Ecosystem-based Adaptation in Tanzania

The Role of Ecosystems for Human Well-Being and Climate Adaptation

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Ecosystems Report for The Economics of Climate Change in Tanzania Project
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Executive Summary

Multiple mechanisms link ecosystem services to human well-being. Tanzania hosts a variety of ecosystems including freshwater rivers, mountains, drylands, wetlands, savannah, coastal and marine ecosystems, many of which are transboundary like the Lake Tanganyika ecosystem, which is shared between four countries. These ecosystems directly and indirectly support the livelihoods of the population and much of the country’s economy.

Although Tanzania is characterized by rich, diverse and distinct terrestrial and marine ecosystems, modification of habitat due to demographic and socio-economic processes is degrading the ecosystems in the country causing disruption of the services they provide and biodiversity loss. Four critically stressed ecosystem services in Tanzania that need immediate attention are: maintenance of biodiversity; food and fiber provision; water supply, purification and regulation; and fuel provision. Some of the main direct drivers of environmental change in the country are: land-use change linked to deforestation and land degradation; sedimentation and water pollution linked to water consumption, agricultural run-off and soil erosion; and over harvesting of natural resources for small- and large-scale markets and industry.

Climate change is expected to put ecosystems and biodiversity at severe risk. As temperature rises, stress on ecosystems is expected to escalate quickly, compounded by other stressors such as infestation of invasive species, over harvesting, land-use change, and water scarcity among others. These stressors will be driven by indirect drivers of change including widespread poverty, and human population and consumption growth, which will increase the demand for food, water, and land within the next decades. Future changes in rainfall and temperature are likely to contribute to changes in plant and animal species composition and diversity, as well as to shifts of species range and of the agro-ecological zones in the country.

Ecosystems are likely to show poor recovery when affected by climatic stressors and natural disturbances if they have been exposed to continuous human activity and they are in degraded state. This is because persistent stresses on ecosystems weaken their resilience making ecosystems more susceptible to natural disturbance that otherwise could have been absorbed. If ecosystems resilience is lost, future climate change effects on ecosystems could lead to irreversible changes in their state. An example of abrupt environmental change in Tanzania that could be considered a signal of the potential effects of climate change and rising sea surface temperatures is the 1998 Indian Ocean coral bleaching event which reduced coral cover in most reefs of the country.

Current and potential impacts of climate change on ecosystems are experienced very differently by the various sectors, communities and households across Tanzania. Currently, large portions of the population are particularly vulnerable to climate change because of their limited livelihood base, poor access to markets and services, and weaknesses in the institutions that govern them. Moreover, the country’s economy is largely dependent on multiple ecosystems and the services and goods these provide. As a result, effects caused by climate change on ecosystems will have both negative and positive implications for human populations and economic sectors in the country and generate different responses that will in turn have effects on the dynamics of the social-ecological system.

Some of the implications of temperature increase and changes in rainfall pattern may be changes in the length of the growing season affecting agricultural activities in the country. In addition, increase in the duration and incidence of droughts associated with climate change are likely to further decrease the area of grazing land available to livestock-keeping communities in Tanzania. Similar to agriculture, climatically induced changes can have implications for the tourism sector.

The Ecosystem-based Adaptation (EbA) approach relates to the management of ecosystems within interlinked social-ecological systems to enhance ecosystem processes and services that help people and ecosystems adapt to the adverse impacts of global change, such as changing climatic conditions. This approach depends highly on healthy and resilient ecosystems, which are able to deliver a bundle of ecosystem services to support adaptation in the face of various pressures. At the core of this approach lays the recognition of existing
interactions and feedbacks between human and ecological systems and the need to understand these to enhance benefit flows from the system. EbA has the potential to generate multiple environmental and societal benefits, while reconciling short and long-term priorities. For instance, EbA can be a synergistic approach that reconciles mitigation objectives by enhancing carbon stocks, with cost-effective management of climatic risks, and conservation objectives by preserving natural ecosystems and biodiversity.

Enhancing the capacity of ecosystems to generate essential services for climate change adaptation requires that they be managed as components of a larger landscape of which human activities are part. The Dynamic EbA Pathways Framework is a conceptual framework based on an adaptive management approach to enhance and maintain ecological processes and ecosystem services at the landscape level. It combines multi-functional land uses and conservation of natural capital\(^1\) to enhance multi-scale benefits from ecosystems that help social-ecological systems adapt to changing and multiple stressors, including climate change. To this end, the Dynamic EbA Pathways Framework combines EbA strategies with flexible enabling mechanisms and adaptive processes.

Given the high uncertainty involved in long-term planning, the Dynamic EbA Pathways Framework uses a step-based approach to explore the range of potential EbA pathways that can be adopted over time. This approach recognizes that not all adaptation decisions are needed now and enables socio-institutional learning, adaptive management, and better understanding over time. By doing so, it deals with the uncertainty inherent to possible futures, overlaps between EbA pathways, synergistic and antagonistic cross-sectoral interactions of adaptation actions, and multiple stressors affecting the social-ecological systems. The step-based approach is also closely linked to an economic rationale for action, whereas no-regret options can generate benefits at lesser costs than investing in pilot actions and multi-scale processes necessary to adapt to and transform with potential future thresholds and tipping-points.

Ecosystem-based adaptation costs relate to expenditure associated with actions taken to enhance ecosystem services that can help avoid or minimize the negative impacts of climate change on both ecosystems and human societies. It is based on the premise that autonomous adaptation of ecosystems and species will not be sufficient to withstand future impacts of climate change and therefore human planned actions are indispensable to maintain or enhance the ecosystem processes and services necessary for climate change adaptation of social-ecological systems. Estimating the costs of EbA is complicated due to several reasons. The first one relates to the uncertainty associated with the direct and indirect costs of climate change impacts. The second challenge is valuing “soft” measures as EbA relies heavily on “soft” adaptation measures through flexible mechanisms. A third challenge is that EbA largely depends on the adaptive capacity of social-ecological systems, which is based on interactions and feedbacks between social and ecological systems that are not well understood yet. A fourth challenge is the poor understanding of the full economic value of ecosystem services, on which benefits from EbA are based. A fifth challenge is the close interaction between ecosystems and other sectors, as different sectoral adaptation strategies can interact synergistically or antagonistically affecting ecosystem processes that enable or prevent ecosystem services, thus reducing or adding to the costs of EbA.

Several no-regret EbA measures can be implemented in the context of Tanzania. This report focuses on one measure, which comes from a pool of adaptation options for the Zanzibar archipelago identified through a participatory process in a recent study. The option relates to restoring the natural coastal vegetation to enhance coastal forest buffer zones in chosen locations along the coast. This option can be considered a no-regret ecosystem-based adaptation measure because it would produce multiple benefits even in the absence of climate change impacts. First, it would function as shoreline protective barrier, for instance, against tsunami waves. Second, it would help prevent excessive erosion by stabilizing beach sand and absorbing wave energy. Third, it would help maintain the ecosystem services to

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1 ‘Natural capital’ refers to the components of nature that can be linked directly or indirectly with human well-being. In addition to traditional natural resources, it also includes biodiversity and ecosystems that provide goods and services (TEEB 2009).
support local livelihoods and essential goods such as firewood, building poles and sawn timber, herbal medicines, edible fruits, mushrooms, plant-derived oils, leaves and beverages, fodder, fibre, honey, ornamental plants, household utensils and handicrafts.

Although costs for enhancing coastal forest buffer zones have not been estimated, no-regret benefits are clear and could be increased if this approach would be extended to the coastal forest area in Tanzania. This strategy would not only have benefits for climate adaptation and social development, but would also have the potential to benefit biodiversity conservation. It could also be explored in terms of reduced emissions from deforestation and degradation (REDD+) through coordinated partnerships between government, non-government and community-based agencies. First steps to implement a national strategy based on this approach would involve: harmonization of institutional conflicts especially in respect to revenue collection/benefit sharing; harmonization of legal issues so as decisions that are made on forests or forest land should not be conflicting; work on energy policies to promote alternative sources at affordable prices so as to reduce dependence and pressure on biomass; capacity building to develop coastal forest management plans; development of criteria, indicators, and mechanisms for managing and monitoring forest resources in coastal forest buffer zones using a participatory approach.

Ecosystem-based Adaptation is gaining interest among different communities of practice because it can bring multiple benefits and be a synergistic approach that reconciles different objectives. Over time and through practice, important knowledge relevant to EbA has been generated. However, this knowledge is incomplete and fragmented across disciplines. Although current information and knowledge is useful, it is insufficient to simulate possible EbA outcomes and costs. More research and actions are needed to understand better the unknowns that are source of uncertainty in EbA decision-making, planning, and costing. The needs identified in this report require collaborative research and action supported by innovative approaches. Progress in addressing these needs will enrich ongoing policy-science dialogues and decisions for future adaptation to global changes.
The United Republic of Tanzania is the second largest country in the SADC Region and the largest in East Africa. It lies in the African east coast between latitudes 1 and 11 degrees south of the Equator. It covers 945,234 sq km comprising mainland and the three major coastal islands of Mafia, Pemba, and Zanzibar. Tanzania hosts a variety of ecosystems that support the livelihoods of the local populations and much of the country's economy. This report highlights the role of ecosystems for human well-being, the future impacts of climate change on ecosystems in the country, and the adoption of an ecosystem-based approach for climate change adaptation.

1. The Role of Ecosystems for Human Well-being in Tanzania

Multiple mechanisms link ecosystem services to human well-being. This section describes some of these links and provides an overview of the main ecosystems in Tanzania and the importance of the services they provide for local livelihoods and the national economy.

1.1 Ecosystem Services for Human Well-being

Although people’s livelihoods, local and global economies depend on a reliable flow and interaction of multiple ecosystem services, it is difficult to draw direct and indirect links between ecosystem services and human well-being. This is because relationships between ecological and socio-economic systems are dynamic and non-linear, and ecosystem services do not operate in isolation, but interact with one another in complex, often unpredictable ways. According to the Millennium Ecosystem Assessment (2005), the range of ecosystem services enjoyed by humans can be divided into four main categories (see Figure 1 below).

![Categories for ecosystem services. Adapted from the MA 2005.](image-url)
• **Provisioning services**: include the production of basic goods such as crops, livestock, water for drinking and irrigation, fodder, timber, biomass fuels, fibers such as cotton and wool; and wild plants and animals used as sources of foods, hides, building materials, and medicines.

• **Regulating services**: involve benefits obtained as ecosystem processes affect the physical and biological environment around them; these include flood protection, coastal protection, regulation of air and water quality, regulation of water flow, absorption of wastes, absorption of carbon dioxide, control of disease vectors, and regulation of climate.

• **Cultural services**: encompass the non-material benefits that people derive from ecosystems through spiritual enrichment, recreation, tourism, outdoors-related sports, education, and aesthetic enjoyment. These services also include societies whose cultural identities are tied closely to particular habitats or wildlife.

• **Supporting services**: these services are necessary for the production and maintenance of the three other categories of ecosystem services. Examples are nutrient cycling, production of atmospheric oxygen, soil formation, and primary production of biomass through plant photosynthesis.

Human intervention and dominant patterns of demographic, social and economic change can affect the interaction between ecosystems and thus affect the flow of multiple ecosystem services directly and indirectly, with implications for ecosystems processes and function. In turn, changes in ecosystems functioning and ecosystem services can lead to changes in human well-being (see Figure 2). The Millennium Ecosystem Assessment (2005) highlights two specific policy-relevant interactions among ecosystem services: synergies and tradeoffs.

![Figure 2. Drivers of change and interactions between ecosystem services and human well-being. Adapted from SAfMA 2004.](image)
Trade-offs in ecosystem services occur when the provision of one ecosystem service is reduced as a consequence of increased use of another ecosystem service. Trade-offs may arise from management choices made by humans, which can change the type, magnitude and relative mix of services provided by one ecosystem, and as a consequence affect the flow of other ecosystem services. For instance, human exploitation of ecosystem services for the production of consumptive goods (e.g. provisioning ecosystem services for food or energy resources) can reduce the long-term quality of regulating and/or supporting ecosystem services (e.g. renewal of soil and soil fertility, maintenance of biodiversity, water regulation). In some instances, trade-offs can be a consequence of planned actions; in others, trade-offs may be unpredictable (Swallow et al. 2009).

In contrast, synergies are defined in the context of the provision of ecosystem services as a situation in which the combined effect of several drivers operating on ecosystem services is greater than the sum of their separate effects. Synergies can also occur when changes in ecosystem services interact with one another in a multiplicative way leading to positive or negative effects on human-well-being (MA 2005). For example, synergies can relate to both the synergistic impacts of increased temperature and overfishing on coral ecosystems; and/or the synergistic effects of reef provisioning of products and reef moderation of waves force both contributing to improved well-being of coastal communities.

1.2 Ecosystem Services and their Importance in Tanzania

Tanzania hosts a variety of ecosystems including freshwater rivers (e.g. Ruaha), mountains (e.g. Eastern Arc Mountains), drylands, wetlands (e.g. Usangu or Malagarsi), savannah (e.g. Selous-Ruvuma), coastal and marine ecosystems (e.g. Tanga or Rufiji-Mfai-Kilwa), many of which are trans-boundary (e.g. the Lake Tanganyika ecosystem, which is shared between four countries). These ecosystems directly and indirectly support the livelihoods of the population and much of the country’s economy, providing goods and services that support different sectors. This section provides some examples of ecosystems in Tanzania and of the services that ecosystems provide.

**Mountain forests**

The forest ecosystem of the Eastern Arc Mountains (EAM) is one of 25 global biodiversity ‘Hot Spots’. One quarter of the EAM plant species are endemic, which constitutes about 60% of all endemic species of Tanzania (NEMC 2006). The forest provides about 40% of the total household consumption of forest and woodland products such as firewood, building materials, medicinal herbs, wild fruits and other food materials in nearby communities (ibid). The EAM forests are major catchments providing water to over 3 million people and several industries. About 70% of Tanzania’s electricity is generated from hydropower sources in these catchments.

The mountain ecosystems of Mount Kilimanjaro are also a key feature of Tanzania’s mountain forests. With a large altitudinal range (700-5,895m) Mount Kilimanjaro has a very rich biodiversity. Vegetation types range from savannah bushland, grassland, pastureland and cropland (mainly maize, wheat, coffee and bananas) in the low-lying areas, through indigenous forest in the mid-altitudes, to alpine vegetation on the higher slopes. The mountain is the primary source of water for domestic supply, agriculture and hydropower, food, fuel, non-timber forest products (including medicinal plants) and building materials for the people of Kilimanjaro region in northern Tanzania. It also provides cultural benefits and is one of the major tourism attractions in Tanzania.
Wetlands and mangroves
Wetlands in Tanzania, including mangroves, support a range of ecosystem services, harboring over 654 associated species, such as mollusks, crustaceans, echinoderms, and fish (Payet and Obura 2004). Wetlands and mangroves are also an important source of food and materials, and are used by the local population for construction, medicinal purposes, and fodder. Moreover, mangroves and wetlands interrupt freshwater discharge, are sinks for organic and inorganic materials as well as pollutants, and can generate an environment with clear, nutrient poor water (Moberg and Folke 1999). In addition, mangroves provide feeding, breeding and nursery areas for prawns, shellfish and many other commercial fish species. Mangroves are also valuable as sources of firewood and charcoal, and as a source of income for many people engaged in selling mangrove forest products. The Integrated Ecosystems Assessment in Tanzania report (NEMC 2006) describes the importance of the mangrove ecosystems of the Jozani Chiwaka Bay National Park; the wetland ecosystem of the Malagarasi; the river ecosystem of the Great Ruaha; and the Lake Tanganyika ecosystem.

Marine ecosystems: coral reefs and sea grasses
Coral reefs are among the most productive and biologically diverse ecosystems. They provide goods such as seafood and reef mining, and services like recreational possibilities, coastal protection, as well as aesthetic and cultural benefits. Coral reefs serve as physical buffer for oceanic currents and waves, creating a suitable environment for seagrass beds and mangroves. Sea grasses serve as breeding, nursery and feeding areas for many invertebrates and vertebrate species; they are a source of food for herbivorous invertebrates, fish and turtles; they trap and bind sediments thereby reducing particulate pollutants over coral reefs; and they provide protection to shorelines by dissipating wave energy (NEMC 2006). A marine ecosystem of great importance in Tanzania is the reef system close to Zanzibar. For example, the Menai Bay Conservation Area, situated in the southwest coast of Unguja Island, extends 470 sq km and attracts tourism associated with diving and snorkelling around coral reefs and sand banks in Fumba, and with dolphins and whales watching in Kizimkazi.

Protected areas
As of 2003, the numbers and distribution of species found in Tanzania were 10,008 plant species, 316 mammals, 229 breeding birds, 335 reptiles, 116 amphibians, and 331 fish species (CBD 2003). Currently, about 6% of the national territory has been designated as protected area (FRA 2010). The latest World Database on Protected Areas (2009) reports 565 nationally designated protected areas in Tanzania, including IUCN categories I-V and other. In terms of internationally recognized sites, there are 3 Biosphere Reserves, 4 Ramsar Wetland sites, and 4 World Heritage Sites. A significant national achievement in terms of conservation was the development and implementation of the Environmental Management Act in 2004, which addresses the issues of protected areas, environmental impact assessment, genetic resources, in situ and ex situ conservation, genetically modified organisms, and ecosystem conservation and management.

Woodfuel and charcoal
Tanzania has a relatively small industrial energy sector, and traditional biomass fuels make up a large proportion of the total energy supply. Even where electricity is provided, paraffin, liquid petroleum gas or coal are available as substitutes. Non-traditional biomass fuels are less affordable, or in some cases an open fire is preferred for cooking and domestic space heating (SAfMA 2004). In 2006, biomass made up 91% of the total national energy supply in Tanzania, followed by far by imported petroleum products (IEA 2009). In 2005, only 11% of the national
The population had access to electricity (IEA 2006). Charcoal is the preferred fuel in urban areas, while wood tends to be used when the wood source is close to the place of consumption, i.e. mostly in rural locations (SAfMA 2004).

**Water resources**
There are five broad categories of water use in Tanzania: domestic consumption (including home gardens), industry (including mining and coal-fired electricity generation), hydroelectric power generation, irrigated agriculture, and the maintenance of aquatic ecosystems. In addition, aquatic ecosystems like river and lake systems and wetlands process and dilute wastes, help with flood control, and provide for recreation, aesthetic satisfaction and religious rituals. In terms of water withdrawals, Tanzania uses almost all water resources for irrigation (89.5 %), 10.1% for domestic consumption, and much less for industry (0.4%). Water resources play a main role in the electricity supply of Tanzania, contributing about 50% to the total production (IEA 2006). Access to safe water has improved over the past decades covering a bit more than half of the population.

**Nature-based tourism**
The Government of Tanzania views tourism as a significant industry in terms of job creation, poverty alleviation, and foreign exchange earnings. In 2001, the tourism sector accounted for about 16% of the GDP and nearly 25% of total export earnings (MNRT 2005). Moreover, it directly supported 156,050 jobs. The main tourist attraction in Tanzania is associated to the natural assets of the country. The country wildlife resources are internationally renown. Most visited sites include the great Serengeti plains, the Ngorongoro Crater, Lake Manyara and Africa’s highest mountain, Kilimanjaro, in the north, Mikumi, Udzungwa and Ruaha National parks and Selous game Reserve in the south. Additional natural attractions include the sandy beaches in the north and south of Dar es Salaam and the deep-sea fishing at Mafia. Furthermore, Tanzania has a rich heritage of archaeological, historical and rock painting sites, a number of which have been designated World Heritage Sites.

### 2. Current Drivers of Environmental Change

Although Tanzania is characterized by rich, diverse and distinct terrestrial and marine ecosystems, modification of habitat due to demographic and socio-economic processes is degrading ecosystems in the country causing disruption of the services they provide and biodiversity loss. The scoping study prepared by the International Institute for Sustainable Development for the United Nations Environment Programme in 2005 identified four critically stressed ecosystem services in Tanzania that need immediate attention: maintenance of biodiversity; food and fiber provision; water supply, purification and regulation; and fuel provision. Table 1 below summarizes the main issues related to ecosystem degradation in different regions of Tanzania. This section describes some of the direct drivers of environmental change in the country, namely land-use change (linked to deforestation and land degradation), sedimentation and water pollution (linked to water consumption, agricultural run-off and soil erosion), and over harvesting of natural resources (for small- and large-scale market and industry).

Table 1. Main issues related to ecosystem degradation in different regions of Tanzania

<table>
<thead>
<tr>
<th>Region</th>
<th>Degradation of ecosystems and biodiversity loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arusha</td>
<td>High risk of desertification and localized land degradation, deforestation, over-stocking of cattle, water shortages and drought, water quality problems</td>
</tr>
<tr>
<td>Dar es Salaam</td>
<td>Deteriorating fish catch, water pollution</td>
</tr>
</tbody>
</table>
Dodoma | Deforestation and land degradation, high risk of desertification and localized land degradation, drought
---|---
Iringa | Low production due to acidic soil, deforestation, drought
Kagera | Refugees cutting trees for firewood and construction, drought and water quality problems
Kigoma | Deteriorating fish catch, refugees cutting trees for firewood and construction, drought and water quality problems
Kilimanjaro | Soil degradation, drought
Lindi | Soil degradation, deforestation of Miombo woodland
Mara | Over-stocking of cattle, soil degradation, water pollution
Mbeya | Low production due to acidic soil, drought
Morogoro | Low production due to acidic soil, deforestation, Miombo woodland degradation, flooding
Mwanza | High risk of desertification and severe localized land degradation, over-stocking of cattle, water pollution
Pwani | Degradation of Pugu and Kazimzumbwe Forest Reserves due to population growth. Mangrove and wetland conversion, especially Rufiji River forests, woodland and wetlands. Degradation of Miombo woodland. Soil degradation
Rukwa | Fish catch deteriorating, water pollution
Shinyanga | High risk of desertification and localized land degradation
Tabora | High risk of desertification and localized land degradation
Tanga | Forest Reserve encroachment and deforestation, soil degradation, flooding

Adapted from UNEP and IISD 2005.

**Land-use change**

Changes in land-use and production systems (e.g. extensification and intensification of agricultural production) have consequences for ecosystems functioning and biodiversity, as habitats are destroyed and ecosystems' resilience is degraded. In Tanzania, changes in land use have caused a chronic loss of natural forest in river basins. The average annual rate of deforestation has increased over the past decades from -1.02% between 1990 and 2000, to -1.1% between 2000 and 2005, and to -1.16% between 2005 and 2010 (FRA 2010). In 1990, the forest area in Tanzania was about 41.5 million hectares. This area has now decreased to 33.4 million hectares or about 38% of the total national territory. An example of deforestation is the loss of 41 sq km of natural forest cover in the southern slopes of Mount Kilimanjaro over the past decades. This loss is mainly due to expansion of intensive crop cultivation, growing population settlements, logging, burning for charcoal production, livestock grazing, and land slides due to logging on steep slopes (Yanda and Shishira 2001, NEMC 2006). Dam projects have also affected riverine forests as a result of decreasing river flows in many areas, such as the Pangani River and Delta.

Degradation of natural forests does not only modify habitat and impact wildlife, but also climate regulation and water storage capacity. Stress and deterioration can also undermine the forests' buffer capacity increasing risk of floods in the rainy season and droughts in the dry season. Despite large deforestation between 1990 and 2010, some efforts have focused on reforesting. Currently, the total area under planted forest is 240,000 hectares, which relates to 1% of the total forest area. The entire forest area in Tanzania is under public ownership and administration (FRA 2010). The primary designated function of 71% of this area is production, 6% is biodiversity conservation, and 24% is multiple use (FRA 2010).

**Sedimentation and water pollution**

Another issue affecting ecosystems in Tanzania is sedimentation and water pollution due to agricultural run-off and soil erosion. For example, sedimentation processes along the Kikuletwa River have converted humid and wet regions into fragmented
forest areas. This has resulted in the migration of several species of wildlife, including river crocodiles, and has negatively impacted freshwater fisheries (Payet and Obura 2004). Around Lake Victoria, rising agriculture and human settlement in the catchments increased the flow of silt, nutrients, and pollutants into the lake, causing eutrophication problems and the expansion of blue-green algae and water hyacinth. In addition, oxygen deprived areas developed over sections of the lake floor. As a result, the diverse fishery changed into one based only on three species, two of which were introduced (Baliwa et al. 2003). Furthermore, coral reefs in Tanzania are also affected by high sedimentation levels from the rivers, pollution from agriculture and industries, sewage and solid-waste discharges along the coast, as well as pollution from commercial port operations (Payet and Obura 2004).

**Over harvesting of natural resources**
The multiple and excessive use of ecosystem services and extraction of goods is an increasing stress for ecosystems in Tanzania. For example, over-exploitation of mangrove services in the Ruvu-Wami basin has lead to the destruction of 10-16% of the total mangrove cover by 1995 (World Bank and DANIDA 1995). Similarly, coral reefs are stressed as a result of human extraction activities. In 1998, an estimated 80,000 Tons of corals were mined for the production of lime in Lindi and Mtwara (UNEP 2001). Coral reefs are also affected by the use of poison fisheries and coral dynamite blasting (Payet and Obura 2004), uncontrolled tourism activities and oil extraction (Moberg and Folke 1999). Moreover, overfishing and destructive fishing are stressing reef fisheries (Grimsditch et al. 2009). For instance, a recent resilience assessment of Pemba's coral reef showed a high dominance of small fish and low populations of commercially-valuable non-herbivores, which are clear indicators of overfishing. The assessment also indicated clear evidence of destructive fishing through beach seines and dynamite fishing (Grimsditch et al. 2009). The loss of key functional species combined with other stresses can have serious implications for the resilience of coral reef communities. If over-fishing continues in the area, the study suggested that the reef ecosystem would be at serious risk of collapse with possibility of a future phase shift to an algae-dominated reef (Grimsditch et al. 2009).

3. Climate Change and Implications for Ecosystems and Human Activities

3.1 Climate Trends and Projections

The climate varies across Tanzania because of the topography, inland lakes and different types of vegetation, as well as proximity / topographic orientation to the Indian Ocean. Two broad rainfall regimes can be identified. The southern and western regions have one rainy season (unimodal rainfall) from November to April, and the northern and coastal regions have two rainy seasons (bimodal rainfall) with the short 'vuli' rains from October to December and the longer 'masika' rains from March to May. Wetter areas around the northern highlands and Lake Victoria contrast with semi-arid western and central regions.

Rainfall also naturally varies quite considerably between years because of feedbacks in the climate system linked to large-scale changes in the temperature and pressure of ocean surfaces, such as the Indian Ocean Dipole and El Niño. Although differences exist between the exact effects of El Niño on the north and the south of the country the broad pattern is that there is increased rainfall during El Niño years and decreased rainfall during La Niña years, frequently associated with floods and droughts. Flooding is particularly severe when El Niño year occurs in combination with the positive phase of the Indian Ocean Dipole, as was the case for the major floods in the north of the country in 1997, 2006, and 2010.
Analysis of observational data from 6 stations in Tanzania carried out by New et al. (2006) as part of a larger assessment for Africa, showed clear evidence of decreasing numbers of cold days and nights and a decrease in cold waves. There has also been an increase in the number of heat-waves, and in the frequency of hot nights. There has been an increase in the average intensity of rainfall, a small increase in the maximum number of consecutive wet days (associated with flooding) and a small increase in the maximum number of consecutive dry days (i.e. longer dry spells).

There is significant uncertainty over climate projections for Tanzania. The information presented below is derived from statistically downscaled climate projections using data from the Climate Systems Analysis Group (CSAG) based at the University of Cape Town, as well as projections from global climate models.

The results from statistically downscaling scenarios from 9 global climate models agree that minimum and maximum temperatures are expected to increase, although the size of the change varies. For the period 2046-2065 average minimum temperatures are expected to increase in the range of 1-3°C, and for the end of the century (2081-2100) average minimum temperatures are expected to increase in the range of 2.1°C-5.2°C. Warming is greatest inland and in the northeast. These results from downscaled scenarios are in agreement with projections from global models.

The pattern of changes in rainfall is less clear. Global climate models disagree over whether there will be an increase or a decrease in precipitation over most of Tanzania. This is particularly the case in the south, where the 20 global models used are evenly split between an increase and a decrease in annual precipitation. For the north of the country more models project an increase in precipitation than a decrease, however this is still less than 75% of the models, meaning there is significant uncertainty in the changes.

Results from global models show that the intensity and the frequency of extreme rainfall events is expected to increase in Tanzania. El Niño will continue to have a large impact on inter-annual variability, however it is unclear how climate change will affect the frequency and magnitude of El Niño events, and thus what effects this will have in Tanzania. While some of the uncertainty in projections will be reduced as climate models are refined there is a significant portion that will always remain due to the complex nature of the climate system. This means that the uncertainty must be accounted for planning processes.

3.2 Possible Impacts on Ecosystems

Climate change is expected to put ecosystems and biodiversity at severe risk. At the continental level, results using several scenarios show that around 5,000 African plant species and over 50% of bird and mammal species will be seriously affected or even lost by the end of this century (Fischlin et al. 2007). McClean et al. (2005) estimated substantial reductions in areas of suitable climate for 81-97% of the 5,197 African species examined, with 25-42% having lost all area by 2085. Moreover, the IPCC (Fischlin et al. 2007) estimates that by 2100 the productivity of Africa’s lakes will decline by 20 to 30%. As temperature rises, stress on ecosystems is expected to escalate quickly, compounded by other stressors such as infestations of invasive species, over harvesting, land-use change, water scarcity, etc (Gaston et al. 2003). These stressors will be driven by indirect drivers of change including widespread poverty, human population and consumption growth, which will increase the demand for food, water, and land within the next decades. Table 2 summarizes current effects...
on ecosystems in Tanzania related to multiple non-climatic stressors, and possible effects caused by current and future climatic stressors.

Table 2. Current and future effects on ecosystems caused by multiple non-climatic and climatic stressors

<table>
<thead>
<tr>
<th>Ecosystems</th>
<th>Non-climatic stressors</th>
<th>Climate-related stressors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater reserves</td>
<td>Sedimentation and water pollution, Land-use change, Over harvesting of resources</td>
<td>Low rainfall can stress freshwater reserves, Increase in evapotranspiration affect water supply.</td>
</tr>
<tr>
<td>Forests and wetlands</td>
<td>Habitat modification and biodiversity loss, Destruction of the ecosystems</td>
<td>Changes in rainfall pattern affect hydrological cycle and vegetation services.</td>
</tr>
<tr>
<td>Arid and semiarid ecosystems</td>
<td>Soil erosion, salinisation, desertification, degradation.</td>
<td>Changes in temperature can affect species composition.</td>
</tr>
<tr>
<td>Coral reefs</td>
<td>Degradation of ecosystem health, Increasing sedimentation loads, Reduction of species diversity and alteration of species composition</td>
<td>Thermal stress can transform coral communities with cascading negative effects on reef fisheries.</td>
</tr>
</tbody>
</table>


Ecosystems are likely to show poor recovery when affected by climatic stressors and natural disturbances if they have been exposed to continuous human activity and they are in degraded state. This is because persistent stresses on ecosystems weaken their resilience making ecosystems more susceptible to natural disturbance that otherwise could have been absorbed. According to Parry et al. (2009), unprecedented global change disturbances are likely to affect ecosystems that are already stressed by multiple non-climatic stressors undermining even further their capacity to respond and adapt. If ecosystems resilience is lost, future climate change
effects on ecosystems could lead to irreversible changes in the state of ecological and social systems (Thompson et al. 2009).

An example of abrupt environmental change in Tanzania that could be considered a signal of the potential effects of climate change and rising sea surface temperatures is the 1998 Indian Ocean coral bleaching event which reduced coral cover in most reefs of the country, with mortalities of up to 90% in many shallow areas (Wilkinson et al. 1999, McClanahan et al. 2001). The year 1998 saw the strongest El Nino ever recorded in the region, resulting in very high water temperatures in the tropical Indian Ocean, with temperatures of 3 to 5 degree C above normal. Despite not all fisheries were susceptible to the immediate effects of coral bleaching and mortality, loss of habitat structure following coral mortality can be expected to affect up to almost 60% of species resulting in changes in the structure of reef habitats and in considerable reduction of the goods and services provided by reefs (Jones et al. 2004, Pratchett et al. 2008, Cinner et al. 2009). There is strong international consensus that climate change and ocean acidification are already affecting shallow water corals (Eakin et al. 2009).

Concerning climate change effects on terrestrial ecosystems, future changes in rainfall and temperature are likely to result in changes in plant and animal species composition and diversity, and shifts of species range (UNEP 2004). Historically, climate change has lead to remarkable shifts in the geographical distributions of species and ecosystems in order for species to adapt (Malcolm et al. 2002, Jansen et al. 2007). Plant and animal species will evolve and adapt in-situ or will migrate or shift in order to find suitable habitats requirements (i.e., water and nutrient availability); this may mean that in some locations the geographical range of suitable habitats will shift outside protected area boundaries. Shifts in species range could have impacts on species population size and could lead to numerous localized extinctions. These consequences could be exacerbated if climate change restricts the range of a species to just a few key sites and an extreme weather event occurs, thus driving up extinction rates even further (Erasmus et al. 2002). Moreover, fragmentation of habitats could easily disrupt the connectedness among species and increase the difficulties for migrating. If some key functional species are not able to respond to climate change, the result could be large changes in ecosystem composition and function and increased vulnerability of ecosystems to natural and anthropogenic disturbance. This could result in further species diversity reductions (Malcolm et al. 2002) and possible collapse or change in the state of ecosystems.

Furthermore, increases in temperature and changes in rainfall are expected to alter the distribution of the agro-ecological zones. For example, under climate change most of the forests across Tanzania are expected to shift towards drier regimes: from subtropical dry forest, subtropical wet forest, and subtropical thorn woodland to tropical very dry forest, tropical dry forest, and small areas of tropical moist forest respectively (Tanzania First National Communication 2003). Currently, assessments of climate change impacts on forests do not explicitly account for the potential effects of climate change on disturbances such as fire. Altered fire regimes could lead to contribute to warmer and drier conditions intensifying the risks for forests (Agrawala et al. 2003). For example, decline in precipitation coupled with a local warming can increase the intensity and risk of forest fires on Mount Kilimanjaro. Forest fires have already affected cloud forests in the mountain, which play a key role in the hydrological balance of the water catchment. According to Agrawala et al. (2003), a continuation of current trends in climatic changes, fire frequency, and human influence could result in the loss of most of the remaining subalpine Erica forests and the water budgets of the high altitude basins in Mount Kilimanjaro, putting at risk the
long-term sustainability of the valuable resources of this ecosystem.

Finally, uncertainty around potential impacts of future climate change on ecosystems is compounded by possible increases in productivity due to climate change, which may also have effects on ecosystems resilience, as these may occur in certain terrestrial ecosystems through likely atmospheric CO\textsubscript{2}-fertilisation effects and/or modest warming. Generating more knowledge on the capacity of ecosystems to tolerate disturbance is critical, as it will help understanding better their “ability to adapt naturally” and predict thresholds and tipping-points.

3.3 Implications for Human Activities

Current and potential impacts of climate change on ecosystems are experienced very differently by the various sectors, communities and households across Tanzania. Currently, large portions of the population are particularly vulnerable to climate change because of their limited livelihood base, poor access to markets and services (notably water supply, energy, transport, healthcare and social welfare), and weaknesses in the institutions that govern them (for a detailed analysis see Paavola, 2003). Tanzania is one of the poorest countries in the world with a GNI per capita of USD 280 (World Bank 2002). In 2000, some 42% of the total population and 50% of the rural population live below the poverty line with 20% of the entire population surviving on less than USD1 per day (World Bank 2002). In 2000, 92% of the population was considered to have vulnerable employment and in 2009 about 34% of the population was considered undernourished (World Bank 2010).

Moreover, Tanzania’s economy is heavily dependent on sectors that are closely linked to the country’s natural capital. The most important economic sector is primary production from agriculture, which accounted for nearly one-half of the GDP in 2000, employed 80% of the work force, and provided 85% of exports (World Bank 2002). In addition, the nature-based tourism sector accounted for about 16% of the GDP in 2001 and nearly 25% of total export earnings (MNRT 2005). Similarly, the annual value of forest goods and services in Tanzania was about USD 2.2 million or about 20.1% of the GDP based on 2006 prices (MNRT 2008), with about 3 million person-years of employment in forest industries, government forest administration and self-employment in forest related activities (MNRT 2008, Blomley and Idd 2009). As such, the country’s economy as a whole is largely dependent on multiple ecosystems and the services and goods these provide. As a result, effects caused by climate change on ecosystem services will have both negative and positive implications for human populations and economic sectors in the country and generate different responses that have in turn effects on the social-ecological system (see feedbacks in Figure 3).
Figure 3. Diagram of climate risks, effects and feedbacks

Increases in temperature and changes in rainfall may change the length of the growing season affecting agricultural activities in the country. Changes in climate combined with changes in pest populations and plant disease outbreaks may negatively impact crop yields. There are projections of large declines in maize production across many parts of Tanzania (Mwandosya et al. 1998). This could lead to increased food insecurity in many parts of the country, given that maize is a staple crop grown by half of Tanzanian farmers for domestic consumption. Model runs using the Crop Environment Resource Synthesis model (CERES-Maize) show yield decrease for maize over the entire country ranging from decreases of 10 to 25% in the southern highland areas of Mbeya and Songea, the Lake Victoria region, and the northeastern highlands, to decreases higher than 80% in the central regions of Dodoma and Tabora. On the other hand, changes in climatic conditions and in agro-ecological zones may potentially increase coffee and cotton yields (Tanzania First National Communication 2003). These changes will differentially impact commercial, emerging and small-scale farmers.

In addition, increase in the duration and incidence of droughts associated with climate change is expected to further decrease the area of grazing land available to livestock-keeping communities in Tanzania. There is already considerable pressure on the land in many parts of the country and this may exacerbate conflicts between pastoralists and agriculturalists, notably in the Morogoro, Mara and Kilimanjaro regions. Furthermore, changes in water temperatures in the large East African lakes, including Lake Tanganyika, are affecting the nutrient loads and thereby the productivity, species composition and size of fish populations, and in turn impacting on the livelihoods of those that rely on these resources (O’Reilly et al. 2003).

Similar to agriculture, climatically induced changes can have implications for the tourism sector. Changes in the spread and growth of natural vegetation due to climate change present a risk to the habitats of Tanzania’s wildlife, an important source of cultural identity within the country, as well as being central to Tanzania’s
tourist economy. This plays out in the context of increasing habitat fragmentation associated with human interventions and land use changes. Tourism activities may also be affected by the severity and frequency of extreme events experienced across the country, and the loss of ecosystems resilience to absorb these disturbances and serve as protective buffer that minimize impacts on human populations (e.g. loss of coral reefs as tourist attraction and as shoreline protection). Tourism and other economic sectors may also be affected by the threat of certain areas experiencing more intense rain events which increases the risks associated with flooding and resultant damage to housing, public and tourism-oriented infrastructure, and hydro-electric plants (e.g. along the Rufiji River). Moreover, the loss of sandy beach areas associated with sea level rise and increased storm surges can have large implications for tourism, especially for the islands on which the economy depends.

4. Ecosystem-based Approaches for Adaptation

Conserving the capacity of ecosystems to generate essential services for climate change adaptation of social-ecological systems requires ecosystems to be managed as components of a larger seascape-landscape of which human activities are part. This section will introduce the concept of ecosystem-based adaptation and discuss a no-regret example of this approach in the context of Tanzania.

4.1 The Dynamic Ecosystem-based Adaptation Pathways Framework

The Ecosystem-based Adaptation (EbA) approach relates to the management of ecosystems within interlinked social-ecological systems to enhance ecosystem processes and services that are essential for adaptation to multiple stressors, including climate change (CBD 2009, Chapin et al. 2009, Piran et al. 2009). In other words, EbA integrates the management of ecosystems and biodiversity into an overall strategy to help people and ecosystems adapt to the adverse impacts of global change, such as changing climatic conditions (Colls et al. 2009).

This approach depends highly on healthy and resilient ecosystems, which are able to deliver a bundle of ecosystem services to support adaptation and well-being of societies in the face of various pressures. These pressures can be internal to the social-ecological system, or external, such as climate variability in the short term or climate change in the longer term (Piran et al. 2009). At the core of this approach lays the recognition of existing interactions and feedbacks between human and ecological systems and the need to understand these to enhance benefit flows from the system (UNEP-WCMC 2010). EbA has the potential to generate multiple environmental and societal benefits, while reconciling short and long-term priorities (TEEB 2009). For instance, EbA can be a synergistic approach that reconciles mitigation objectives by enhancing carbon stocks, with cost-effective management of climatic risks, and conservation objectives by preserving natural ecosystems and biodiversity (TEEB 2009).

Enhancing the capacity of ecosystems to generate essential services for climate change adaptation requires that they be managed as components of a larger landscape of which human activities are part. The Dynamic EbA Pathways Framework is a conceptual framework based on an adaptive ecosystem management approach to enhance and maintain ecological processes and ecosystem services at the landscape level. It combines multi-functional land uses
and conservation of natural capital\(^3\) to enhance multi-scale benefits from ecosystems that help social-ecological systems adapt to changing and multiple stressors, including climate change. It is based on the recognition that the ability of ecosystems to adapt naturally can be affected by the quality, quantity and nature of changes in the landscape, and that beyond certain thresholds natural ecosystems may be unable to adapt at all, hence active human intervention for planned adaptation is necessary. To facilitate the adjustment of human societies and ecological systems to changing conditions and multiple stressors, the Dynamic EbA Pathways Framework combines EbA strategies (active core, in blue), with flexible enabling mechanisms and adaptive processes (supportive milieu, in green) (see Figure 4).

![Dynamic EbA Pathways Framework](image)

Figure 4. Principles of adaptation and concept of ecosystem services brought together under the Dynamic EbA Pathways Framework.

Following this approach, a number of potential ecosystem-based adaptation strategies are available, which include:

- To maintain and increase ecosystem resilience: enhancing the ability of ecosystems to absorb and recover from change while maintaining and increasing biodiversity.
- To accommodate the potential impacts of climate change: considering both gradual change and extreme events.
- To facilitate knowledge transfer and action between partners, sectors and countries: successful adaptation requires ecosystem and biodiversity conservation to be integrated with other sectoral management activities.

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\(^3\) ‘Natural capital’ refers to the components of nature that can be linked directly or indirectly with human well-being. In addition to traditional natural resources, it also includes biodiversity and ecosystems that provide goods and services (TEEB 2009).
To develop the knowledge/evidence base and plan strategically: to effectively plan for an uncertain future, the best available evidence is needed to help social-ecological systems adapt.

To use adaptive management: to deal with uncertainty using a flexible approach for effective conservation and adaptation planning, based on iterative processes of learning by doing, reviewing, and refining.

To enhance vulnerability assessments and monitoring systems: to allow evidence to be collated, existing schemes to be strengthened and new requirements incorporated.

Moreover, there is a range of potential ecosystem-based adaptation measures that relate to the management of ecosystems to address existing and future climate risks. They include:

- Reducing and managing existing stresses, such as fragmentation, pollution, over harvesting, population encroachment, habitat conversion and invasive species.
- Maintaining ecosystem structure and function as a means to ensure healthy and genetically diverse populations able to adapt to climate change.
- Increasing the size and/or number of reserves.
- Increasing habitat heterogeneity within reserves and between reserves by including gradients of latitude, altitude and soil moisture and by including different successional states.
- Building in buffer zones to existing reserves.
- Increasing connectivity, for example with the use of biological corridors or stepping stones to link areas, removal barriers for dispersal, linking of reserves and refugia.
- Increasing landscape permeability through introduction and/or expansion of sustainable management practices and increasing area for biodiversity dispersal e.g. through agro-ecological schemes.
- Increasing and maintaining monitoring programs to study response of species to climate change (i.e. physiological, behavioral, demographic) and socio-ecological dynamics.
- Integrating climate change into land-use planning and programmes.
- Assessing, modelling, and experimenting at different spatial scales for improved predictive capacity and simulation outcomes.
- Improving inter-agency, regional coordination.
- Conducting restoration and rehabilitation of habitats and ecosystems with high adaptation value.
- Development of novel ecosystems that are more resilient.
- Translocation or reintroduction of species at risk of extinction to new areas that are climatically suitable for their existence.
- Ex situ conservation e.g. seed banks, zoos, botanic gardens, captive breeding for release into wild.

These EbA measures can be implemented through a series of mechanisms that have the potential enhance ecosystem services, including:

- Regulation: robust regulatory frameworks and enforcement mechanisms, including standards, codes, compliance and liability regimes, that can help reduce threats to biodiversity and ecosystems, while enhancing ecological services for climate adaptation.
- Economic instruments: that can influence or incentivize markets, practitioners, and society to adopt them. The pool of economic instruments includes mechanisms such as innovative tax and fiscal policies, performance standards,
verification systems, compensation, subsidies, intergovernmental fiscal transfers, government spending, debt-for-nature swaps, among others.

- Integration: integration of policies and mainstreaming of ecosystem management into the planning process would need to adopt a multi-scale (i.e. national, regional, local) and cross-sectoral approach. Integrating policies would increase the cost-effectiveness of investment aimed at enhancing the flow of ecological services with co-benefits that would support multiple objectives shared across different stakeholder groups.

- Market-based mechanisms: create incentives and reward efforts for maintaining or enhancing multiple ecological services. These mechanisms are highly flexible and can be established and used by different actors and at different scales.

- Green Investment: finance flows targeting green investment are growing. Green investment can enhance ecological functions and services supporting initiatives such as bio-commerce (e.g. organic production, fair trade, eco-tourism); certification and labeling schemes (e.g. ecologically certified production, sustainable management of forests, see Box 23); corporate social responsibility (e.g. private and public businesses monitoring compliance with ethical standards and international norms); green public procurement (e.g. contracting entities that take environmental issues into account when tendering for goods or services); among others.

To deal with uncertainty, these mechanisms will support the implementation of EbA measures and strategies through adaptive processes that include:

- Building research capacity and supporting knowledge sharing: orchestrating a number of processes that help to improve multi-disciplinary research capacity, to monitor relationships and feedbacks, to generate and share new information and knowledge, and to integrate new understandings into practices.

- Promoting technology and innovation: technology innovation, commercialization and transfer have the potential to support adaptation processes, while at the same time capturing economic value ‘at home’ through entrepreneurship, job creation and new venture development. Technology deployment and transfer do not only depend on technological means and financial investment, but also on the decision context, systems of thought, belief and knowledge that will determine the capacity of a society to innovate and adopt this approach to find solutions or support decisions for adaptation.

- Applying adaptive governance: this involves an iterative process that facilitates flexibly adjusting decisions, plans and actions to the changing environmental and social contexts, considering the complex dynamics between ecosystems and interactions of social-ecological systems. A robust way of starting the learning process under this approach in the context of EbA is to build on ‘no-regret’ actions that would lead to multiple benefits in ecological, social, and economic terms under different possible futures. Adaptive governance for EbA would require closer links and collaboration between actors and organizations at different governance levels, integration of policies, better coordination of sectoral plans, and assimilation of the ecosystem-based approach into planning processes.

- Supporting socio-institutional change: governance and planning of EbA pathways across multiple governance levels will trigger social and institutional reorganization, particularly in face of rapid change. In this context, bridging organizations will evolve to bring together a range of actors and formal and informal institutions with a diversity of knowledge. Such organizations will stimulate the development of interactive spaces where actors and social networks will coalesce around common interests and share and produce collective ideas and knowledge that will enhance the process of social learning. Better
understanding and new configurations of EbA pathways stemming from this process and through the implementation, evaluation and adjusting of EbA strategies will lead to the development of new institutions and/or organizational change within existing institutional arrangements and social networks.

Given the high uncertainty involved in long-term planning, the Dynamic EbA Pathways Framework uses a step-based approach to explore the range of potential EbA pathways that can be adopted over time. This approach recognizes that not all adaptation decisions are needed now and enables socio-institutional learning, adaptive management, and better understanding over time. By doing so, it deals with the uncertainty inherent to possible futures, overlaps between EbA pathways, synergistic and antagonistic cross-sectoral interactions of adaptation actions, and multiple stressors affecting the social-ecological systems. The steps considered in this approach are divided into four categories (i.e. no regrets, building institutional capacity, pilot actions, ecosystem-based transformation) that have been used to plot in a coloured matrix a range of potential EbA pathways (see Figure 5). The green bottom left area relates to early priorities, no-regret options and capacity building. The mid yellow area corresponds to pilot actions that need testing and refining before up-scaling and full sectoral implementation. The move towards the right red area represents more integrated and extreme responses to possible climate risks, thresholds, and tipping-points. This area will demand transformation in the management of ecosystems and in the social-ecological systems themselves. The matrix also comprises the flexible mechanisms that can be used to implement the measures and strategies that combined make up the EbA pathways.

![Illustrative matrix of ecosystem-based adaptation pathways following a step-based approach](image)

Figure 5. Illustrative matrix of ecosystem-based adaptation pathways following a step-based approach. Note: R=Regulation; PES=Payment for ecosystem services; PI=Integration into planning processes; EI=Economic Instruments; KS=Knowledge Sharing; GI=Green Investment. The matrix is based on the concept of ‘adaptation signatures’ used in adaptation cost studies conducted in Kenya, Rwanda and Burundi.
The step-based approach adopted by the Dynamic EbA Pathways Framework is closely linked to an economic rationale for action, whereas no-regret options (in green) can generate benefits at lesser costs than investing in pilot actions (in yellow) and pro-active multi-scale processes necessary to adapt to and transform with potential future thresholds and tipping-points (in red). The need to move towards a resource efficient economy, and the role of ecosystems and biodiversity in this transition are still to be explored and better understood. The Dynamic EbA Pathways Framework provides a window for this exploration with the flexibility to develop and accommodate strategies tailored to specific contexts and interests that account for social-ecological interactions across spatial and temporal scales.

4.2 Costs of Ecosystem-based Adaptation

Ecosystem-based adaptation costs relate to expenditure associated with actions taken to enhance ecosystem services that can help avoid or minimize the negative impacts of climate change on both ecosystems and human societies. It is based on the premise that autonomous adaptation of ecosystems and species will not be sufficient to withstand future impacts of climate change and therefore human planned actions are indispensable to maintain or enhance the ecological processes and ecosystem services necessary for climate change adaptation of social-ecological systems.

Estimating the costs of EbA is complicated due to several reasons. The first one relates to the uncertainty associated with the direct and indirect costs of climate change impacts (e.g. direct costs of increased natural disasters, indirect costs for development, as climate impacts can become obstacles in the achievement of the MDGs and other development processes). Without knowing with certainty the expected damage, it is difficult to calculate the level that could be avoided by adaptation. Most impacts are projected to increase non-linearly with climate change, and adaptation costs to increase correspondingly (Parry et al. 2009). In this context, it is helpful to analyze costs of adapting to varying amounts of impact, thus providing a choice range for preparedness to pay and the residual impact that adaptation is not likely prevent, indicating residual damage costs that need to be anticipated (ibid). Estimating costs of actions that can facilitate adaptation considering multiple possible futures needs to recognize: 1) synergies with mitigation; 2) the limits to adaptation (e.g. impacts that cannot be avoided even if unlimited funding is available due to, for example, lack of technology); and 3) the boundaries of willingness to pay for adaptation (e.g. priority actions that are economically feasible, budget constraints, national and global visions).

A second challenge that complicates the assessment of EbA costs is valuing “soft” measures (Parry et al. 2009). While it is easier to estimate the costs of measures like infrastructure to avoid soil erosion in water catchment areas, it is more difficult to assess behavioral change and organizational capacity that lead to a decrease of deforestation and introduction of more sustainable production practices. EbA combines both measures, but relies heavily on “soft” adaptation measures through flexible mechanisms.

A third challenge is that EbA largely depends on the adaptive capacity of social-ecological systems, which is based on interactions and feedbacks between social and biophysical systems that are not well understood yet. Nor are thresholds and tipping-points that could transform the state of these systems and the nature of interactions.
A fourth challenge is the poor understanding of the full economic value of ecosystem services. Benefits from EbA are based on services provided by ecosystems for climate change adaptation. Although economic valuation methods for specific ecosystem services exist, efforts to value multiple services of ecosystems for a range of users at different scales are still in their infancy, and work to integrate these results into economic assessments for planning at the landscape-level is only starting.

A fifth challenge, and probably one of the most important ones, is the close interaction between ecosystems and other sectors. It is probably easier to cost adaptation actions that focus on preserving the existence of particular ecosystems and species (e.g. setting or expanding the network of protected areas) than actions that enhance ecosystem services at the landscape-level to facilitate climate adaptation (e.g. increasing permeability of the wider landscape matrix encompassing multi-functional land-uses). The latter is more complicated because it can incur in double counting, as land-use changes or different sectoral adaptation strategies can interact synergistically or antagonistically affecting ecosystem processes that enable or prevent ecosystem services (Berry 2007, Parry et al. 2009). This interaction can reduce or add to the costs of EbA.

Recognizing the above complexities is important when costing ecosystem-based adaptation. Their acknowledgment leads to more robust decisions that can be improved through iterative processes of learning and refinement over time. Under this approach, it is also important to account for current financial deficits, sensitivities and differentiated vulnerabilities of social and ecological systems, which need to be addressed as the first step to build adaptive capacity.

4.3 Case study: No-regret EbA Measure for Zanzibar and other Coastal Areas in Tanzania

Unguja Island is the largest island of the Zanzibar archipelago, located 40 km from the Tanzanian mainland. The coastal platform in Zanzibar stretches from the coral reef landward to a cliff or beach ridge plain 2-3 meters above the mean water level. The stability of the beach ridge plain is influenced by patterns of beach erosion and sedimentation that depend on the East African Coastal Current. Although losses of beach sediment are subject to temporal variation, presently it appears to be exacerbated by coastal storms and anthropogenic alterations to the shoreline (Arthurton et al. 1999).

Coastal communities living on the island depend on multiple livelihood strategies that are closely linked to services provided by the coastal ecosystems, such as fishing, subsistence farming, seaweed farming, tree planting, coconut farming, firewood and building pole collection. Tourism-related livelihoods have also developed in recent years (Mustelin 2007). Nevertheless, the employment opportunities for locals expected from international tourism have not materialised partly due to low levels of education, low investments in tourism education, and lack of knowledge of foreign languages and tourism-related skills among the local communities (Mustelin 2007).

Activities that have direct impact on the Zanzibar shoreline relate mainly to uncontrolled growth of the tourism industry, which has caused demand for coastal land and lead to disputes for land rights, ownership and sales among the tourism industry, government institutions and local communities (Mustelin 2007). Removal of beach sand for construction, obstruction of natural water and sediment flow, destruction of protection against wave activity, as well as development of hotels and villages too close to the beach have all contributed to erosion along the Zanzibar
shoreline (Nyandwi 2001). In addition, land scarcity has aggravated trends of deforestation in Unguja, compounded by increasing demand for firewood. There is also an increasing pressure on water resources due to growing demand (Gossling 2001).

Zanzibar is likely to experience climate change impacts similar to those of the small island states (Paavola 2006). Some of the projected impacts suggest increases in rainfall on the Tanzanian coast, which indicates more severe flooding on coastal areas and the possibility of more frequent storm surges (Paavola 2003). In general, the activities described above have fractioned the natural system in the island leaving both the communities and the environment highly vulnerable to future stressors such as climate change (Mustellin 2007). The Tanzanian NAPA (2006) recognizes the current vulnerability of coastal communities and the need to develop adaptation strategies for the coastal areas.

A recent study conducted by Mustelin et al. (2010) identified a number of adaptation measures for Unguja Island using semi-structured interviews with local community members and questionnaire interviews with hotel managers and staff. The array of proposed measures reflect the adaptive capacity of the local communities, as they are perceived as possible and effective. Four out of the six mostly cited measures relate to ecosystem-based adaptation options linked to “soft” adaptation measures, involving: vegetation planting/restoration (trees, shrubs and creepers), prohibiting sand mining (hotels extracting beach sand), awareness raising (harmful effects of tree cutting), and cooperation (working on environmental issues with hotels). About 80% of all the informants propose planting/restoring vegetation as the most important adaptation measure. The other two mostly cited options relate rather to “hard” adaptation measures and are not directly linked to ecosystem-based approaches. The options include seawalls building (physical structures) and debris deposition (placing litter on the beach).

The option of restoring the natural coastal vegetation to enhance coastal forest buffer zones in chosen locations along the coast can be considered a no-regret ecosystem-based adaptation measure because it would produce multiple benefits even in the absence of climate change impacts. First, it would function as shoreline protective barrier, for instance, against tsunami waves. Second, it would help prevent excessive erosion by stabilizing beach sand and absorbing wave energy (Turker et al. 2006, Forbes and Broadhead 2007). Third, it would help maintain the ecosystem services to support local livelihoods and essential goods such as firewood, building poles and sawn timber, herbal medicines, edible fruits, mushrooms, plant-derived oils, leaves and beverages, fodder, fibre, honey, ornamental plants, household utensils and handicrafts.

In addition, it is important to consider that the local population suggested restoring the coastal vegetation as an adaptation option. This means that this option is the manifestation of local perceptions on multiple stressors that consider the existing societal, political, environmental and economic contexts, which will largely determine its adoption and implementation by the local population. In this regard, this option is context-specific and carries different values as local communities see in it a way to protect their livelihoods, while the tourism industry would benefit from maintaining an aesthetically pleasing landscape (Mustelin et al. 2010). This measure also goes in line with national policies such as the Forest Policies of 1995 and 1998 that encourage participatory forest management and set up an institutional framework for forest management in Tanzania, the National Integrated Coastal Environment Management Strategy and the Development Vision 2025 to reduce the widespread poverty in the Tanzanian society (Mustelin et al. 2009).
Although costs for enhancing coastal forest buffer zones have not been estimated, no-regret benefits are clear and could be increased if this approach would be extended to the coastal forest area in Tanzania. Currently, this area covers about 70,000 ha of scattered remnants left of the original forests (Dallu 2004). As coastal forests are usually rich in endemic tree species, this strategy would not only have benefits for climate adaptation and social development (as highlighted above), but would also benefit biodiversity conservation. It could also be explored in terms of reduced emissions from deforestation and degradation (REDD+) through coordinated partnerships between government, non-government and community-based agencies (Burgess et al. 2010). First steps to implement a national adaptation strategy based on this approach would involve: 1) harmonization of institutional conflicts especially in respect to revenue collection/benefit sharing; 2) harmonization of legal issues so as decisions that are made on forests or forest land should not be conflicting; 3) work on energy policies to promote alternative sources at affordable prices so as to reduce dependence and pressure on biomass; 4) capacity building to develop coastal forest management plans; 5) development of criteria, indicators and mechanisms for managing and monitoring forest resources in coastal forest buffer zones using a participatory approach.

5. Future Research Needs

Ecosystem-based Adaptation is gaining interest among different communities of practice because it can bring multiple benefits and be a synergistic approach that reconciles different objectives. Over time and through practice, these communities (e.g. conservation, disaster management, adaptation, development, and resilience communities) have generated important knowledge relevant to EbA. However, this knowledge is incomplete and fragmented across disciplines. Although current information and knowledge is useful, it is insufficient to simulate possible EbA outcomes and costs. More research and actions are needed to understand better the unknowns that are source of uncertainty in EbA decision-making, planning, and costing. Some of the steps required to fill in the gaps and push the knowledge boundaries for effective EbA involve:

1) Understanding better the value of multiple ecosystem services for human well-being and the benefits of EbA in economic, environmental, and social terms:

- Developing approaches and methods to assess in quantitative and qualitative terms the use and non-use value of ecosystem services, particularly when considering ecosystem configurations that deliver multiple services to different users. This process needs to consider that the value of ecosystem services varies according to scale of use and over time.

- Developing approaches and methods to measure trade-offs and synergies that account for interactions among ecosystems and between biophysical and human systems at different temporal and spatial scales.

2) Understanding how EbA strategies can be facilitated through different mechanisms and processes allowing for effective EbA pathways at the landscape level:

- Verifying evidence on the positive relationship between incremental change in ecosystem services and adaptation of social-ecological
systems through monitoring systems, assessment of effectiveness, and pilot actions. This will help developing reference systems and evidence-base knowledge.

- Strengthening knowledge sharing systems and social networks that enhance collaboration, dissemination and integration of useful information, tools, and methods, and co-generation of new knowledge.

- Exploring innovative approaches and technologies that support decision-making processes and help up scaling successful pilot actions.

3) Learning and generating knowledge on how to effectively enhance ecosystem functions and services for adaptation of socio-ecological systems:

- Researching the role of biodiversity and the effects of species extinctions in the maintenance of ecosystem services and how this is critical for ecosystems functioning, and thus for adaptation. Improve representation of species function for migration within current Dynamic Global Vegetation Models (DGVMs).

- Improving the integration of climate models with different biophysical and socio-economic/land-use models to project responses of species and/or ecosystems to climate change across heterogeneous landscapes (including feedbacks such as CO₂ fertilization effects). This helps simulating possible macro-level outcomes resulting from a compound of multiple drivers.

- Developing approaches and methods to assess and simulate complex interactions between social and ecological systems across space and time. This helps understanding better strategies that address current vulnerability and pro-active multi-scale processes necessary to build resilience to potential future thresholds and tipping-points.

- Improving models that account for non-linear relationships with complex feedbacks across spatial extents and time horizons. Simulating non-linear systems can help understanding unexpected behaviors at macro-levels based on micro-level dynamics. Simulating non-linear interactions of social and ecological systems can help exploring possible EbA outcomes at the landscape level. This can also help predicting possible thresholds and tipping-points and exploring factors that control abrupt changes and threshold probabilities.

The needs listed above require collaborative research and action supported by innovative approaches. Progress in addressing these needs will enrich ongoing policy-science dialogues and decisions for future adaptation to global changes.
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