Climate Change Impacts on Tropical Forests in Central America

An ecosystem service perspective

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8 Ecosystem-based adaptation

Nature-based responses to climate change impacts

Giacomo Fedele, Raffaele Vignola and Marco Otárola

Introduction

Societies have always sought to protect themselves and their valued assets from natural pressures and reduce their vulnerabilities (e.g. the hunting of large predators, the suppression of wildfires and the location of settlements in strategic areas). In modern times, engineering solutions have been widely used to safeguard infrastructure and productive systems from various hazards. Slopes have been stabilized with terraces, while rivers and coastal areas have been modified with dams and seawalls to regulate floods and provide irrigation. In recent years, increasing interest is being directed towards adaptation approaches that use ecosystem services to build socio-ecological resilience for extreme climatic events. From a socio-ecological perspective, resilience is characterized by the amount of change that a coupled system can undergo and still retain the desired functions and structure (resist); the degree to which it is capable of self-organizing (recover); and its ability to build and increase learning capacity and to adjust (adapt) (Gunderson and Holling 2002; Trosper 2002; Magrin *et al.* 2007). Improving the resilience of both ecosystems and people is one of the most readily available and accessible strategies for responding to unwanted changes and risks such as those caused by climate variability.

Ecosystem-based adaptation (EbA) is defined as a set of adaptation policies or measures that consider the role of ecosystem services to respond to the adverse impacts of climate change and can be used at multiple scales and in different sectors (CBD 2009; Vignola *et al.* 2009). EbA initiatives support development aspirations and adaptation objectives through the sustainable management of biodiversity and ecosystems (Naumann *et al.* 2011). Healthy natural and semi-natural ecosystems provide a range of services for people's well-being (e.g. fuelwood, clean water, raw materials, medicines, shelter and food). In addition, ecosystems form natural buffers against extreme weather events, thus supporting the resilience of people to climate variations and hazards (CBD 2000). For example, revegetating a degraded steep slope with trees helps to reduce the risks of landslides by protecting the soil from erosion. At the same time, trees can increase the food security of the local community by providing fruits and fuelwood.

Although EbA is mostly intended to decrease people's vulnerability, it should also aim to reduce ecosystem vulnerability (e.g. SBSTA 2013). Both socio-ecological systems are intrinsically interconnected and if ecosystems are not able to adapt to climate change, their ability to provide benefits would be compromised with negative consequences on people's vulnerability (Locatelli *et al.* 2008). Similarly, EbA has been described to be "about saving ecosystems and about using them to help people and the resources on which they depend" in the face of climate change (Burgiel and Muir 2010). The use of "green," "soft" or "ecological engineering" as strategies of defense against climate change is particularly relevant considering that "in most places in the world, nature is the single most important input into local economies and human well-being" (Roberts *et al.* 2011). Ecosystems, in contrast to hard engineering measures such as steel or concrete infrastructures, are often immediately available and more accessible and integrated into communities (CBD 2009). EbA has synergies with community-based adaptation approaches and can effectively build on local knowledge and needs, while providing particular consideration to the most vulnerable groups of people, including women and the poorest, and to the most vulnerable ecosystems (see Figure 8.1).

This chapter focuses on EbA in forest ecosystems and the provision of additional benefits whose economic and ecological impacts are discussed along the book. In the first section below we discuss the process needed to implement EbA. The following section illustrates possible EbA applications with three case studies from Central America in which the resilience of socio-ecological systems toward climate change was strengthen. The case studies show how EbA support resilience while generating additional benefits relevant to reduce the negative impact of climate variability on other economic and ecological factors such as carbon stocks and timber, water regulation, and recreation. Finally, we summarize the main points and the policy implications in the Central America context.

Ecosystem-based adaptation implementation

People enhance or maintain particular goods or services of interest by altering the type, magnitude, and relative mix of services in landscapes. These interventions build the technical basis of EbA and include the sustainable management, conservation and restoration of ecosystems (CBD 2009). There is a demand to see concrete examples translated into practice, but these remain limited due to the relative novelty of the EbA concept (World Bank 2010; Pramova *et al.* 2012). So far, most of the evidence for successful EbA interventions is embedded in studies that are not explicitly labeled as such, but focus on the impact of ecosystems on biophysical parameters without linking them directly to socioeconomic benefits or adaptations (Doswald *et al.* 2014). Several other EbA relevant experiences can be classified outside of adaptation-oriented studies, in ecosystem restoration, soil and water conservation, and disaster risk reduction. Lessons learnt in these fields are contributing to develop good practice for EbA (see Box 8.1).

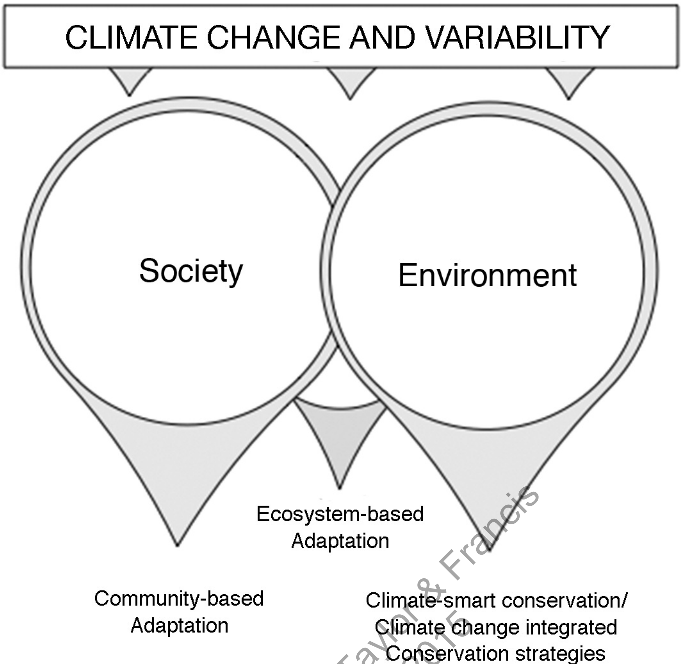

Figure 8.1 Socio-ecological systems and related management strategies for climate change adaptation

The choice of the EbA intervention to be used strongly depends on the context. The consequences of climatic variations can be manifested in different ways according to local characteristics (socio-economic and biophysical). Addressing climate vulnerability must consider a *particular* outcome (e.g. food security) of a *selected* system (e.g. a rural village) to a *given* exposure (e.g. flood) within a *definite* time horizon (e.g. in the last 10 years). Accordingly, generalizations about the climate vulnerability of a place can be misleading (Luers *et al.* 2003; Füssel 2007) and measures cannot be designed in a "one size fits all" manner. In order to develop appropriate EbA interventions that consider the local context and are relevant for different time scales, we require a clear understanding of the characteristics and dynamics of the socio-ecological systems. We need information on (i) climate variation and impacts, (ii) expected changes, (iii) ecosystem services and trade-offs across time, space and social groups, and (iv) progress towards the ideal state. This knowledge can be gained through several studies that constitute crucial steps for good EbA implementation. They usually involve the gathering of information from the laboratory and fieldwork; metadata reviews of literature, modeling and scenario-building; expert opinions and local knowledge from different groups.

Box 8.1 Ecosystem-based adaptation principles

EbA-relevant measures have long been applied by communities in response to the effect of climate variations, sometimes supported by a wide range of organizations from the field of conservation, development and disaster reduction. These experiences have led to the development of a number of guiding draft principles (e.g. from CBD, CIFOR, IUCN/CATIE, UNEP and UNFCCC) to assist practitioners in designing and implementing adaptation projects. A summary of shared principles that are emerging from different processes to characterize EbA include:

- Maintain ecosystem interactions and processes and promote the resilience of both ecosystems and societies, especially the most vulnerable.
- Support multi-sectoral approaches to adaptation as required by the cross-cutting nature and complexity of climate change and ecosystems.
- Consider multiple geographical and temporal scales and operate at scales that are appropriate to the objectives ensuring that management decisions are decentralized and taken at the lowest accountable level.
- Integrate flexible management structures and processes that enable adaptive management to anticipate and provide timely responses to changes.
- Recognize ecosystem limits and minimize negative social and environmental impacts and trade-offs.
- Use information and knowledge from multiple sources including traditional, local and scientific sources.
- Involve all stakeholders in the decision-making processes and balance their interests, in a participatory, transparent, accountable way.

Sources: adapted from CBD (2000), Heath *et al.* (2009), Colls *et al.* (2009), Andrade Pérez *et al.* (2010), Devisscher (2010), Glück *et al.* (2009), Doswald and Osti (2011), and UNEP (2012).

Climate variation and impacts: understanding the vulnerability context

Planning for EbA interventions usually starts with a vulnerability and risk assessment to identify who (i.e. specific population group) and what (i.e. ecological systems, human activities, infrastructure etc.) are particularly susceptible to the impact caused by climate variability and hazards (Magrin *et al.* 2007). These assessments include information on possible impacts on ecosystems and their implications for human well-being. Knowing the state of exposure and level of sensitivity of the socio-ecological system is important for planning EbA and can serve as a baseline for checking the effects of implemented adaptation interventions. Data can be collected using social field surveys in consultation with local stakeholders (e.g. through participatory rural appraisal tools) or environmental assessments (e.g. field inventories and satellite images) or a combination of both. According to a recent study, either method can be used for vulnerability assessments (Doswald *et al.* 2014).

Expected changes: choosing the right intervention

Information on current vulnerabilities can identify future climate situations and possible risks. Changes in the system's exposure to climate variations can alter its conditions, making some interventions unsuitable for species and habitats in the future. Taking into consideration the expected variations does not imply that we develop landscape interventions aimed at resisting or reverting changes by all possible means. Rather, EbA measures can help to facilitate ecosystem transitions and natural adaptation processes towards a new, socially acceptable conditions.

Ecosystem trade-offs: evaluating alternatives

Scenarios can include visions or projections of alternative situations depending on varying parameters and management choices that allow a comparison between EbA and other alternatives. Since EbA decisions may prioritize specific ecosystem services for adaptation interests at the expense of others, it is important to recognize and incorporate trade-offs that might occur. For example, a project targeting the stabilization of soil by revegetating slopes with exotic species might appear successful for that specific purpose, but it might provide relatively few products for local communities and increase the risk of fire. An adequate evaluation of ecosystem services would allow for a better comparison between the different ecosystem benefits and avoid undesirable side effects. Furthermore, the analysis of possible EbA effects should be extended to include technical alternatives with their costs and benefits. Such information are crucial for deciding which option should be undertaken and later can serve as a basis for designing interventions that balance human and ecosystem concerns, reducing the possibility of conflicts among different stakeholders. However, to date it seems that during the development of EbA, different options and social/environmental impact assessments are usually not considered (Doswald *et al.* 2014).

Progress towards ideal state: monitoring interventions and changes

Apart from methodologies and data availability, there are difficulties in measuring the impact of the interventions. This is partly due to the complex dynamics between people and ecological systems, which change over time and are greatly influenced by external inputs. In addition, ecosystems usually respond with weak signals during the duration of most projects and adaptation benefits are often recognized after several years. For these reasons, it is important that a monitoring and evaluation system is established to check progress and provide an indication of changes so we can implement the necessary adjustments. A sound documentation and description of effective changes in the system can help to fill the gap in the scarcity of successful EbA experiences. Monitoring systems are currently found in the majority (65 per cent) of interventions related to EbA (Doswald *et al.* 2014).

Ecosystem-based adaptation and forest ecosystem service case studies

Comparing the experiences gained through the successful use of EbA in similar cases can help to select appropriate EbA measures. The next section includes case studies in which the adoption of EbA measures brought additional benefits related the topics addressed by the previous chapters. In particular, the three cases studies presented focus on implementing EbA measures to decrease the impacts on carbon stocks and timber (Chapter 6), water runoff (Chapters 3, 4 and 5), and recreation (Chapter 5) in tropical forests in Central America.

Ecosystem-based adaptation with benefits for carbon storage/mitigation

The reduction of carbon concentration in the atmosphere due to the ability of trees to absorb and store carbon in biomass is not the primary objective of EbA interventions. However, EbA increase the ability of the system to sequester and store carbon by improving overall ecosystem health and resilience. In addition, the possibilities offered by the carbon market can be exploited. For example the revenues gained from the sale of carbon credits can enhance the financial sustainability of ecosystem interventions for adaptation. Nevertheless, mitigation projects can have considerable transaction costs in order to estimate, validate and verify the carbon stored. To be profitable these projects need to be implemented on a large scale.

A case study on incentives for the conservation/restoration of ecosystem services: a Costa Rican payment for environmental services scheme

During the period 1950–1985, Costa Rica experienced a radical loss of forest cover, coupled with a demographic explosion (Rosero-Bixby and Palloni 1996). Forest cover declined by 50 per cent in this period, reaching 17–31 per cent mostly located on less accessible, steep mountain slopes (Sader and Joyce 1988; Lutz *et al.* 1993). During this 35-year cycle, the trend in land-use change has been driven, among other reasons, by the combination of market and policy incentives motivating landowners to expand crops and livestock (Lutz *et al.* 1993; Sanchez-Azofeifa *et al.* 2001).

National policies in the form of subsidies (forest payment titles), fiscal incentives, expropriation for protected areas and bans on land-use change in forest areas have stopped deforestation. Since 1996, Costa Rica adopted a new paradigm of compensating landowners to restore or maintain land uses that promise to provide ecosystem services of interest, such as: climate regulation, watershed protection, landscape beauty and biodiversity conservation. The combined effects of payment for ecosystem services (PES) and the legal banning of land-use changes in forest lands allowed forest cover to reach 52.3 per cent of national territory in 2010 (FONAFIFO 2012).

Land-use activities such as forest conservation, reforestation, forest management, forest regeneration and agroforestry that are eligible for the Costa Rican PES scheme contribute to both climate change mitigation and adaptation objectives. These practices have positive effects on the conservation or enhancement of tree biomass[1] and protection of water resources, while helping to conserve biodiversity that can have a value for adaptation (Box 8.2).

Box 8.2 Possible ecosystem-based adaptation interventions with mitigation benefits

Afforestation and revegetation of degraded lands:

- Enhance forest recovery after natural or man-made disturbances.
- Decrease rotation periods for coppices used for energy production.
- Establish new forests areas through planting or assisted regeneration.
- Facilitate natural expansion of forests.
- Increase tree cover density in agricultural lands (e.g. agroforestry).

Reducing forest degradation and avoiding deforestation:

- Practice low-intensity forestry and low-impact logging and prevent conversion of primary forests to plantations.
- Work with authorities and stakeholders to address the causes and drivers of deforestation.
- Ensure law enforcement for illegal logging and NTFPs.
- Implement a sustainable level of firewood collection.

Sustainable management:

- Modify thinning practices (timing, intensity) and rotation length to increase growth and turnover of carbon.
- Promote research and cooperation to increase the socio-ecological system understanding.
- Minimize soil disturbance through low-impact harvesting activities.
- Manage forests fires and pests to decrease the impact of natural disturbances on carbon stocks.

Conservation:

- Preserve ecological process while maintaining access to ecosystems.
- Protect through protected area systems.

Sources: adapted from CBD (2009), Innes *et al.* (2009), FAO (2013), and UNEP (2012).

The linkages between mitigation and adaptation have become clearer in the 18-year-long experience of the Costa Rican PES scheme. Indeed, this scheme started with an explicit recognition of carbon benefits provided by the considered land-use activities to evolve in the formal mechanism for supporting the REDD+[2] goals. With the REDD+ Readiness Proposal of 2010 we find a formal recognition of the EbA benefits provided by those land-use activities to society (GoCR 2011). The prioritization criteria for the selection of beneficiaries listed by FONAFIFO have evolved based on experiences gained through the implementation of the scheme. These criteria have evolved from a general conservation-oriented approach defined at local level to a more refined approach, responding to national priorities and to the applicants' location (in term of socioeconomic and environmental aspects) and land-use context (Porras *et al.* 2013). These criteria guide the selection of areas where incentives are targeted and help the scheme by providing important benefits to both mitigation and adaptation (Table 8.1).

The Costa Rican PES scheme has stimulated the recent literature to identify how to improve the design of the PES scheme in order to increase its synergism with EbA objectives and offer institutional support. Some literature has looked at additionality issues (Pfaff *et al.* 2008), highlighting that many areas targeted for conservation payments had low opportunity cost of land (i.e. the amount of the payment is not attractive for areas with higher opportunity cost), which may not be the most suitable for achieving EbA goals. The challenge remains for ecosystem services-conservation efforts to ensure that EbA-relevant areas are targeted, regardless of their opportunity costs. Other authors have referred to the effectiveness and conditionality aspects of the PES scheme, indicating that targeted land uses (and management alternatives) might not deliver the required ecosystem services (Wunder *et al.* 2008). For example, certain forest management practices aimed to protect watersheds and increase biological connectivity can have unforeseen side effects. This can make it difficult to predict their effectiveness, as site conditions determining their function might change with changing climatic and hydrological conditions (Hagerman and Chan 2009; IIED 2011).

Ecosystem-based adaptation with benefits for water runoff regulation

One of the consequences of climate variability is the increased frequency in the disruption of water availability, causing either a shortage or an excess. Trees and vegetation help to regulate water runoff and river discharge during periodic interruptions in seasonal rainfall, help to improve the water quality and retention, and to buffer against coastal damage from tropical storms and tsunamis. There are a limited number of studies that support the important role of forested landscapes in regulating these processes (Pattanayak and Kramer 2001; Ilstedt *et al.* 2007) and generalizations are difficult to make (Bruijnzeel 2004). In fact, the total contribution of trees in regulating the water cycle is a result of complex processes and interactions that depend on a number of factors such as: land-use practices, topography, vegetation types, soil properties, and the intensity of the hazard. In particular, the scientific debate remains on the protective potential of vegetation

Table 8.1 Linkages between forest conservation activities promoted by Costa Rican PES scheme and forest adaptation and mitigation

Activity funded	*FONAFIFO prioritization criteria*	*Rationale*	*Potential benefits for adaptation*	*Potential benefits for mitigation*
Forest conservation	Forest located in conservation gaps Forest located within biological corridors	Biodiversity conservation	Adaptation of forest ecosystems through addressing conservation gaps in biological corridors to increase landscape connectivity and reduce fragmentation (Locatelli *et al.* 2011)	Conservation/restoration of tree biomass
	Forest located in areas relevant for protection of water resources	Water quality and regulation	EbA benefits forest biomass conservation/ restoration and the future supply and/or quality of water ecosystem services	Conservation/restoration of tree biomass
	Forest located in indigenous territories	Multiple ecosystem services considered	Forest conservation can provide important adaptation benefits to indigenous communities helping to protect their livelihoods and culture	Conservation/restoration of tree biomass
Reforestation	Reforestation in highly productive sites Reforestation with native species or species facing extinction	Ecosystem restoration and sustainable use	Adaptation benefits can be achieved since reducing pressures on ecosystems increases ecosystem resilience in the face of climate change (Malhi *et al.* 2008)	Enhances carbon stocks by increasing tree biomass
Forest management	Forest management in highly productive sites using sustainability standards			
Agroforestry	Promoting agroforestry in highly productive sites			

in the case of extreme floods and storms (Osti *et al.* 2009). In addition to water regulating services, vegetation coverage protects against erosion, reduces soil loss and transportation of sediments and debris (which if mixed with floodwater, increases its destructive power and reduces water quality). Therefore the role of forested landscapes in preventing average and most frequent floods should not be overlooked.

The case of water runoff related ecosystem services in Honduras

Honduras is highly vulnerable to the impact of climate change especially due to:

- the observed and projected impacts of extreme rainfall events (Aguilar *et al.* 2005; Magrin *et al.* 2007);
- the sensitivity of its agricultural production systems that are located in high sloping areas (Perotto-Baldiviezo *et al.* 2004); and
- the high per centage of its population living in extreme poverty (especially in these sensitive areas).

In such a context, soil laminar erosion is a serious threat to upstream marginal farmers affected by soil fertility degradation (Holt-Gimennez *et al.* 2001) and to downstream users of water resources that can be polluted by transported sediment. Here, ecosystem-based responses such as watershed conservation efforts to reduce soil erosion and water infiltration can be important in reducing the impacts of extreme runoff, and help the conservation of water-related services such as those associated with water quality under climate change.

Guacerique Watershed, which provides an important share of the drinking water to the capital city of Tegucigalpa, illustrates how EbA options can reduce the costs of water delivery and increase water quality in the face of climate change. Guacerique Watershed is a mountainous region with a mean altitude of 1450m and the majority of the land area is comprised of slopes greater than 15 degrees (SANAA and ICF 2011). These sloping areas are best suited for forest land uses but many are under subsistence agriculture farms, of which only 43 per cent have carried out soil and water conservation measures (TroFCCA 2009). The upper section of the watershed has been declared a biological reserve (Decree 87-1987) managed by the Secretary of Natural Resources (SERNA) and municipalities. Guacerique Watershed has undergone significant changes in land use in recent decades, including deforestation and conversion to agriculture (even within the boundaries of the biological reserve) and human settlement (Shlomo *et al.* 2004), resulting in an annual aggregate rate of deforestation for the period 1993–2008 of 1.36 per cent (TroFCCA 2008).[3]

The pressure on ecosystems' ability to provide goods and services combine with the pressure of climate change, as indicated by projected increases in temperature and uncertain annual precipitation trends ranging from a reduction of 34 per cent to an increase of 9 per cent by 2080 (Vignola *et al.* 2013). This vulnerability which threatens water resources supply is aggravated by the projections of population

Box 8.3 Possible ecosystem-based adaptation interventions with water regulation benefits

Regulation of water flows and provision of clean water:

- Maintain forests on crests and steep slopes to promote mist and fog interception.
- Protect forests in water catchment areas and consider excluding harvesting in areas subject to waterlogging.
- Select water-efficient and drought-resistant species and varieties for afforestation and reforestation.
- Carry out vegetation management (e.g. weed control) to limit adverse hydrological effects.
- Reduce evapotranspiration and competition for water by vegetation management (e.g. thinning, pruning and planting deciduous species).
- Promote multilayered root systems by encouraging growth (e.g. through natural regeneration or planting) of deep-rooted and shallow-rooted species.

Buffer effect of water fluctuations:

- Ensure unimpaired water flow by removing debris and blockages (stones, logs, waste) that could increase hazards to people.
- Consider reverse channelization through renaturation interventions, in particular: increase natural vegetation to absorb impacts of floods and block sudden storm surges and incursions of seawater (for coastal and marine ecosystems) and around river systems to provide space for floodwaters.
- Leave a buffer strip of forest between a stream or river and any area used for forestry operations.
- Protect peatlands.
- Encourage species and varieties capable of benefiting from or withstanding increased rainfall and waterlogging.

Stabilization of soil:

- Decrease possibilities of sediment runoff (stabilization).
- Minimize soil disturbance and avoid soil compaction with low impact harvesting techniques and timing.
- Plan road construction carefully.
- Promote afforestation and reforestation to protect against wind erosion (e.g. establish windbreaks).
- Stabilize sand dunes and desert margins in areas affected by desertification.
- Adjust harvesting schedules to reduce erosion and siltation.
- Maintain or increase vegetation cover.

Sources: adapted from CBD (2009), Innes *et al.* (2009), FAO (2013), and UNEP (2012).

increase in Tegucigalpa (expected to double its population by 2030) and its increased demand for drinking water, which will be 4.52 m^3/s of water stream flow, compared to 1.8 m^3/s available today (SOGREAH 2004).

In the face of these complex challenges, local authorities are implementing an Adaptation Fund project which aims to design and implement a robust watershed management plan to reduce current and future vulnerabilities under the supervision of the National Water Utility (SANAA) and the Honduran Ministry of Forests (ICF). This plan aims to ensure long-term water availability and to lower sediment loads in the Guacerique River in order to maximize the watershed's utility as a source of drinking water for Tegucigalpa (SANAA and ICF 2011).[4] The six-year watershed management plan costs US$4,216,000 (in 2012) and includes both environmental and poverty alleviation objectives. It will implement activities such as:

- reforesting 1236 ha around springs and creeks;
- creating 100 ha of fuelwood plantations;
- transitioning to agroforestry on 161 ha of steeply sloping agricultural land (on slopes of 30 degrees or more);
- concentrating forest fire control on reforested areas;
- reducing illegal timber extraction on 6063 ha classified as forest reserve;
- concentrating pest control on 4338 ha of existing pine forests; and
- implementing soil and water conservation measures on 2000 ha of agricultural fields.

SANAA is already implementing an agricultural extension project in the watershed to encourage adoption of soil retention measures by local producers, in the hope that a compensation mechanism will help to sustain these soil conservation activities. Similarly, several initiatives are already being implemented to promote the conservation of the Guacerique Watershed including conservation planning with local communities on their micro-watersheds, solving legal problems related to tenure in biological corridors, and installing micro-irrigation systems to increase water-use efficiency in farming. A more extensive set of possible EbA interventions with water regulation benefits is presented in Box 8.3. Even if the financial sustainability of this plan (after the adaptation fund start-up costs) is an ongoing challenge, some monetary benefits can already be estimated. A recent analysis shows that the watershed management plan can have important benefits as measured by: sedimentation rates, turbidity, dissolved oxygen and water inflow (Vignola *et al.* 2013). The monetization of these benefits suggests that the overall annual economic benefit of the watershed management plan to the national water utility for 2030 to 2035 (expressed in undiscounted 2012 dollars) ranges from US$3.7 million (under a less pessimistic scenario) to US$9.2 million (under a pessimistic scenario). The net economic benefit expected to accrue from the watershed management plan ranges (depending on the social discount rate used) from US$23.6 million to US$34.7 million for the less pessimistic climate change scenario and from US$63.6 million to US$91.5 million for the pessimistic one. These economic benefits only estimate the value of the watershed management plan for drinking water, while several other benefits, as indicated by local experts, can be provided by conserving Guacerique Watershed. These should be included in an overall assessment of the benefits of EbA options, if a cost-benefit analysis is required to compare with the benefits of infrastructure. Indeed, at least in the Guacerique case, infrastructure alternatives to deal with the challenges of drinking water provision to Tegucigalpa have been discussed and feasibility studies have been developed but to date, it has been impossible to implement them, given their high costs (over a hundred million US dollars; Vignola *et al.* 2013). The EbA option in this case is a relatively cheap and available alternative. This confirms its advantages in helping society to design and implement short-term responses to severe and complex problems related to ecosystems' goods and services degradation due to climate change.

In order to use this EbA alternative to achieve sustainable provision of drinking water to Tegucigalpa in the face of climate change, some challenges and barriers must be addressed (Vignola *et al.* 2013). National experts identified these as a need to ensure an adequate flow of financial resources and a more efficient use of scarce resources through inter-organizational coordination. They also outlined the importance of a combination of incentives mechanisms for good practices and more patrolling for control of illegal uses of the watershed's ecosystems. They highlighted the need for more effective communication mechanisms to improve information-sharing from monitoring systems. They outlined the existence of enabling policies for PES schemes; the importance of forest ecosystems' conservation and sustainable use in national forest and climate change policies; and the important role assigned to local communities and municipalities in managing their ecosystems.

Ecosystem-based adaptation with benefits for recreation values

EbA interventions do not directly aim to increase recreation opportunities. However, by using green solutions instead of concrete/steel infrastructure for adaptation, positive co-benefits in term of visual impact and attractiveness might occur. Due to cultural differences and preferences in how forest aesthetics are considered, it is difficult to determine how adaptation measures help to maintain or increase the aesthetic value associated with landscapes. Nevertheless, a loss of habitat and diversity and the consequent simplification of landscapes often has a major impact on the attractiveness of a place in terms of recreational use.

A case study on ecosystem-based adaptation options for ecosystems' recreation services in Central America

The relationship between nature-related tourism and the impacts of climate change on associated ecosystems is increasing our awareness of the importance of ecosystems' goods and services preservation to maintain recreation services, which represent, especially in Central America, an important economic sector. However, efforts focusing on EbA options to conserve ecosystems' recreation services in the face of climate change are still in their infancy in the region. On the other hand, there are interesting experiences in the region in designing and implementing sustainable tourism initiatives related to ecosystems' recreation services which can represent ecosystem-based cost-effective measures providing multiple co-benefits among which the potential to contribute to climate change adaptation (Box 8.4). In Panama, ecotourism has grown by more than 100 per cent over the last decade (Christ *et al.* 2003). Community-based ecotourism activities represent an important share (10 per cent) of national GDP and have been analyzed over the past 15 years (ATP 2011). The barriers and priorities identified by the experiences in Panama can be relevant for designing EbA options for ecosystems' recreation services. Among the most important tourism assets in Panama (in terms of quality, variety and potential) are protected areas (representing 73 per cent of the national tourism attraction asset; Análisi Diagnostico General Del Turismo En Panama 2008) where indigenous groups make up the majority of the residing population. Many of these natural habitats are already threatened by extreme climatic events such as hurricanes and tropical storms, which can cause forest loss and damage to tourist infrastructure and roads (CEPAL 2010).

Box 8.4 Possible ecosystem-based adaptation interventions with recreation benefits

- Include traditional knowledge about climate change into planning.
- Expand tourism and recreational services to multiple season operations.
- Include information about natural and cultural heritage values in the decision-making processes.
- Promote natural and cultural heritage values through the marketing of products based on local ecosystem goods and traditional practices.

Source: adapted from CBD (2009), Innes *et al.* (2009), FAO (2013), and UNEP (2012).

Community-based ecotourism can protect ecosystems' recreation services in areas that are vulnerable to climate change, while at the same time providing opportunities to empower local communities and diversify their livelihood strategies, which can lead to an increased capacity to cope with, and recover from, climate impacts.

Consultations held with communities of the Panama Canal (Lumpkin 1998) highlighted the importance of their involvement in ecotourism and provided interesting examples for EbA promotion in similar contexts. These communities are, as in the case of Embera indigenous communities, already implementing, actions to value their culture in relation to ethnic/cultural benefits for eco-tourists. Communities mentioned traditional uses of many non-timber forest products (e.g.

medicinal plants and domesticated wildlife in home yards) and timber products for traditional construction (e.g. canoes, thatched-roofed huts) as assets for community ecotourism development. In these consultations, equity gains were also highlighted, such as the empowerment of women through their role as providing community hospitality for tourists and the opportunity to create corresponding women-run small enterprises. The inclusion of former illegal hunters as ecosystem conservation guardians or as ecotourism guides enhanced the effectiveness (and acceptance) of these ecosystem-based options for community development, while smoothing out potential conflicts and unequal distribution of tourism benefits[5] and making use of traditional knowledge developed by these hunters.

On the other hand, important barriers hamper the capacity of potentially interested communities to participate in, and benefit from, recreation services. One important barrier to the effective achievements of benefits from these initiatives is the poor state of infrastructure that allows access to these habitats during the rainy season and especially during extreme rainfall events. There are no reported efforts to plan adaptation measures for poor road infrastructure, even if the intensity and frequency of extreme rainfall is expected to increase. An additional limitation mentioned by local communities is the national legislation that prohibits the local use of some resources (e.g. timber and some protected species) posing high transaction costs to harvest material for traditional construction.

Many of the benefits of ecosystems' recreation services identified during local consultations are relevant for community development purposes and for specific adaptation concerns. Indeed, community empowerment, addressing equity concerns and valuing traditional knowledge and lifestyles as in the case of Panama, can increase the capacity of communities to negotiate adaptation plans and enhance their sense of place and territorial identity. Furthermore, such actions can consolidate communities' abilities and motivation to care about habitat conservation, which is necessary for planning, implementing and sustaining ecosystem-based recreation services strategies with community ownership (Plummer and Fennel 2009; Strickland-Munro *et al.* 2010).

In 2012 Panama was rated first in the *New York Times*'s list of tourist destinations (Williams 2012). If ecotourism is to maintain its sustainability promises, communities must be directly engaged in the design and management of natural habitats and related tourist facilities. In order to do so, enabling activities should be promoted by national policies such as improving: communities' education and capacity to run tourist businesses; road infrastructure; and communication technologies (e.g. facilitating access to the Internet) (Eddins 2013). Important initiatives (e.g. from the Inter-American Development Bank) are to promote low-impact ecotourism within Panama's national system of protected areas (SINAP) on the basis of innovation, participation of local businesses and local sustainable social development.

The case of Panama's ecosystems recreation services for ecotourism highlights a couple of key relevant lessons for tropical forest ecosystems and indigenous culture and livelihoods. In order to ensure that the EbA benefits are accrued by vulnerable populations, attention should be paid to conservation efforts; infrastructure building and maintenance; business education and empowerment; revision of legal settings allowing for sustainable use of local ecosystems' goods and services; among other things.

Conclusion

Understanding climate impacts and possible adaptations in socio-ecological systems is essential to avoid, or plan for, undesired changes and their negative repercussions on human well-being. Knowledge of socio-ecological systems and their dynamics provide a fundamental basis for developing appropriate adaptation interventions that are locally based and relevant for extended time scales. In order to reduce people's vulnerability, interventions should focus on enhancing adaptive capacity (e.g. availability of alternative livelihoods, removal of practices that increase pressure on ecosystems, adoption of appropriate technologies and good governance), decreasing exposure (e.g. buffers between system and climate hazards), or decreasing sensitivity (e.g. dependency on a few, weather-prone productive activities). Adaptation strategies based on the use of ecosystems can be used to address the complex linkages between climate change and people's well-being, through ecosystems' ability to provide goods and services relevant for adaptation and beyond. EbA often offers a set of options that is immediate, flexible and cost-effective, and complements other technical and development interventions.

Many Central American countries acknowledge the role of ecosystem services in their policies because of the relevance that natural resources have in their economies. Several approaches have been designed and are implemented in the region, including PES, protected areas, and biological corridors. These landscape interventions can strengthen the delivery of important ecosystem services for biomass, water and recreation services. However, the region is only beginning to acknowledge the adaptation values of these policies to promote ecosystem-based alternatives to reduce the impacts of climate change.

Many of the barriers that hamper regional advances in EbA are related to (i) those identified in the literature evaluating the performance of PES schemes and (ii) those related to the evolution of the climate change agenda. An example of the first set of barriers is represented by the scarcity of data and knowledge of the relationship between different land uses and management options and the provision of ecosystem services (i.e. the conditionality requirement of PES schemes), which might reduce the capacity of institutions to design effective and efficient ecosystem service conservation schemes. The second set of barriers is represented by how, only recently, the regional agenda has been moving towards adaptation efforts by examining synergies with land-use mitigation efforts (e.g. in REDD+). Following the Rio Conference in 1992, the land-use-based responses to climate change in the region focused on the climate regulation role of forest ecosystems, with acknowledgement of the potential positive development externalities of these mitigation initiatives. The recent recognition of the failure of land use, land-use change and forestry (LULUCF) initiatives in the region has led to the acknowledgement of a wide range of ecosystem services which play an important role in maintaining productive activities, leisure and spiritual goods for society in the face of climate change.

The first Central American Conference of Ecosystem-Based Adaptation was attended by more than seventy participants (from NGOs, community-based organization, government agencies, multilateral and scientific organizations) and outlined ways of fostering nature-based adaptation alternatives (Vignola *et al.* 2009). Most of the messages targeted the role of NGOs, scientists and policy-makers in designing and implementing EbA alternatives, highlighting the importance of strengthening institutional coordination and communication mechanisms, and effective community participation. This reinforces the issues highlighted in the cases presented here. Integrating EbA in promising initiatives in the region can help to reconcile different aims in sectoral policies and achieve multiple objectives in a cost-effective way for more resilient societies and environments.

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Notes

1 During 2000–2005, forest regeneration mitigated by sequestration around 11.2 Gg of CO_2 per year (GoCR 2011), which represents more than double 2005's CO_2 emissions of energy sector (Chacón *et al.* 2009).

2 Reducing Emissions from Deforestation and Forest Degradation.

3 However, TroFCCA (2008) reports disaggregated rates for mixed and conifer forests for the same period as high as 2.8%, which are higher than the national mean recorded in other studies such as Rivera (1998).

4 As mandated by the Law on Forests, Protected Areas and Wildlife, forest-related management plans, including watershed management plans, are the responsibility of ICF. However, the watershed management plan for the Guacerique Watershed has been a collaborative effort between SANAA and ICF and responsibility for implementation has been delegated to SANAA.

5 This unequal distribution is associated with the exclusion of this part of the population whose livelihoods based on wildlife would have been affected.