense, flooding which would lead to harvest loss, human property damage, erosion, degrading biodiversity and water pollution;
- 2) a decrease in harvests and increasing variability of agricultural production which would lead to product losses, increasing hunger and poverty and an increased pressure on the NP;
- 3) an increase in the intensity of erosion

which would lead to a decrease in land for agriculture, forestry and human livelihoods; and

- 4) an increase in the intensity and frequency of fires, shortage of water and prolonged droughts; aspects like fire-making, slash-and-burn and lightning are considered to further fuel the increase of fires.

Some actions have already been taken, including the establishment of an early warning system, climate resilient constructions, changes in plant varieties or the creation of fire corridors. Measures have been taken due to both official regulations and autonomous efforts by the local population. Fröde and Le Anh Tuan (2011) however point out the need for further strengthening of current measures, such as the extension of the early warning system to the whole region, awareness raising for changes in agricultural production and related harvesting techniques or awareness raising and warnings of local people for forest fire

protection in dry and hot seasons. Table 5 summarizes challenges, actions taken and recommended measures.

With regards to strategies and plans in place at the provincial level, the extent to which PNKB/the SUF plays a role or is recognized in their formulation and their proposed response measures is not known (though consideration in cross-cutting areas like awareness raising or study of solutions for watershed protection is assumed). Only one specific mention of PNKB was listed under the priority activities rolled out within Decision 3073 (Table 3), indicating the necessity to conduct an assessment of climate change impacts on the biodiversity and socio-economic conditions of the PNKB NP region and to subsequently propose feasible measures. Yet, Fröde and Le Anh Tuan (2011) caution that the lack of coherence of the BZDP with socio-economic development planning systems (i.e. content and planning ‘rhythms’) at provincial, district, commune and village level, as well as a lack of ownership of the BZDP, is likely to undermine active support to integrate proposed priority actions to counteract adverse effects from climate change.

To date, some preliminary studies are in the course of being carried out with governmental funding sources, including a study on the impact of invasive species on PNKB, and on micro-climatic conditions existing within the Park. Moreover, the Management Board of the Park considers taking precautionary (construction) measures to reduce the deterioration of the karst landscape (e.g. above roads) as well as to apply remote-sensing technology to better determine impacts on the forest resources and on the Park’s biodiversity. Yet, there has been little advances made in delineating financing mechanisms of the BZDP despite the initiation of a Buffer Zone Development Fund. Given the size of the

Table 4: Climate risks projected for the Phong Nha – Ke Bang National Park Region.

- Increase of annual mean temperature in Viet Nam by 1.1-1.9°C by 2100; temperature increase in North Central Viet Nam (including Quang Binh Province) projected at 1.1/1.2 degrees by 2040 and 1.5 degrees by 2050
- Increase in annual mean rainfall by 1.0-5.2% up to 1.8-10.1% in Viet Nam; percentage change of annual mean precipitation for North Central Viet Nam (including Quang Binh Province) by 3.0/ 3.1% in 2040 and 4.0/ 3.7°C in 2050
- Increase in variability of precipitation (droughts and floods)
- Increase in storm and cyclones frequency and intensity
- (Sea level rise in the range of 65-100 cm in Viet Nam; in 2040: 23-24 cm and in 2050: 28-33 cm)

Fröde & Tuan, 2011; ISPONRE, 2009; MONRE, 2009

Table 5: Identified challenges for the PNKB buffer zone.

Challenge	Action already taken	Priority recommendations
Challenge 1 Increase in intensity and frequency of flooding	<ul style="list-style-type: none"> • Basic early warning systems in place, people look at water level and inform each other, they also help the people in the low-lying areas to get into higher lying regions • Evacuation plans and self-help systems partly in place, government has sensitized communes through training (how to deal with floods and storms) • Climate-resilient buildings with high and thick walls partly by private initiative and partly by government regulations • Building standards have partly changed (e.g. some buildings have a 3rd floor) • Lifevests are provided (1,000-2,000 / year). 	<ul style="list-style-type: none"> • Recheck and if necessary strengthen early warning system for whole region • Establishing community shelters in each village. It should be equipped with food, medicine etc. The shelters can also be used for community meetings or other social purposes when there is no flooding • Consolidating youth volunteers for helping people in case of floods and storms has happened.
Challenge 2 Decrease in harvests and increasing variability of agricultural production	<ul style="list-style-type: none"> • Autonomous adaptation by individual farmers, e.g. decrease in potato cultures, abandoning of cattle husbandry • New varieties are sold in the regions which are better adapted to shorter vegetation periods, however these are expensive and poorer farmers do not use adapted varieties, Government partly supports. 	<ul style="list-style-type: none"> • Research for adjusting local cropping calendars for adapting to recent changes in weather and climate. Finding new crops and animal varieties should be linked to cropping calendars and local weather conditions • Cooperation with agricultural extension service for delivering climate-adapted messages (e.g. on water-saving methods for rice cultivation, cassava as alternative for drought-prone areas) in adaptation to climate change, build capacity of agricultural extension services with regard to climate change and develop educational material on improved agricultural techniques • Spread information on climate-resilient varieties and make them available to poorer population by loan schemes or covering of additional costs • Considering cropping credits from the agricultural and rural development bank and a cropping assurance policy from the government.
Challenge 3 Increasing intensity of erosion	<ul style="list-style-type: none"> • There is not a lot of action taken against erosion despite the extent of erosion increasing a great deal. 	<ul style="list-style-type: none"> • Human settlement planning • Making warning signs • Reforestation along rivers (community nurseries which can contribute to people's income and can be used to replant the riverbank with a wide belt of trees)
Challenge 4 Droughts and fires	<ul style="list-style-type: none"> • Corridors have been established, which are free of trees or feature trees more resistant to fire (but often not broad enough yet). • Fire-fighting committees exist at province, district and commune level, but are only partly equipped, often no action to fires possible as fire committees away from the villages and population doesn't have the necessary equipment. • Forest owners organize fire-fighting themselves. 	<ul style="list-style-type: none"> • Plan for more effective and wider fire corridors in the context of the BZDP, especially to protect the park. • Surveying and building available reservoirs and ponds inside and nearby the forests. A floating pumping station may be installed in the water storage with a flexible soft tube system for fighting forest fires. • Making a forest fire risk map for local communities. • Raising awareness and warnings of local people for forest fire protection in dry and hot seasons.

area, this fund may however not reach a wide scope including the core zone of the National Park and its surrounding buffer zone (Fröde & Tuan, 2011).

4. Discussion

PAs serve many purposes, but with the increasing adverse importance given to them, that is in serving as 'means' for human 'ends', their intrinsic and egalitarian values decrease (nature as 'ends'). However, given the growing impact of changes in weather and climate on natural resources, and inevitably also on human livelihoods, integrated solutions must be sought for. To date, there is only limited evidence that PAs and National Parks in particular, seriously follow implementations of climate change activities and disaster risk reduction in their core or buffer zones. This small-scale analysis thus examined the implications of national level policy-making on local action-taking in view of adverse effects of climate change based on the 'case' of the Phong Nha – Ke Bang National Park region.

The PNKB NP region is already affected by extreme weather events, and is likely to be further adversely affected by such hazards with changes occurring in climate. However, adaptive measures can, to date, only be described as sporadic at best. Likewise, current buffer zone development planning, which is, until the final revision of the BZDP and its official approval, based on the socio-economic development plans at the district level, rarely considers hazards resulting from disasters for future socio-economic and conservation-oriented development planning. In fact, the initial draft of the BZDP had been denounced by governmental stakeholders, claiming that the socio-economic aspects and links to the District SEDPs are under-represented. The Phong Nha – Ke Bang Region Project has funded a study on how to better integrate climate change into buffer zone development planning. The findings and recommended solutions emerging from the study have not until now been given sufficient consideration by either the Management Board or the provincial authorities, at least not to an extent which would rationalize action-taking.

5. Conclusion

Disaster risk reduction and climate change adaptation have become integral parts of development planning

in Viet Nam. The examination of the PNKB National Park case, however, suggests that despite planning instruments being in place, there is little integration of PAs taken into account. This further devalues natural resources' importance for buffer zone development (conservation- and population-wise) and points at a still low recognition of PAs and their role in mitigating adverse effects of climate change (e.g. in the protection of water sources, erosion prevention or desertification). Depending on sub-national perceptions, such considerations may depend on socio-economic development goals, whereby awareness of the integration of climate issues into development goals, and their importance for both future socio-economic development targets and for the protection and maintenance of PAs, seems either low, or existing links and how challenges in this can be responded to may not yet be understood by relevant authorities. Natural hazards as they occur still largely remain critical thresholds for addressing the urgent need to take precautionary actions rather than actions based on ad-hoc human resources and financial resources allocation. By the same token, there has been a trend to converge responses (if there have been responses at all) with disaster risk management responses.

Overall, laws, strategies and plans put in place to specifically address climate change adaptation responses fail to specifically address PAs roles' for prevention or mitigation of impacts emanating from natural hazards.

Though structures are in place, from national to the local commune level, for disaster risk reduction planning, there is still little clarity over impacts and response patterns to disasters and climate change at the PA level and its surrounding environment in Viet Nam. National level ownership of PA resources to some extent fuel ambiguous responsibilities among local government parties and National Park management boards, which may explain doubts over the extent to which national policies have affected locally-led planning (DIIS, 2013; Worldbank, 2011). In this regard, Suntikul *et al.* (2010, 215) also highlight that still 'no single entity or interest can be said to have a complete vision for, or complete control of, the development of Viet Nam's national parks' (see also

Larsen, 2008) which may still be a legacy of the political reforms of *Doi Moi*³. Doi Moi has significantly influenced the way PAs are managed and governed, leading to more decentralized and self-determined governance.

A number of recommendations exist for PNKB to integrate climate change considerations into strategies and development plans of the Province and to set and widen the socio-economic development agenda at the sub-national level. An initial attempt for this has been made with the BZDP. The approval of an integrated climate 'proofing' method application would be a first valuable step to increase awareness, procure funding and start precautionary responses. In this regard, awareness needs to be raised particularly at the provincial level government. Knowledge on possibilities to react to climate change is limited so far. The recognition of implementation necessities could generate important funding sources from the Province. In order to institutionalize activities, Fröde and Le Anh Tuan (2011) recommended the establishment of a Provincial Standing Committee on climate change which would coordinate action and communicate funding needs to relevant provincial government departments. Yet, difficulties arise for the longevity of such a Standing Committee without external expert support. Working mechanisms with already existing working groups such as the FSC & SR Committee are still unclear.

Additionally, a few questions also emerge for the recognition of climate change and disaster risk reduction within PA management not only for Viet Nam, but also for PAs in general: What is the role of the World Heritage Convention in bringing forth climate adaptive management practices with listed PA sites? How is local knowledge integrated into disaster risk and adaptation planning at local, but also at sub-national and national levels? How can overlapping responsibilities in sub-national and PA level planning be addressed? How can populations and relevant authorities become more alert for the urgency to protect the

³ Doi Moi is called the 'renovation' period of reforms in the beginning of the mid 1980s, introducing 'open-door' policies that encouraged a shift from a socialist-oriented to a market-oriented economy in Viet Nam.

provision of essential ecosystems? Also, what cultural aspects may hinder or facilitate DRR and CCA? Responses should be sought to better understand the processes and underlying factors which drive

responses to natural hazards by both the public and private sector.

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Conclusions and Recommendations

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The 18 case studies cover a range of ecosystems that are spread across the national parks, world heritage, marine and terrestrial protected areas in the 16 countries. Some chapters address all the impacts related to climate change collectively while others focus specifically on hazard events such as coastal hazards, wind and storm surges, flooding, typhoons and cyclones. All chapters conclude with key observations, recommendations and conclusions. This chapter highlights selected conclusions and recommendations that are common amongst the case studies or are pertinent to operationalising Protected Area (PA) management for Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA).

It is important to note that ALL case studies demonstrate the fact that **healthy ecosystems provide valuable services to the resilience of a community**, in the face of disasters and climate change impacts. They also note that investing in ecosystem preservation and sustainable management provide multiple benefits and consequently address multiple socio-economic and ecological challenges we face. As physical barriers, not only do the green spaces protect people and property from direct impacts of the disaster, but they also provide protection to the livelihood sources such as agricultural fields (as in the case of India – Bhitarkanika National Conservation Area). In the Uganda case study, several PA management projects were analysed in the Mount Elgon National Park and all of them demonstrate the role of the projects in risk reduction

and adaptation, including those which contribute unintentionally. Additionally, all case studies demonstrate that ecosystem management approaches such as PA management are no-regret solutions, regardless of whether a disaster or climate change impacts eventuate.

The issue of **PA connectivity** to the wider ecosystems is a common message that is evident in majority of the case studies. Management of upstream rivers and forests is critical to the coastal mangrove sanctuaries in Cambodia's Peam Krasaop Wildlife Sanctuary mangrove forest. Similarly, the Monterrico Multiple Use Natural Reserve in Guatemala demonstrates the fact that flood management actions within a PA are not sufficient to address a potential flooding disaster. The key point highlighted in this is including the actors and actions outside the PA who/that may exacerbate the risks inside the PA in decision-making and management of the PA.

There is an urgent establish ownership of risks. As mentioned in the case study from the Wet Tropics World Heritage Area in Australia *"With the onset of climate change, coupled with development pressures associated with coastal population growth, levels of vulnerability and risk in storm surge prone areas will only increase."* The need for risk transfer mechanisms is also elaborated on in the Barbados case study. Not only do risk reduction actions such as PA management save lives but early and proactive investments rather than post-disaster actions, are more cost effective. According to the Barbados

case study *"every dollar invested in the Folkestone Marine Park on the west coast of Barbados, for instance, could reduce 20 dollars of hurricane loss"*. For Hurricane Katrina in the case study from the United States of America preserving, restoring and maintaining natural processes of the ecosystem before the event would have been less expensive than the post disaster rehabilitation being carried out. Accordingly, case studies highlight that funding is challenging to obtain for proactive interventions as the matter is not treated as urgent prior to the disaster. Funding required to preserve the buffering capacities of PAs is also challenging to obtain from sources that may be more conservation focused.

Traditional (and local) knowledge and practices must be an integral part of PA management plans. The local communities have managed their natural resources and have survived harsh conditions, including past disasters, in these landscapes over generations. Their knowledge and practices can be cost effective measures for risk reduction and adaptation, and at the same time considerate of the natural environment. In India, the practice of constructing micro-dams, channelizing and regulating water as per a systematic plan is almost a century old and greatly assists in sustainable use of water resources within the Royal Manas National Park. Local rangers in Peru were critical in defining the climate change adaptation strategies that are suited to the socio-ecological context of the area. The Elsipogtog community in Canada know exactly where the sweetgrass

and other medicinal plants occur in the Kouchibouguac National Park and are therefore well placed to identify areas for relocation of the species if required due to sea level rise.

Community ownership features strongly in majority of the case studies. Commitment from the local community to conserve and sustainably manage their natural resources is critical in the longer term implementation and monitoring of any management intervention. While in many communities ownership/stewardship of natural resources is embedded in traditions, their priorities of facing livelihood and development challenges may conflict with the traditional values. Therefore they require knowledge, support and incentives to (re)establish ownership. Additionally, as apparent from the case study on the Christchurch Coastal Parks of New Zealand, ownership and concern for the PA or natural environment can also exist at varying levels. While the coastal community in this case does not fully depend on the Parks for their livelihoods, their opinions through the public perception survey were important and influential in the decision making processes to restore the sand dunes. Detrimental effects of the lack of public participation in such situations are elaborated on, in the case study from Spain.

Beyond Ownership...Community Empowerment - Developing capacities of community members to be able to carry forward the messages and actions, helping establish the required social mechanisms for self-organisation and making tools/technology/approaches more accessible will ensure the sustainability of actions. In the Madagascar case study from Nosy Hara Marine Protected Area, the community has identified the need for an early warning system, which is important in the longer term viability of PA management for DRR and CCA. In Canada, the success of the community's actions is dependent on tools and further technical support to act upon the adaptive measures they developed jointly.

Partnerships and collaborative relationships through **formal/informal agreements** that reflect (and protect) each party's stake enables all stakeholders to have common objectives and expectations. Additionally, such agreements can also



be useful in differentiating the immediate priorities from the long term priorities when dealing simultaneously with DRR and CCA, within PA management. Such agreements also enhance transparency of all parties involved. For the Philippines case study on conservation agreements in the Mount Mantalingahan in Palawan, *"The conservation agreements served not only to outline roles and responsibilities but to also train the local communities in soft skills such as accounting and financial management, business marketing, and administrative organization"*.

The importance of **rigorous regulatory frameworks**, that are the basis of **PA management**, are essential in preserving the integrity of the biodiversity and ecosystems of the area. In promoting the role of PAs for DRR and CCA, it is important to harmonize the objectives of all priorities and identify any negative impacts of one on the other. To ensure this, joint planning of the management of the area, collaborative efforts in identifying the DRR strategies and working out the response to climate change must be done together. This is argued in the case study from Italy on the Po River Delta Protected Area. In almost all case studies these processes are currently carried out in isolation from each other, from the national to the local levels. Such regulatory policies also need ownership from all stakeholders involved, as highlighted in the case of the Cham Islands Marine Protected Area in Vietnam.

Several case studies also elaborate on the need to consider **combined solutions using hard infrastructure and PA management**. Cham Islands in Vietnam describes the use of dykes and seawalls in combination with *Nypa* palm and mangrove forests while the case study from the US National Parks on the northern Gulf of Mexico, United States of America

mentions the management of storm surges using a combination of levees, marshes and swamps.

Scaling up and out of ecosystem management for DRR and CCA is also highlighted in several case studies by showing PAs as an effective ecosystem management approach. This is not to say that more PAs should be declared worldwide but due to the nature of PAs, especially the governance and social structures, they can be useful testing ground for integrated approaches to conservation, DRR and CCA. This is a point made in the South Africa case study using the Fish River Nature Reserve, Baviaanskloof Nature Reserve and Addo Elephant Park – *"These protected areas can then provide a platform for learning lessons of the rehabilitation of Albany Thicket even on private lands."* The issue of scaling out is particularly relevant to the earlier point on PA connectivity with the surrounding landscape.

Political commitment to (at least) consider ecosystem management approaches such as PA management as part of DRR and CCA planning is essential in mobilizing implementation and upscaling. Policy coherence and alignment is urgently needed amongst PA management, disaster planning and management and climate change adaptation planning since each group of actors are most often part of 3 different ministries. Additionally, ministries responsible for planning, development and finance also need to enhance their knowledge and appreciation of such nature based solutions, which will mobilize resources and mandates to coordinate. This is clearly demonstrated in the case study from Phong Nha – Ke Bang National Park in Vietnam, which proposes some mechanisms for facilitating coordination at national levels.



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