The Influence of Ecosystems Services Depletion to Climate Change Adaptation Efforts in Africa

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Abstract

Climate change is one of the major challenges societies round the world face at present. Apart from efforts to achieve a reduction of emissions of greenhouse gases so as to mitigate the problem, there is a perceived need for adaptation initiatives urgently. Ecosystems are known to play an important role in climate change adaptation processes, since some of the services they provide, may reduce the impacts of extreme events and disturbance, such as wildfires, floods, and droughts. This role is especially important in regions vulnerable to climate change such as the African continent, whose adaptation capacity is limited by many geographic and socio-economic constraints. In Africa, interventions aimed at enhancing ecosystem services may play a key role in supporting climate change adaptation efforts. In order to shed some light on this aspect, this paper reviews the role of ecosystems services and investigates how they are being influenced by climate change in Africa. It contains a set of case studies from a sample of African countries, which serve the purpose to demonstrate the damages incurred, and how such damages disrupt ecosystem services. Based on the data gathered, some measures which may assist in fostering the cause of ecosystems services are listed, so as to cater for a better protection of some of the endangered Africa ecosystems, and the services they provide.

Key-words: Africa, ecosystem services, climate change, adaptation, best practices.

1 Introduction

Climate change is one of the major challenges societies round the world face at present. Apart from efforts to achieve a reduction of emissions of greenhouse gases so as to mitigate the problem, there is a perceived need for adaptation initiatives. Ecosystems are known to play an important role in climate change adaptation processes, since some of the services provide, may reduce the impacts of extreme events and disturbance, such as wildfires, floods, and droughts. Ecosystem Services (ESs) have the potential to reduce vulnerability to climate change and enhance adaptation capacity (Pettinotti et al., 2018; Von Möllendorff and Hirschfeld, 2016; Hannah, 2015; Munang et al., 2013). Ecosystem-based adaptation (EbA), leverages nature's inherent capacity to protect communities from the severe effects of climate change. Capitalizing on ecosystems adaptation can increase the efficiency and effectiveness of adaptation strategies while promoting the resilience of social-ecological systems (Jones et al., 2012; Scarano, 2017, Pettinotti et al. 2018, Fedele, 2019). Productive EbA boosts biodiversity and thus ecosystem services which in turn eases adaptation to climate change impacts (CBD, 2009; Chong 2014; Zölch et al., 2018). It entails proper management of ESs to reduce the role of humans in altering ecosystems. Properly managed ecosystems can increase the guarantee of human safety from common natural hazards (Munang et al., 2013). For instance, ecosystems can be harnessed to minimise severe climatic impacts such as the rise of sea levels in coastal areas (Hannah, 2015). Generally, healthy ecosystems function as barriers to natural hazards thereby enhancing the resilience of socio-economic systems to climate change shocks (Abramovitz et al., 2002; Morecroft et al., 2012). Considering that ecosystem services also significantly support human well-being, it is imperative to preserve and enhance their integrity, by adopting appropriate management practices. In addition to protecting societies from disasters- bearing in mind that some are not strictly connected with climate change-, healthy ecosystems also improve societies' capacity to adjust to the impacts of such disasters and cope better (Sudmeier-Rieux et al., 2006; Gupta et al. 2017).

The wise use of ecosystems services in a climate change context focuses on utilizing various conservation strategies to safeguard these ecosystems -and the biodiversity they host- from climate change. This process also entails approaches aimed at the prevention of the occurrence of destructive factors like fire, coral bleaching, deforestation (Ojea et al., 2016; Hannah, 2015), and depletion of coral reefs, among others. The process of protection of ecosystems services is also helpful in the sense that it prevents the deterioration of coastal and marine ecosystems (Liu and Stern, 2008), wetlands (Chaikumbung et al., 2016), mangroves (Brander et al., 2012), and peatlands (Pettinotti et al., 2018), among others. The safeguarding of such services has been documented as an effective strategy for climate change adaptation and to foster climate change resilience (Uy and Shaw, 2012, Leal Filho 2020).

For instance, mangroves' reforestation enhances coastal resilience by providing strong protection to shorelines, and flood plain management is a proven solution to flooding. Wind-sheltering and windbreaks to enhance the resilience of rangelands. Differentiating planting dates and crop types have a positive contribution to adaption in the agricultural sector (Munang et al., 2013). Tree planting forestalls erosion by enhancing soil stability. Mountain meadows, bushes, and forests serve as buffers from landslides and flash floods. Coral reefs serve as offshore breakwaters that minimize the effects of sea surges as well as storm waves on the shoreline (UNFCCC, 2008).

Multi-sectoral ecosystems services may also help to indirectly mitigate the effects of other phenomena such as landslides, floods, and erosion. Health ecosystems may also contribute to fight water and air pollution, to control diseases and pests, and to promote carbon sink (Nalau et al., 2018; Munang et al., 2013). A green environment created by a mix of trees, shrubs grass etc. helps decrease the negative impacts of the Urban Heat Island effect (UHI) (Chiabai et al., 2018). Collectively, the regulating services offered by ecosystems significantly influence climate change adaptation by reducing vulnerability and increasing overall resilience to extreme events. Similarly, ecosystems provide people with basic necessities such as food and water which increase their adaptive capacity (Uy and Shaw, 2012). The gradual depletion of ecosystem services seriously deprive people of their livelihoods. Low-income levels, high rate of unemployment, and poverty are chronic stresses which negatively impact adaptation capacity in various regions, especially in Africa (Leal Filho et al., 2018).

The socio-economic, environmental, and cultural benefits emanating from ecosystems services conservation is a key component of sustainable adaptation. This is validated by the increasing body of evidence that highlights the crucial role of ecosystem services in building communities' resilience. The growing call for safeguarding ecosystems services, and mainstreaming this approach as part of climate change adaptation policies and implementation, illustrate the huge benefits and vast potentials offered (Uy and Shaw, 2012), which are often flexible, cost-effective, and have proven effective (Jones et al., 2012). This is also so in the context of urban planning through enhancing biodiversity and increasing recreation avenues (Doswald et al., 2014; Wamsler et al., 2014; Zölch et al., 2018), also harmonizing diverse interests of several stakeholders (Wamsler, 2017) and contributing to human security (Bourne et al., 2016).

Against this background, this paper reviews the role of ecosystems services and investigates how they are being influenced by climate change in Africa. It contains a set of case studies from a sample of African countries, which serve the purpose to demonstrate the damages incurred, and how such damages disrupt ecosystem services.

2 The importance of ecosystems services in an African context

Historically, ecosystem services had often been associated with tropical forests, freshwater, lakes, rivers, soil, minerals, and biodiversity (Holland et al., 2012; Green et al., 2013; MEA, 2014). Ecosystem services have been the bastion to livelihoods of most rural and urban communities in Africa. According to the IPBES (2018), more than 62% of the rural population depends directly on these services, while the urban and peri-urban population supplement their incomes, as well as their energy, medicine, and other essentials, from ecosystem-based resources. Ecosystem services also significantly contributed to the macroeconomy of many African countries (MEA, 2014; Ryan et al., 2016; IPBES, 2018). The tourism sector is a major contributor to the national economies of East Africa (Kenya, Uganda, Ethiopia, Rwanda, Democratic Republic of Congo, and Tanzania) with annual average revenue of over USD 7 billion (World Bank, 2015).

Additionally, ecosystems have substantial spiritual value in traditional African belief systems. Such belief systems have ecological roots or foundations (Schoffeleers, 1979; MEA, 2014; IPBES, 2018). Also, these services function as gravesites and the dwelling places of powerful ancestral spirits (Byers et al., 2001). Moreover, they are used as places to communicate with the ancestors and for the annual rain-making ceremony (Wilson, 1989; Ryan et al., 2016). The medicinal plants, generally classified as a provisioning service, also have a strong cultural component, mainly for health problems (Ryan et al., 2016).

In Zambia, Mali, and Tanzania ecosystem services functioned as important assets to reduce vulnerability during extreme climatic events (droughts and floods) (Robledo et al., 2012). Additionally, the services provided by mangrove forests of the East Africa coast have been extremely important in containing coastal erosion, reducing the intensity and frequency of extreme climatic winds caused by tropical cyclones along the Indian Ocean coast (Ghermandi et al., 2019).

The post-extreme event restoration of degraded areas in South Africa has carried out through ecosystem-based adaptation which revived coastal and marine plant species (Mugwedi et al., 2018). According to Ghermandi et al., (2019), coral reefs significantly prevented coastal erosion in Comoros, Madagascar, Mayotte, Mozambique, Seychelles, and Tanzania with 100%, 55%, 98%, 16 %, 98%, 63% respectively. Services provided by seagrass were responsible for 99% of the carbon sequestration in Comoros and Mayotte. Likewise, mangroves contributed for to about 100% and 77% carbon sequestration in Seychelles and Tanzania respectively. Finally, salt marshes were crucial for 75% carbon sequestration in Mozambique (Ghermandi et al., 2019).

Besides, mangroves, sea grass, salt marshes, the woodlands play a crucial role in southern Africa (Ryan et al., 2016). Besides sinking a large amount of carbon, the ecosystem service contributed to biogeochemical regulation in the context or after extreme climatic events in southern Africa (Ryan et al., 2016). Additionally, woodlands considerably reduce erosion effects soil after climatic events by keeping the relatively nutrient and organic-rich surface soil in place (Mkanda, 2002; Ryan et al., 2016). The water storage and regulation of the hydrological cycle are attributable to the ecosystem service of woodlands in Southern Africa (Bruijnzeel, 2004; Lopa et al., 2012; Ryan et al., 2016).

3 Methodology: case studies on ecosystems services in Africa

This work used three different methods. It initially consisted of an analysis of the literature, aimed at identifying some key scientific works, which focused on ecosystem services in Africa. Secondly, we deployed a set of case studies, which illustrate some of the pressures that ecosystems are facing. These include:

a) Rangelands (Ethiopia, Kenya)
b) Mangroves (Benin, Mozambique)
c) Forests (Nigeria, Zambia)

To systematize data collection, a matrix was developed and used. The data was obtained by the authors' teams of experts, all of whom live or have worked in the corresponding areas, hence having first-hand information and experience with the sites. The case studies provided by the experts were chosen based on the fact that there is sufficient evidence and literature which supports them. They are also relevant since they provide examples from various African regions. Thirdly and finally, we used the *Driving Force – Pressure – State – Impact – Effect - Response (DPSIER)* (Gabrielsen and Bosch, 2003; Waheed et. al, 2009) model to: identify different pressures caused by human activities on ecosystem services, providing elements that predict the evolution of the problem concerning climate change and response actions carried out by the society, institutions, and governments to reduce or mitigate environmental degradation and expand capacity to adapt to climate change. The results obtained are described and discussed in the next section.

4 Results and Discussion

One of the first findings which characterize the case studies, is that the investigated ecosystems (i.e. rangelands, mangroves and forests) in the sampled countries (Figure 1). suffer from the interaction of multiple stressors, occurring at various levels such as endemic poverty, complex governance, and limited access to capital, including infrastructure and technology; ecosystem degradation; and complex conflicts (Boko et al., 2007). The countries studied already face serious environmental damages, which undermine ecosystem services and lead to land degradation, deforestation, and loss of biodiversity, among others. Such factors worsen vulnerability to climate change in the three ecosystems studied.

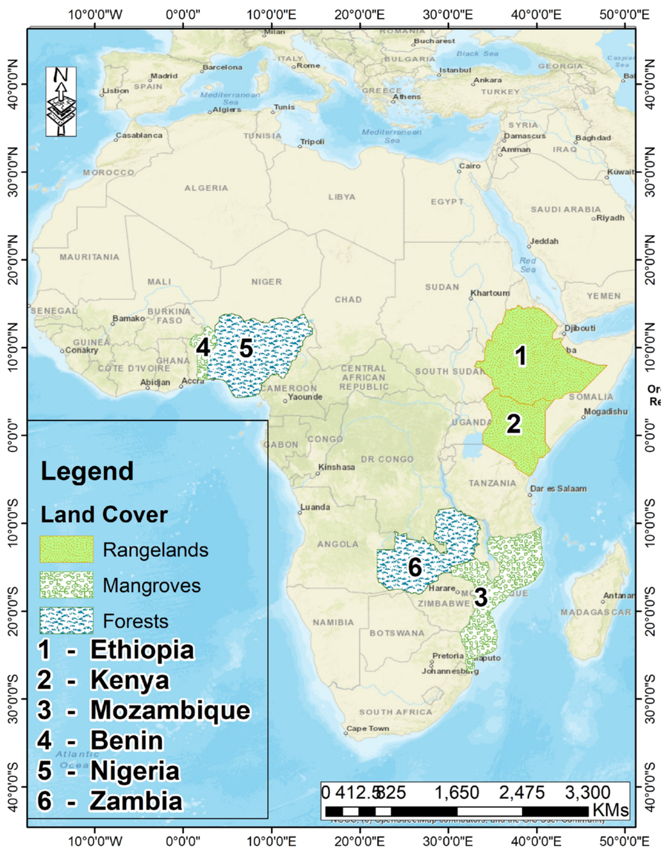


Figure 1. Case studies sites and ecosystems

Ecosystem services have on the one hand the potential to reduce vulnerability to climate change and to recover more easily from extreme weather events (Colls et al., 2009), but there are limits as to which what they can perform. The following case studies present an overview of the current situation.

4.1. Impacts of rangelands degradation on ecosystem services in Ethiopia and Kenya

Rangelands are defined as the land on which the potential native vegetation is predominately grasses, grass-like plants, forbs or shrubs. Rangelands produce a great variety of ecosystem services, including the provision of food and fiber, maintenance of biodiversity (conservation), regulating (carbon sequestration), and cultural services (Yahdjian et al., 2015).

However, rangelands are threatened ecosystems and are often undervalued as providers of ecosystem services. Table 1 lists climate-related pressures and impacts on rangelands in Ethiopia and Kenya, which were identified as part of the study.

Table 1. Rangelands in Ethiopia and Kenya

Ecosystem-service provided	Climate-related pressures	Impacts	References
Food (crop, livestock)	Temperature increase, increase in extreme events including droughts and floods, changes in the spatial and temporal variability in rainfall	Increased evapotranspiration and reduced soil moisture, soil degradation, invasive bush encroachment, reduction of crop yield, livestock sickness, and death, reduction in market value, increased food insecurity, increased resource-based conflicts	Shiferaw et al., 2018; Belay et al., 2018; Briske, 2017; Mussa et al., 2016; Lemma, 2011; Opiyo et al., 2015; RCRMD, 2016; Sala et al., 2017; Worden et al., 2009
Pastures	Drought, flood, reduction rainfall amount	Invasive bush encroachment, soil erosion, water depletion, and pollution, siltation of water points, reduction of the load capacity of rangeland, the decline in pasture availability and palatability, reduction of livestock production and productivity, reduce biodiversity, migration of wildlife, the proliferation of climate change sensitive livestock diseases, resource-based conflict, food insecurity	Assefa et al., 1986; Abule, 2009; Fenetahun et al., 2018; Mussa et al., 2016; Kassahun et al., 2008
Biodiversity	Drought, flood	Water pollution, siltation of water points, reduced biomass, the proliferation of climate change sensitive zoonotic diseases, soil erosion, reduced rangeland carrying capacity, the decline in graze availability, woody vegetation the encroachment, water scarcity, encroachment of migratory routes	Opiyo et al., 2015; Worden et al., 2009
Water	Increased extreme events, marked rainfall and, temperature variability, predicted temperature rise	Food insecurity, agrarian-pastoral communities' conflict, increased poverty, the proliferation of diseases	Kiggundu, 2002; Kubbinga, 2012; Malesu et al., 2006; Ngigi, 2003

In Ethiopia, the rangeland covers about 65% of the landmass (Bolo et al., 2019), supports more than two million people, contributes 19% of national DGP, and provides 80% of total annual milk production (Nyariki, 2017; Nyariki and Amwata, 2019). In Kenya, the rangeland covers over 70% of the country. It contributes to the country's GDP through livestock production and the tourism (RCRMD, 2016).

However, both countries' rangeland services are affected by recurrent drought and non-climate stressors. These include human and livestock pressure, overgrazing, erosion of customary resource management, deforestation, bush encroachment, and poor land use policy, a trend which is consistent with what has been documented by the literature (e.g. Fenetahun et al., 2018; Belay et al., 2018; Briske, 2017; Cerretelli et al., 2017; Abdu and Robinson, 2017; Mussa et al., 2016; Hicks et al., 2015; Worden et al., 2009).

Rangelands degradation is associated with a decline of the carrying capacity of these ecosystems, a decline of pasture availability and palatability, and high rate of soil erosion. Rangelands degradation also triggers the migration of wildlife and is known to be associated with resource-based conflicts, which have increased over the past decades (Bolo et al., 2019). For instance, the Borana rangeland is affected by bush encroachment which claimed 40% of the rangeland in the 1980s (Assefa et al., 1986). This increased to 63% in the 2000s (Abule, 2009). The cumulative effect of rangeland degradation altered the natural ecosystem service thereby worsening poverty and food insecurity especially in the lowlands of Ethiopia (Fenetahun et al., 2018; Mussa et al., 2016; Kassahun et al., 2008).

In Kenya, poverty is exacerbated by the harsh environment, poor infrastructure, and low access to basic services. Pastoralism is the predominant source of livelihood accounting for agropastoral and fisherfolks in the rural and peri-urban areas. Pastoralist households largely bear the brunt of negative impacts of extreme climate events like drought, which include increased poverty, water scarcity, resource-based conflicts, disease outbreaks, and food insecurity (Opiyo et al., 2014).

The loss of key ecosystem services undermines the ability of the biophysical environment to sustain human livelihoods, hence the need for adaptation efforts. Key areas for adaptation include the livestock sector, water provision and access, biodiversity conservation, and carbon sequestration (Sala et al., 2017).

Challenges to adaptation occur due to several socio-economic, political, and ecological factors, affecting opportunities for long-term adaptation strategies to climate change (Opiyo et al., 2015). In northern Kenya, these have been identified to include violent conflicts, lack of affordable credit facilities and financial services, limited access to markets, land tenure changes, and poor infrastructure (Opiyo et al., 2015).

In Ethiopia, cross-border and internal conflicts based on ethnic tensions are serious and chronic problems that contributed to the prevalence of poverty and vulnerability to climate change. As a survival strategy, most of the households are highly dependent on natural resources for livestock-keeping, cropping, fishing, beekeeping, and hunting. However, extended droughts and extreme flooding have increased the infestation of livestock diseases, and conflicts. Differences in wealth, power, social values and natural resource bases within the communities also determine their vulnerability to climate change and their capacity to adapt to this also varies in time, and space (Mekonnen and Biruk, 2006; PROLINNOVA, 2009, IPCC 2012).

4.2 Impacts of mangrove degradation in Benin and Mozambique

Mangroves are important ecosystems for a wide range of various terrestrial and marine organisms. Mangrove forests accumulate carbon in tree biomass, and most of this carbon is lost by decomposition and export to adjacent ecosystems (Carugati et al., 2018; Igulu et al., 2014). Table 2 presents an outline of the ecosystems services provided by mangroves in Benin and Mozambique.

Mangroves' resources provide ecosystem services which influence the well-being and livelihoods of local communities across the tropical and subtropical zones in Africa (Boateng, 2018; Chow, 2018). Over the last decades, it is widely reported that mangroves are facing a high-pressure. For instance, due to both rapid demographic change in coastal mangrove areas and the effects of climate change, West-African mangrove diminished from 20,500 km^2 in 1980 to the current 9000 km^2 (Boateng, 2018; Feka and Morrison, 2017).

Table 2. Mangrove areas in Benin (B) and Mozambique (M)

Ecosystem-service provided	Climate-related pressures	Impacts	References
Physical barrier to floods	(B) Rapid demographic growth in coastal mangroves areas	(B) Increased vulnerability of local communities, mainly salt producers and Peda fishing communities	Boateng, 2018; Feka and Morrison, 2017; Ajonina et al., 2014; Teka et al., 2019
	(M) Floods, storms, and high wind speeds are caused by the tropical cyclones.	(M) Mangrove massive destruction: shifts in species composition; mangrove drowning; pronounced erosion; mangrove mortality	Charrua et al., 2020; Massuanganhe et al., 2015
Biodiversity protection	(B) Over-exploitation of mangroves resources	(B) Degradation of the fragile mangrove ecosystem	Teka et al., 2019
	(M) Prolonged submergence periods due to the combined effect of river flooding and heavy rains associated with the cyclone	(M) Variability in mangrove covers, changes in mangrove structure (tree mortality, canopy gaps, and a great amount of woody debris). Reduced capacity to feeds and protects juvenile fish, prawns, and endangered species, such as the dugong of Mozambique	Macamo et al., 2016; Chevallier, 2013
Food (fish, shrimps)	(B) Increased temperatures, a decrease in rainfall and the rapid sea-level rise	(B) Loss of biodiversity, especially the endemic species (Rhizophora racemosa Meyer and Avicennia germinans (L.) Stearn)	Boateng, 2018; Chow, 2018
	(M) Sea level rise: changes in inundation duration and frequency as well as salinity levels	(M) Reduction in species production, and fishing productivity	Makowski et al., 2018

In Benin, mangroves offer a wide range of goods, and services to communities, including fisheries, fuelwood, salt extraction and non-timber forest products with medicinal properties (Teka et al., 2019). But the over-exploitation of mangroves resources both for domestic use and for infrastructure building results in the degradation of the fragile mangrove ecosystem (Teka et al., 2019). The pressure on this ecosystem affects biodiversity conservation, especially the distribution of *Rhizophora racemosa* Meyer and *Avicennia germinans* (L.) species. It also increases the vulnerability of local communities, mainly salt producers and Peda fishing communities who make their livelihoods from the mangrove ecosystems (Ajonina et al., 2014; Teka et al., 2019).

Mozambique is often affected by natural disasters, including droughts and floods associated with the El Niño Southern Oscillation (USAID, 2012). Flooding, heat waves, cyclones and drought are all getting more frequent and severe as the Earth gets hotter (Coumou and Rahmstorf, 2012). Niquisse et al. (2017) assessed the changes of ecosystem services in Mozambique between 2005 and 2009. The compound effects of climate change resulting from increased temperatures, a decrease in rainfall, and the rapid sea-level rise are likely to pose a significant threat to mangrove species adapted to a specific water salinity level (Boateng, 2018; Chow, 2018). Some mangrove species have been described as highly tolerant to salinity during the sea-level rise, which reduces the susceptibility of mangroves due to salinity variation. This was particularity the case in Sofala province which has the largest area of mangrove distribution and abundance in Mozambique. Mangroves of the Zambezi River Delta are indicated as having a high capacity to store carbon (C) (Stringer et al., 2015). The degradation of mangrove habitats will increase coastal vulnerability, magnifying the effects of climate hazards and erosion, including the loss of lives (Cabral et al., 2017).

4.3 Deforestation and the dangers of climate change in Nigeria and Zambia

The importance of forests to man's survival cannot be overemphasized due to the various environmental, socia,l and economic benefits they provide. The wooded land areas have decreased during the past two decades in Africa. Nigeria is among the five countries with the biggest annual loss of (-3.7%) (Chakravarty et al., 2012) and Zambia has fast disappearing forests (276, 000 hectares/annum) (Kalaba et al., 2013a).

With this trend, the potential of key ecosystem services (cycling of water, oxygen, carbon, and nitrogen; stability to the hydrological system; supply of freshwater, prevention of flood and soil erosion) is at risk (Oregon Forest Resources Institute, 2018; Adebayo, 2009). Table 3 presents the impacts on ecosystem services in forest areas in Nigeria and Zambia.

Table 3. Ecosystem-service provided climate-related pressures and impacts in forests in Nigeria (N) and Zambia (Z)

Ecosystem-service provided	Climate-related pressures	Impacts	References
Habitat for fauna and flora	(N) (Z) Drought, temperature rise, desertification	Washing away habitat for wildlife, loss of biodiversity, reduction in fish yields, food insecurity	Adeleke et al., 2019; Akande, 2017; Emeodilichi, 2018; Burivalova et al., 2015; Lembani et al., 2019; Kalaba et al., 2013; Ng'onga et al., 2019
Source of timber	(N) Land degradation, drought, increased desertification, soil erosion	Soil depletion, widespread flooding, loss of human settlements	Akande, 2017; Elisha et al., 2017; Ebele and Emodi, 2016; Olaniyi et al., 2013
Physical protection against extreme events	(N) (Z) Droughts, floods: landslides and bushfires	Soil erosion; loss of biodiversity and freshwater resources	Amanchukwu et al., 2015; Enete, 2014; BNRCC, 2011; Fashae and Onafeso, 2011
Balancing of hydrological regime	(N) Drought, sea-level rise, seawater temperature rise	Changes to ocean salinity, disturbance of marine life	Ifeanyi-obi et al., 2012; FAO, 2007; Nicholls and Cazenave, 2010

Despite the numerous advantages of the forest to man, fauna, and flora, a changing climate may increase and worsen the threats to forest and forest products. This in turn would intensify incidences of severe floods, drought, forest fires, landslides, temperature rise, rainfall variability, as well as insect and disease outbreaks (Adeleke et.al., 2019).

Nigeria is naturally endowed with a vast expanse of forest land the swamp forests in the extreme Southern part of the country, the tropical rainforest in the South-western axis, and the wooded savannah in the middle belt. Forests represent about 12% the total vegetation cover of the country and the forest resources account for 2.5% of the country's GDP (FAO, 2010).

In terms of Zambia, the majority of population depends on forest products for their livelihoods. Forest provisioning ecosystem services in the Miombo woodland, for instance, are an important adaptation strategy to reduce the impacts and to help communities cope with stresses and shocks (Kalaba et al., 2013a).

Habitats for fauna and flora are currently threatened by a reduction in forest cover driven by anthropogenic activities exacerbated by climate change. In Zambia the Miombo woodlands are habitat for fauna and flora and are sources of timber. Besides carbon sequestration and regulation of watersheds, woodlands play a crucial role in preventing extreme weather events (Kalaba et al., 2013).

In freshwater ecosystems such as Lake Bangweulu, there is depletion of fish for fisheries-based economy which may be attributed to the increase pressure of humans and increasing temperatures (Ng'onga et al., 2019). Increased vulnerability of the rural people to climate change further weakens their already low adaptive capacity. Fisheries-based livelihood provides a full range of activities that involve the harvesting of fish, through the intermediary phases of landing, processing, transporting, and delivery to final consumers. Temperature increases have implications on fish yields.

4.4 Conceptual models and ecosystem services

Conceptual models summarize, produce a visualization of, and explain both actual or predicted situations, as well as point out how they could be addressed, determining their causes and consequences. In the last few years, the model *Driving Force – Pressure – State – Impact – Effect - Response (DPSIER)* (Gabrielsen and Bosch, 2003; Waheed et. al, 2009) have been crucial to the conceptualization of ecosystem issues, and to translate them to shareholders, environmental managers and researchers (EC, 1999; Smith et al., 2016).

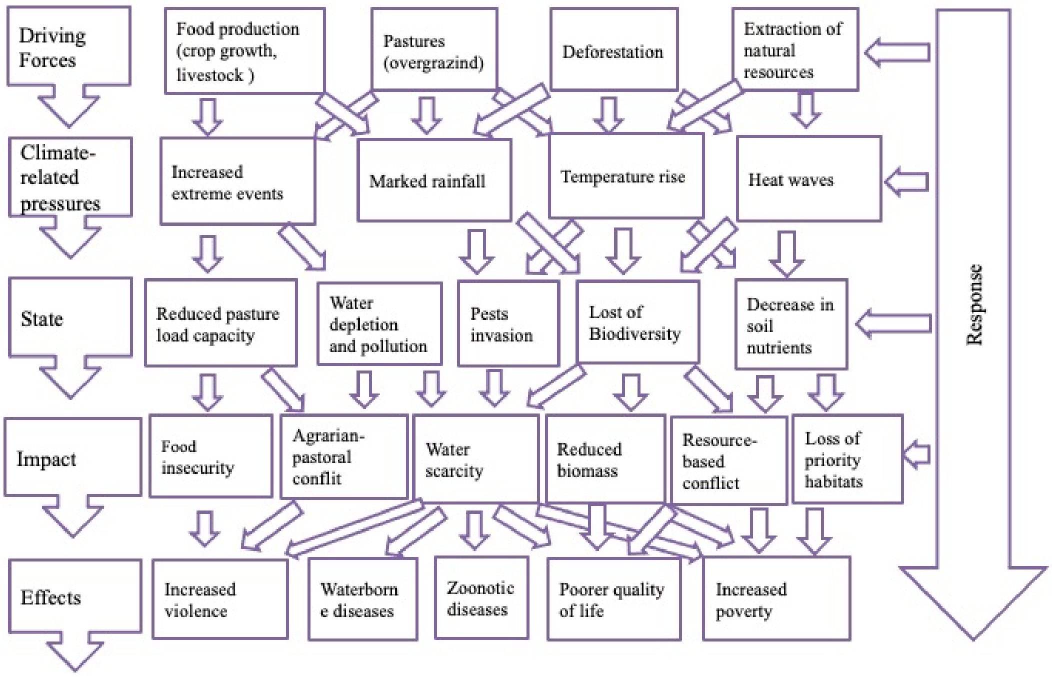
It is possible to observe how these issues are connected when we highlight cause-effect relationships, although the product is a simplistic representation, given that not only it suggests a linear relationship between human activities, the environment, and health, which, generally is not true, but also hides underlying complexities in such interactions (OECD, 1993), which could be linked, and take place simultaneously (Gari et al., 2015). Moreover, it does not stress differences in the nature, severeness, and time scales of changes in the state concerning the intensity, frequency and duration of the pressure (Smith et al., 2016).

Although a single DPSIER cycle (Figures 2, 3 and 4) excessively simplify the "real world", it could provide us with a conceptualization of the relations between environmental changes, anthropic pressures and their effects (Svarstad et al., 2008; Smith et al., 2016) in the cases studied.

4.4.1 Identification of problems in rangelands areas, mangroves and forest

Multiple environmental factors affect the health of the population and its ability to adapt to climate change, thus forming complex cause and effect relations. When people are exposed to a change in their environment, their health might be affected, let alone other socioeconomic and cultural impacts possibly caused by the reduction or the loss of a few ecosystem services. The review of the literature on pressures that rangelands, mangroves, and forests are facing showed a vast range of reasons for changes in ecosystem services (Figures 2-4).

Figure 2. Factors related to the degradation of rangelands areas in Ethiopia and Kenya



We analyzed food production in the context of climate change, food insecurity and violence as an important example of the complexity of interactions in ecosystem services in rangeland areas in Ethiopia and Kenya.

We live in a global agri-food system guided by commercial interests and aimed at the consumption of ultra-processed items. Together with a lack of will of political leaders and a lack of effective action of the society as a whole, this led us into the current global syndemic – a synergic combination of the pandemics of obesity, malnutrition and climate change, which take place concurrently and have shared causes and effects, which feed into one another (Swinburn et al., 2019).

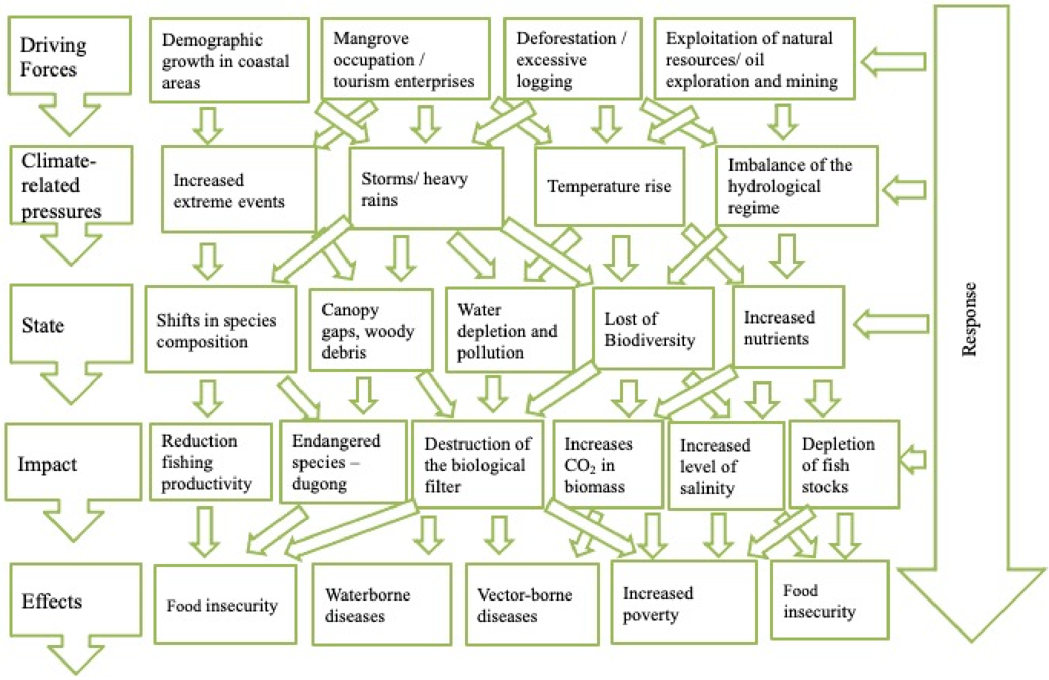
An example of that is what has been going on in Eastern Africa (Ethiopia, Kenya, Somalia, Tanzania and Uganda), which, for three consecutive years has been recording less than half the usual levels of seasonal precipitation, causing families to lose their crops and rangeland. The high cattle mortality rate, the low production of milk, the drop in market value of the animals who survive such adverse conditions, the lower agricultural production and the inflation in grain prices have increased hunger for approximately 20% of the population, and it is estimated that a million children under the age of five require treatment for acute malnutrition (FAO et al., 2018).

On the other hand, African obesity indexes have been growing faster than that of any other region in the world and causing a public health crisis. Eight of the twenty countries with the most drastic adult obesity rates are in Africa. The expanding economy and the presence of multinational companies in the food sector, which noticed the promising consumer market of developing countries, resulted in this high adult obesity prevalence (Jaffar and Gill, 2017; Gettleman, 2018; Martins, 2018). Factors such as a lack of access to nutritious foods and physiological adaptations to food deprivation explain how people that were subject to food insecurity have an increased risk of gaining weight and a tendency towards obesity (FAO et al., 2018).

Climate variability, which affects rain patterns and agricultural seasonality, as well as extreme climate events (such as droughts and floods) are among the greatest drivers of food insecurity, together with wars and economic crises (FAO et al., 2018).

Water stress and the spread of climate change-related plagues – such as the swarm of locusts that emerged in Kenya, Ethiopia and Somalia in 2019 (FAO, 2020) – are devastating to these countries in which agriculture and cattle are crucial means of living, thus aggravating poverty because of a shortage of resources and income that can assure people sustainable means, and also due to the increase of hunger levels, malnutrition, the limited access to basic services, social exclusion and violence. In this case, social vulnerability is also linked to flooding events, which, in turn, generate even more poverty because of material loss and submit the population to an even greater risk of disease and death by water-borne diseases or other infectious diseases.

Figure 3. Factors related to mangrove degradation in Benin and Mozambique

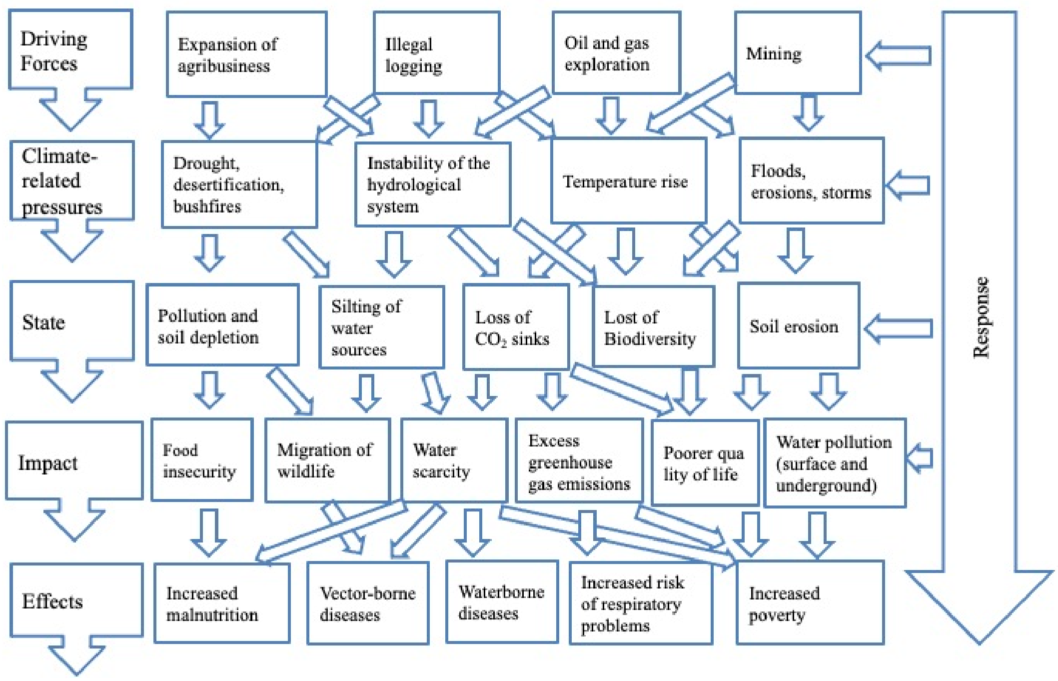


The ability to recycle and retain nutrients is what makes mangroves an important ecosystem for the survival of thousands of species and for the climate adaption and extreme weather events. To understand and model the dynamic interaction between climate change-related risks, ecosystem services, means of living and adaptation to climate change in coastal areas, we have evaluated the context of the humanitarian crisis produced by natural disasters.

Mozambique and Benin are highly socially vulnerable to climate disasters. Besides human loss, this type of disaster deeply affects the economy of these countries, which, in turn, have poor indexes such as basic sanitation, drinking water, food safety and others concerning income and literacy (UNISDR, 2018). On the other hand, these countries are developing very rapidly because they are exploring natural resources such as wood, coal, gas and other minerals. However, poor wealth and resource distribution continues to worsen poverty and social inequality, as well as generate generalized pollution and the destruction of habitats, including mangroves (Chevallier, 2013).

Therefore, the degradation of mangroves is a product of human activities related to survival, the exploration of natural resources and urbanization, which impacts the environment (loss of biodiversity, pollution, water shortage, increased salinity in the water, CO_2 release, soil contamination.) The degradation of these ecosystems also causes a considerable socioeconomic impact, increasing poverty, unemployment, conflicts, nutritional diseases, water-borne diseases, vector-borne diseases, etc. Investing in disaster risk reduction strategies based on ecosystem services – as well as in the adaptation to climate change to reduce the social, environmental and economic impact of natural disasters – is fundamental. Environmental management and the impact of climate change are interrelated, and the management of their risks demand ecosystem approaches.

Figure 4. Factors related to deforestation in the forest of Nigeria and Zambia



An important example of the complexity of interactions between environmental damage, ecosystem services and adaptation to climate change is the extraction of natural resources and the march of agribusiness and anthropic activities threatening the forests of Nigeria and Zambia. Deforestation in these countries takes place fundamentally for three reasons: producing charcoal, their main source of fuel at national level, which is also exported to countries in the European Community; exporting wood to China; and opening new agricultural land, since mining is no longer profitable and the population started growing corn to make ends meet (Chaves et al., 2020).

The population of Nigeria is growing at astounding rates, which drives a huge demand for agricultural land, firewood, water and housing. Besides the effects of deforestation on climate change, the excessive use of fertilizers and pesticides degrades the soil and pollutes the water. The impact includes food safety, water scarcity, deforestation, desertification, forest fires, loss of biodiversity, air and land pollution, rising sea levels and an excess of greenhouse gas emissions.

The accelerated use of ecosystem services that are crucial to life (water, food, energy, medications, genetic resources among others) also drives climate change, which, in turn, affects food production, threaten livelihoods, increases poverty and is associated with the numbers of environmental refugees, especially in Africa (Leal Filho et al 2021). This social vulnerability increases the risk of nutritional diseases, water-borne diseases, vector-borne diseases and respiratory problems.

An increase in the risk of malaria, for instance, is pushed by the export of raw materials for rich countries. Chaves et al. (2020) showed that the global consumption and international trade of commodities related to deforestation in tropical countries – such as wood and agricultural products like tobacco, cocoa, coffee and cotton – increase the risk of contracting malaria in Africa, Southeast Asia, India and South America by 20%. The study includes a number of examples from developing countries where the exportation of commodities for the developed world is related to deforestation and an increase in malaria cases.

As far as adaptation approaches focusing on the protection of ecosystems services is concerned, a framework is necessary, and which may take into account four main components:

a) The adequacy of the adaptation initiatives to be pursued

b) The extent to which a particular ecosystem or set of ecosystems will benefit

c) The long-term prospects of the services to be protected

As Figure 5 shows, there are some means which may be deployed in order to maximise the contribution of ecosystems services to support climate change adaptation efforts in Africa.

Figure 5- Optimising the contribution of ecosystems services to climate change adaptation efforts.

But in order to yield the expected benefits, attempts to achieve such an optimization should not only be technically sound, but also financially viable, socially just and ethically acceptable. This is so in order to make sure that the many socio-economic problems which accompany climate change (e.g. inequalities, social justice, poverty) may also be addressed, also increasing the resilience of local populations, and helping them to better adapt to the manifold impacts of a changing climate.

5 Conclusions

Livelihoods and well-being are directly dependent on the presence of healthy ecosystems. Sustainable ecosystems may help to prevent the impact of extreme events and facilitate recovery processes. They may also assist people to adjust, reduce their vulnerability, and increase their resilience. However, as this paper has shown, many ecosystems are being threatened by climate change and extreme weather events, which show that urgent action is needed.

The diversity of causal factors confirms the complexity of the factors leading to the degradation of the ecosystems studied. Previous works have documented the link between the degradation of ecosystems and poverty. Echeverria (2000) for instance, relates poverty to a trap (poverty-trap thesis), in which individuals, to survive, degrade the environment, and that degradation, in turn, worsens poverty in a vicious cycle (Prakash, 1997; Stephens et al., 2012). Meadows et al. (1973) connected the exacerbated consumption of natural resources to economic and population growth, which, in turn, may lead to the depletion of resources and an increase in social inequality (CMMAD, 1987; Drexhage and Murphy, 2010). In this context, depressed economies lead to migration, food insecurity, exposure to the risk of disasters, health risks and potential escalation of deeply-rooted socio-political tensions (CEPAL, 2020).

The trends in Africa have been exacerbated by the COVID-19 pandemic, which has unleashed the deepest global recession in the continent since the 1930s, leading to increased poverty, food insecurity, unemployment, violence against women, inequality and vulnerabilities to diseases (Sachs et al., 2020) and has been linked to environmental impact, habitat destruction and indiscriminate exploration of natural (Afelt et al., 2018; Giatti et al., 2020; Andersen et al., 2020).

Apart from social problems, the continuous degradation of African ecosystems also limits their ability to respond to extreme events (e.g. droughts, floods), and to recover from them. Thus there is an urgent need to address the threats posed to ecosystems, to stem the steady loss of ecosystem services. To achieve this, some measures are needed. For instance:

a) a better monitoring of those ecosystem services which are being and likely to continue to be influenced by climate change, so that the steps to reduce these impacts are taken. This is especially needed in respect of aquatic ecosystems -especially rivers and lakes- which are currently under a double pressure: excessive use of the water resources and irregular rainfall due to changing climate conditions;

b) an improvement in the means to determine the climate sensitivity of ecosystem services, to avoid them reaching a tipping point. Here, aquatic ecosystems on the one hand, but terrestrial resources (e.g. forests) on the other, known to be already influenced by climate change need to be better understood, since there are signs of decline;

c) more efforts to optimize ecosystem services in a way that the resources and commodities deriving from them serve as an encouragement to actively pursue their protection. This is the case, for instance, of fishery in a lake or forests resources. If carefully planned, these resources and commodities may be available for a long period of time, avoiding the risks a sudden exhaustion could bring about;

d) to design, test and implement adaptive responses that are cost-effective, to upkeep the productivity of the ecosystems on the one hand, but without risk damaging them on the other. Here, the prevention of potential damages to ecosystems is an important component, so as to allow them to continue to function. Here, traditional knowledge may play a key role, since it is based on proven practices known to be successful.

This paper has some limitations. For instance, it has not covered all African countries and regions. Secondly, the fact that it aimed at providing an overview of the trends related to ecosystems depletion, means that it did not undertake an in-depth analysis of the many variables which characterize their vulnerability, nor it has looked at specific adaptation strategies. The paper is nonetheless a welcome addition to the literature, in the sense that it offers a unique assessment of the extent to which large African ecosystems are being negatively influenced by climate change. It also describes some of the measures which may be deployed, so as to reduce the vulnerability of ecosystems and allow them to provide their important contributions to climate change mitigation and adaptation efforts.

The drive towards protecting -or restoring- ecosystem services in an African context needs a joint effort of all types of stakeholders. This includes government organizations, enterprises and other representatives from the private sector on the one hand, but also the civil society (e.g. citizens groups, non-governmental organizations, regional agencies) on the other, so as to address the main constraints seen. Especially at the local level.

Moving forward, apart from the measures listed above, it is also important to assess how impacts related to ecosystem services provision may affect the local populations, so that suitable adaptation measures may be implemented, hence avoiding a situation where these impacts may become irreversible.

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