# 7 An Assessment of Vulnerability and Adaptation of Coastal Mangroves of West Africa in the Face of Climate Change

Isaac Boateng

**Abstract**

This chapter seeks to evaluate the current status of West Africa's mangroves. It assesses Climate Change vulnerability and adaptation options for mangroves in West Africa. West African mangroves contribute a wide range of environmental services, economic goods and social services. In spite of the important contributions of mangroves in the region, they experiencing high rate of degradation. It is estimated that the degradation and the deforestation of mangroves in the region have resulted from their uncontrolled anthropogenic exploitation due to urbanisation, population growth, salt production, industrial pollution and the cutting of mangroves for firewood. Besides the afore-mentioned anthropogenic impacts on the mangroves, the anticipated effects of climate change such as increased temperatures, sea level rise, increased intensity of storm and precipitation are likely to have the most severe impacts on mangrove ecosystems. Climate change and the anthropogenic driven variations of these environmental forces will inevitably have a profound effect on coastal zones and mangroves. The challenge of reversing the degradation of mangrove ecosystems in the face of uncontrolled exploitation and impacts of climate change seems to be a very complex problem. This assessment has identified that both the past and the present vulnerability were more controlled by anthropogenic activities than the effects of climate change, though it is expected that climate change may be the major driving force in the long-term. However, many adaptation options exist to enhance specific ecosystem services in ways that reduce negative trade-offs, but these involve changes in policies, institutional framework and better practices for exploitation, and good management strategies. The chapter concludes that West Africa should implement adaptation policy options including reducing anthropogenic impacts, maintaining coastal buffer zones, restoration of mangroves, catchment management, establishing regional monitoring and regulations and education and local participation to enhance sustainability.

**Keywords**

Climate change · Mangrove ecosystem services · Vulnerability · West Africa · Mangroves adaptation

## 7.1 Introduction

Mangroves have been described by different names including coastal woodland, tidal forest and mangrove forest. However, mangroves are complex and unique forests that thrive at the interface between the land and the sea, mostly around where rivers and lagoons enter the sea in the tropical and subtropical regions of the world. They have adaptation mechanisms that enable them to endure high concentrations of salt and consistent inundation of their root systems by a mix of tidal and fresh water. Mangroves require freshwater inflow, which brings silt with it as substrate for support and nutrients from upstream (Kathiresan and Bingham 2001; AFROL 2002).

According to the IUCN WCPA (2005), mangroves and associated lagoons provide ecosystem services, which include provisioning services (food and water); regulating services (flood and pollution control); cultural services (spiritual, recreational, and cultural benefits); and supporting services, (nutrient cycling) that maintain the conditions for life on Earth. These ecosystem services have economic, protection, environmental and social values that support local and national economies of many countries that have mangroves.

In West Africa, mangroves play a key role in coastal fisheries, which is estimated to contribute over $400 million

I. Boateng (✉)
School of Civil Engineering and Surveying, University of Portsmouth, Portsmouth, UK
e-mail: isaac.boateng@port.ac.uk

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annually to the regional economy (USAID 2014). Besides the fisheries contribution, West African mangroves contribute to a wide range of environmental, economic goods and social services. In spite of these important contributions of mangroves in the region, they are experiencing deforestation at a rate of 1.7% per year (USAID 2014; Feka and Ajonina 2011). It is estimated that the degradation and the deforestation of mangroves in the region have resulted from their uncontrolled anthropogenic exploitation due to urbanisation, population growth, salt production, industrial pollution and the cutting of mangrove for firewood. These have led to the loss of 20–30% of mangrove over the past 25 years (Ajonina and Usongo 2001; Ajonina et al. 2005).

Previous assessments have identified that humans have changed ecosystems more rapidly and extensively over the past 50 years than in any comparable period of time in human history, largely to meet the increasing demands for food, fresh water, timber, fibre, and fuel (IUCN WCPA 2005; Ellison 2015). The overexploitation has resulted in a substantial and largely irreversible loss in the diversity of life on Earth (IUCN WCPA 2005). The challenge of reversing the degradation of mangrove ecosystems in the face of uncontrolled exploitation and increasing demands for their services seems to be a complex and an unsurmountable problem. However, many options exist to enhance specific ecosystem services in ways that reduce negative trade-offs, but these involve changes in policies, institutional frameworks and better practices for exploitation, and good management strategies.

Further, apart from the afore-mentioned anthropogenic impacts on mangrove, the anticipated effects of climate change such as increased temperatures, sea-level rise (SLR), increased intensity of storms and precipitation are likely to have the most severe impacts on mangrove ecosystems (Intergovernmental Panel on Climate Change [IPCC] 2014; Ranasinghe 2016). The world's coastlines are shaped by mean sea level, wave conditions, storm surge, and river flows. Climate change and the anthropogenic driven variations of these environmental forces will inevitably have a profound effect on coastal zone and mangroves (Ellison 2015; Ranasinghe 2016; Nicholls et al. 2014). These impacts are exacerbating the ecological damage of mangroves and threaten not only the goods and services obtained from the coastal mangroves, but the coastal communities that subsist on mangrove resources. Feka and Ajonina (2011) have identified that as these mangroves dwindle, the livelihoods and well-being of millions of vulnerable coastal communities and local governments that directly or indirectly depend on their resources are at risk.

Nonetheless, local knowledge on the vulnerability and adaptation of mangroves to Climate Change and its implications for environmental sustainability of ecosystem services provided by mangroves are limited in West Africa (USAID 2014). Is the present exploitation of mangrove in West Africa sustainable? What policies and institutions are available to ensure sustainable mangroves exploitation and management? How could we reverse the past degradation of mangrove ecosystems, while meeting the current increasing demands for their services? What are the present and future impacts of climate change on mangroves in West Africa? How vulnerable are West African mangroves to climate change? And finally what are the adaption options available for implementation to facilitate sustainability? There is the need to conduct detailed assessment of the vulnerability and impacts of climate change on West African's mangroves in order to determine how to facilitate the development of adaptation policies to reduce the effects. This chapter seeks to evaluate the current status of West Africa's mangroves. It assesses vulnerability and adaptation options for mangroves in West Africa to climate change.

## 7.2 West African Mangroves

West Africa is mainly a political and economic region, which is located west of the Africa continent. It includes all the countries in the region except Cameroon, Chad, Equatorial Guinea, and the Northern Saharan part – Mauritania and Niger. West Africa covers an area of 5,112,903 $km^2$ and has an estimated population of over 340 million. The region is governed by a regional body called the Economic Community of West African States (ECOWAS). ECOWAS was established in 1975 and has 15 member countries of which 11 are maritime countries with variable areas of mangrove forests along their coast and one is an archipelago (Cape Verde islands). West Africa mangroves represent 13% of mangrove forests in the world and cover more than 2.4 million hectares (USAID 2014). Nigeria and Guinea Bissau – two of the world's most mangrove-rich countries are located in West Africa (Fig. 7.1).

There is a significant amount of recent literature on mangroves in the sub-region (Table 7.1). At least 34 titles of papers have been published on Mangroves in West African as a whole or on countries within the regions, since 2000 (Table 7.1). Of the 34 publications only two of them focus on the impact of climate change on Mangroves – one covers the whole West Africa and the other focus on Ghana mangroves only (Table 7.1). This highlights the importance of this assessment.

According to Feka and Ajonina (2011), the indigenous mangrove species in West Africa belongs to three families, including *Rhizophora racemosa*, *Rhizophora mangle*, and *Rhizophora harrisonii*, the white *Avicennia germinans* and *Laguncularia racemosa*. *Nypa fruticans* is an exotic species introduced in Nigeria from Asia, while *Astrotichum aureum* and *Cornocarpus erectus* are associates. Table 7.2 shows the

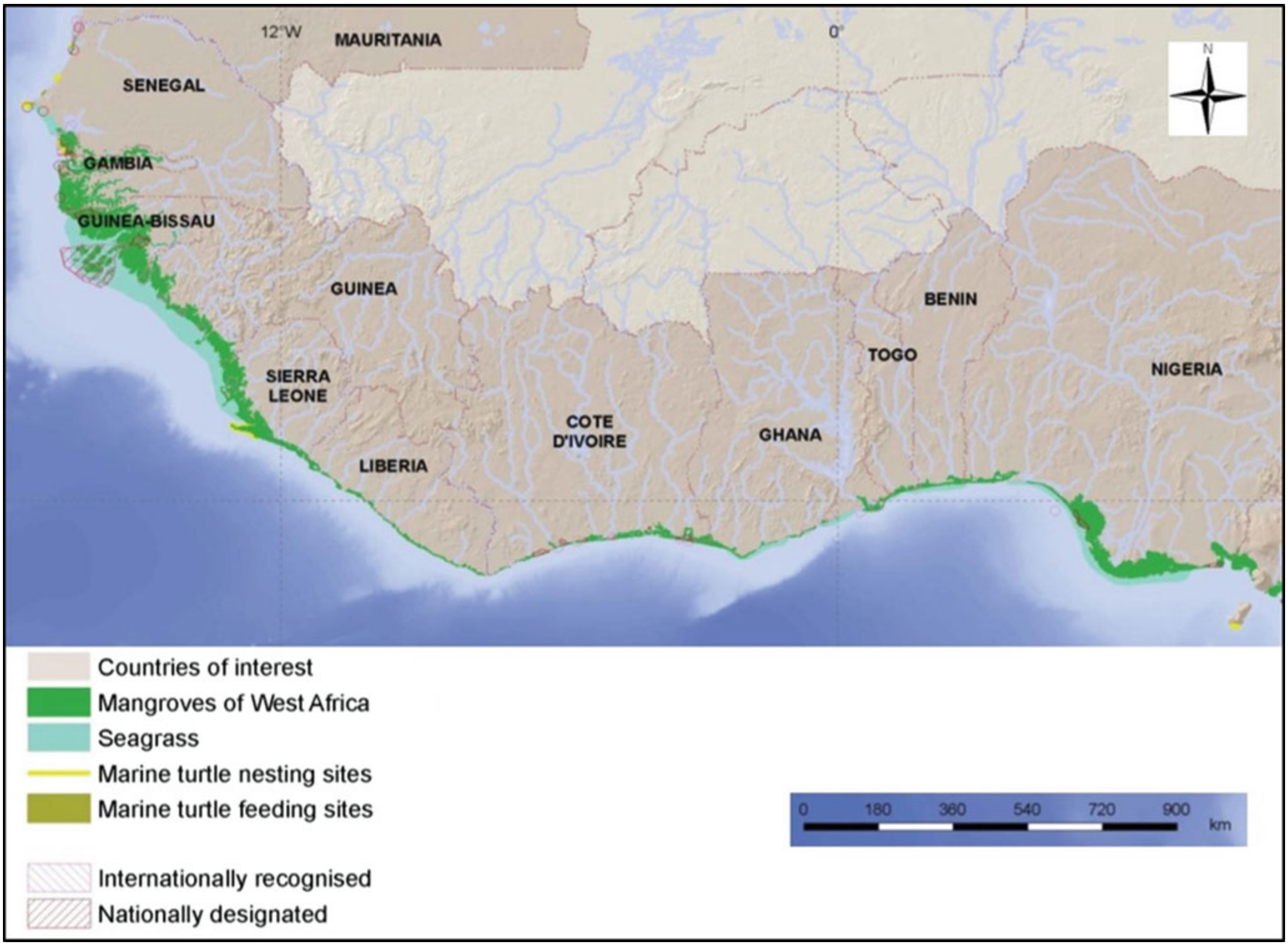


**Fig. 7.1** Mangroves cover in West Africa (After UNEP-WCMC 2007)

distribution of mangrove species across the maritime countries in the region. There is little variation of mangrove species across the sub-region. In all, there are seven main species of mangroves (Table 7.2). These mangroves grow in the intertidal zone of West Africa and are subject to the influence of various factors: oceanographic, sedimentary, geomorphologic and anthropic (UNEP-WCMC 2007; Goussard and Ducrocq 2014).

Previous studies have indicated that West African mangroves have diminished from 20,500 km$^2$ in 1980 to their current 9000 km$^2$, dues to the increasingly effects of deforestation and overexploitation (Bojang and Ndeso-Atanga 2009; Feka and Ajonina 2011). The degradation of mangroves species and associated ecosystem services has direct economic consequences for human livelihoods, especially in areas with low ecosystem resilience to species loss (Polidoro et al. 2010).

Historically, mangrove resources were exploited by local coastal communities on a subsistence scale. However, recently both mangrove resources and the land covered by mangroves are exploited for economic purposes. The large-scale commercial exploitation of mangrove resources and mangrove lands threatens the livelihood of the local subsistence coastal communities, but contribute significantly to the Gross Domestic Products (GDP) of the local economies.

## 7.3 Direct and Indirect Contribution of Mangroves to West African Countries

West Africa has a rich mix of natural resources both on land and at sea, that provide many ecosystem services. These resources support local economy, provide resilience in the face of climate change, and support the livelihoods of many coastal communities. In fact, the coastal area between Nigeria and Senegal, offers the richest variety of marine biodiversity. The fishing industry earns the countries along this section of Atlantic coast an estimated $4.9 billion per year, increasing GDP at the national level and sustaining incomes, and providing food security for fishing communities at the local level (Worldbank 2013). These fisheries are very well supported by the coastal mangroves

**Table 7.1** Recent literature related to understanding and management of mangrove forest in West Africa

| Authors | Year of publication | Location or study area | Main topic area | Total number of publication |
|---|---|---|---|---|
| USAID | 2014 | West Africa | A policy brief on mangroves and climate change | 9 |
| Tang et al. | 2014 | | Biomass and carbon of mangroves | |
| Tang et al. | 2016 | | Mangrove biomass and carbon | |
| Corcoran et al. | 2007 | | Distribution and biodiversity of mangrove | |
| UNEP | 2007 | | Biodiversity and importance of mangrove | |
| Feka | 2015 | | Sustainable management of mangrove biodiversity in rice fields and mangroves | |
| Bos et al. | 2006 | | West African mangroves as habitat for wintering European warblers | |
| Zwarts et al. | 2014 | | Mangrove ecosystem | |
| Carney et al. | 2014 | | | |
| Luiselli and Akani, | 2002 | Nigeria | Snake communities in the mangroves | 4 |
| James et al. | 2013 | | Social valuation of mangroves | |
| Ainodion et al. | 2002 | | Mangrove restoration in the Niger Delta | |
| Adekanmbi and Ogundipe | 2009 | | Mangrove biodiversity, restoration and sustainability | |
| Laleye | 2000 | Benin | Acadja fisheries enhancement systems | 1 |
| N/A | N/A | Togo | N/A | 0 |
| Mensah | 2013 | Ghana | Mapping mangroves depletion | 7 |
| Ntyam et al. | 2014 | | Importance of mangrove litter production | |
| Boatemaa et al. | 2013 | | Impacts of sea level rise on mangroves | |
| Agyeman et al. | 2007 | | Inventory and classification of mangrove | |
| Adotey | 2015 | | Carbon stock assessment of Mangrove | |
| Ntyam | 2014 | | Mangrove ecosystems and ecological value | |
| Nortey et al. | 2016 | | Assessment of mangrove biomass and fish assemblages | |
| Koné | 2008 | Côte d'Ivoire | Methane in the mangroves of Côte d'Ivoire | 3 |
| Egnankou | 2009 | | Rehabilitation of mangroves | |
| Kwassi and Blivi, | 2004 | | Mapping mangrove forest | |
| N/A | N/A | Liberia | **Not available:** reason may be due to civil war | 0 |
| N/A | N/A | Sierra Leone | **Not available:** reason may be due to civil war | 0 |
| Kovacs et al. | 2010 | Guinea | Mangroves assessment classification and mapping mangroves | 3 |
| Flores De Santiago | 2013 | | Rice farming in the mangrove-fringed and salinity intrusion | |
| Wolanski and Cassagne | 2000 | | | |
| N/A | N/A | Guinea Bissau | N/A | 0 |
| Satyanarayana et al. | 2013 | Gambia | Socio-ecological assessment of mangrove | 2 |
| Crow, B., and Carney, | | | Mangrove conservation and female oyster collectors | |
| Coberly | 2014 | Senegal | Mangrove dependencies and participation in rehabilitation | 5 |
| Hiraldo | 2013 | | Mangrove conservation | |
| Vidy | 2000 | | Estuarine and mangrove systems and the nursery concept | |
| Conchedda et al. | 2007 | | Monitoring changes in mangrove ecosystems | |
| Sakho et al. | 2011 | | Natural and anthropogenic factors on mangrove dynamics | |

(Fig. 7.1), which serve as spawning grounds and habitats for several species of fish.

In coastal communities across West Africa, the ocean is a way of life. It is key to providing incomes and a critical source of nutrition, especially for the poor. Yet overfishing, poor fishing practices, and pollution are depleting fish stocks in some of the world's most important ocean habitats. Nevertheless, we hardly estimate the contribution of the mangroves (Table 7.1). The contributions of mangrove to the GDP of these countries are often captured either in the fisheries value or in the value of forestry resources (Feka and Ajonina 2011; Salem and Mercer 2012). Hence, the exact contribution of mangroves are difficult to obtain. This is based on the reason that a number of services offered by mangrove have no market value. Mangrove forests are key to protection of coastal areas from storm surges and coastal

**Table 7.2** Species of mangrove in West Africa

| Countries | *Acrostichum aureum,* | *Avicennia germinans* | *Conocarpus erectus* | *Laguncularia racemose* | *Nypa fruticans* | *Rhizophora harrisonii* | *Rhizophora mangle* | *Rhizophora racemosa* | Total species |
|---|---|---|---|---|---|---|---|---|---|
| Nigeria | x | x | x | x | x | x | x | x | 8 |
| Benin | x | x | x | x | – | – | x | x | 6 |
| Togo | | x | x | – | – | – | – | x | 3 |
| Ghana | x | x | x | x | x | x | – | x | 7 |
| Côte d'Ivoire | x | x | x | x | – | – | – | x | 5 |
| Liberia | x | x | x | – | – | x | x | x | 6 |
| Sierra Leone | – | X | X | x | – | x | x | x | 6 |
| Guinea | x | x | x | x | – | x | x | x | 7 |
| Guinea Bissau | – | x | x | x | – | x | x | x | 6 |
| Gambia | x | x | x | x | – | x | x | x | 7 |
| Senegal | x | x | x | x | – | x | x | x | 7 |

After UNEP (2007), Polidoro et al. (2010), and Goussard and Ducrocq (2014)

**Table 7.3** The estimated value of mangroves to West African countries

| Countries | The values of mangroves per $Km^2$ | Current mangrove area in $km^2$ | Total annual contribution of mangroves in $ |
|---|---|---|---|
| Nigeria | $ 200,000 | 7386 | 1,477,200,000 |
| Benin | $ 200,000 | 66 | 13,200,000 |
| Togo | $ 200,000 | 11 | 2,200,000 |
| Ghana | $ 200,000 | 137 | 27,400,000 |
| Côte d'Ivoire | $ 200,000 | 99 | 19,800,000 |
| Liberia | $ 200,000 | 110 | 22,000,000 |
| Sierra Leone | $ 200,000 | 1050 | 210,000,000 |
| Guinea | $ 200,000 | 2039 | 407,800,000 |
| Guinea Bissau | $ 200,000 | 2999 | 599,800,000 |
| Gambia | $ 200,000 | 581 | 116,200,000 |
| Senegal | $ 200,000 | 1287 | 257,400,000 |
| West Africa | $ 200,000 | 15,767 | 3,153,400,000 |

flooding including saline intrusion of coastal aquifers; densely populated coastal areas are particularly vulnerable and likely to become more so as climate changes over time. In addition, mangroves constitute key habitats of juvenile fish for the coastal and marine fisheries, which are of great economic importance in West African countries (Bromhead 2012).

There are many direct and indirect economic contributions of mangroves and therefore it is necessary to estimate the real contribution of mangroves to the national economy. This will strengthen the case for protection and conservation of mangrove forest. This chapter attempts to estimate the monetary value of mangrove services to the countries in the sub-region. UNEP-WCMC (2006) estimate suggests that the annual values of the benefits and services provided by one kilometre square of mangrove range from US$ 200,000 to 900,000. Based upon this value, we can estimate the value of mangroves services to a country if we know the area of mangroves coverage in square kilometres. Table 7.3 presents estimated monetary values of mangroves forests to each of the countries. Based on the current area of mangrove coverage in the each country (Feka and Ajonina 2011), the lowest range (US$ 200,000) of the 1 $km^2$ values of mangroves (UNEP-WCMC 2006; Corcoran et al. 2007).

The estimates in Table 7.3 show that mangroves contribute over $3 billion to the economies of West Africa annually, with Nigeria leading with over a billion dollars per annum. This estimate is based on the lowest annual yield from per square kilometre of mangrove. Thus, some countries may be receiving more than the estimates on Table 7.3. The various services and benefits derived from mangroves, upon which these monetary valuation have been estimated are outlined in Table 7.4.

Table 7.4 clearly shows that the exploitation of services and benefits from mangroves are not without a threat to the resource. Hence the need to assess the impacts various usage of the mangrove ecosystems and develop the appropriate and sustainable way of getting the benefits at present without destroying a similar benefit to the future generations.

**Table 7.4** Services and benefits derived from mangroves in West Africa

| Economic/non-economic uses | Details benefit of mangroves | Threat associated with the usages: direct, neutral or Indirect threats |
|---|---|---|
| Aquaculture | Coastal mangroves in the region are cleared to create fish ponds for commercial aquaculture activities | **Direct threat:** aquaculture pond destroy mangroves |
| Fisheries | More than 3 million people in the coastal areas of WA are dependent on fisheries as their source of food (protein) and their livelihoods | **Indirect threat:** mangroves are used as fuel (i.e. wood) for fish smoking |
| Hunting and harvesting | Mangrove forests serve as a habitat for non-aquatic animals and also provide edible fruits and plants that are hunted and harvested by the local for food | **Neutral threat:** hunting and harvesting do not cause much damage |
| Fisheries spawning grounds and habitat | Mangroves and associated wetland in WA serves as a habitat and a spawning grounds for several species of fish, shellfish and wintering migratory birds from Europe | **Neutral threat:** no threat associated if the carrying capacity is not exceeded |
| Cultural use | Mangroves have cultural and spiritual value/usage. They provide special materials for cultural and festival rituals | **Neutral threat:** it does not cause degradation |
| Oil exploration and production | Oil exploration, production and associated development in Niger Delta Nigeria and at the western coast of Ghana are occurring in areas covered by mangrove | **Direct threat:** it causes clearing and deforestation of mangroves |
| Timber and firewood usage | Mangroves are harvested by locals and use as fuel wood for fish smoking, salt production, and construction of boats, houses and fences as well as production of tools | **Direct threat:** it causes cutting and degradation of mangroves |
| Tourism | The diversity of life inhabiting mangrove systems, and their proximity in many cases to other attractions such as estuaries and sandy beaches, offers unique attractions | **Neutral threat:** facilitates mangrove conservation for tourism purposes |
| Salt production | Coastal mangroves in the region are cleared to create salt pans for commercial salt production | **Direct threat:** through the clearing and cutting of mangroves for firewood |
| Handy Craft production | Mangroves and other affiliated vegetation's are harvested by local's core domestic and commercial handcraft e.g. Cane chairs, bags, bird cage etc | **Direct threat:** it causes cutting and degradation of mangroves |
| Medicine | Mangroves have a number of therapeutic uses. For instance the leaves, stem and roots are used for the treatment of malaria, diarrhoea, ulcer, skin infections, diabetes and snake bite | **Neutral threat:** the amount of mangrove use for the this purpose is very small |
| Pollution filter | Mangroves do not only trap nutrients, but also polluted runoff, treated and untreated sewage and heavy metals and facilitate improved water quality | **Indirect threat:** provide filter, but excess pollution affect water quality and habitat |
| Carbon sequestration | **Mangroves** absorb $CO_2$ out of the atmosphere through photosynthesis and store it away in their rich soils. Mangroves **are natural carbon cleanser** | **Neutral threat:** help scrub excess carbon and reduce climate change |
| Coastal protection: Storm break and shoreline stability | Mangroves act as a barrier against storm in coastal areas, also their root systems and peat facilitate the interception and storage coastal sediment and thus improve coastal stability | **Neutral threat:** help to prevent coastal erosion and provide coastal protection |

## 7.4 Threats to West African Mangroves

Many anthropogenic activities in the coastal areas such as exploitation of mangroves and some natural hazards have threatened the sustainability of mangroves forest of the world in the twenty-first century (Gilman et al. 2008; Polidoro et al. 2010; Ellison and Zouh 2012; Chaudhuri et al. 2015) the following are the specific threats that effects mangroves in west African:

- **Clearing of mangrove for development:** Population growth, migration to coastal zone, economic growth and beach tourism development have led to the clearing of mangrove forests to make room for human settlements, agricultural and infrastructure (such as harbours, hotels, aquaculture, and industrial development). In Ghana and Sierra Leone mangroves are cleared to create salt pans and shed to support commercial salt production (Thompson 2008; Affam and Asamoah 2011). Figures 7.2 and 7.3 present evidence of the conflict between mangrove conservation and development. While Fig. 7.2 shows the competition between mangrove and property development around Kpeshie lagoon in Accra, Ghana, Fig. 7.3 shows the clearing of mangrove for artisanal salt production at Nyanyano west of Accra, Ghana.

- **Pollution:** In West Africa many types of sewage flows untreated into the sea. The coastal lagoons, rivers and associated mangroves suffer from land based pollution (domestic, industrial and agriculture) (Ukwe et al. 2006), which weakens their ability to produce the ecosystem services, For instances, fertilizers, pesticides, and other toxic man-made chemicals applied in farms and the solid

**Fig. 7.2** Mangrove squeeze in Accra, Ghana

**Fig. 7.3** Clearing of mangrove for salt production at Nyanyano, West of Accra, Ghana

**Fig. 7.4** Pollution of Mokwe Lagoon and associated mangroves in Ghana

waste like plastics (Fig. 7.4) are washed and carried by river systems from sources upstream to the mangrove wetlands downstream. The pollution can kill many species that use the mangrove forests as their habitat. For instance, oil pollution can smother mangrove roots and suffocate the trees. This severe pollution threat not only affect mangroves, but they also contaminate various species of fish and could enter the food chain.

- **Overharvesting**: the use of mangrove trees as both domestic and commercial fuel in the form of firewood, construction prop, wood chip and charcoal is a common practice in West Africa. The cutting of mangrove for this purposes have occurred for centuries, in this region, but it is no longer sustainable, as harvesting threatens the future of the Mangrove forests.

- **Dams and irrigation**: mangroves require a certain amount of freshwater to flourish. However, dams and irrigations upstream of coastal rivers reduce the amount of freshwater reaching mangrove wetland, which in return, increases the salinity levels and negatively affects the growth of the mangrove forest. Conversely, freshwater diversions for irrigation can also lead to mangrove wetland drying out. Dam and irrigation reduce the fertility and the filtering ability of mangrove forest and that affect the growth and ecosystem services of mangroves.

- **Overfishing**: Mangrove forests provide a large variety of fish and shellfish. These fisheries form an essential source of food for thousands of coastal communities in West Africa. The mangroves forests also serve as nurseries for many fish species. The increased global population and the corresponding increased demand for food has led to overfishing globally and for that West Africa the traditional artisanal fishing (Fig. 7.5), have been displaced by international commercial fishing that applies larger fishing vessels and bad fishing practices like par-trawling, and pirate fishing due to poor surveillance and enforcement of local and international fishing regulation in the region (Daniel 2016). These do not cause only overfishing, but also affect the ecological balance of food chains and mangrove fish communities (Fig. 7.6).

- **Climate change**: The effects of climate change such as increased temperatures, sea-level rise (SLR), increased intensity of storms and precipitation are likely to have the most severe impacts on mangrove ecosystems (Alongi 2008; Ellison 2015; Ranasinghe 2016). Mangrove forests require stable sea levels, a certain amount of freshwater and temperature for long-term survival. They are therefore extremely sensitive to current rising sea levels, rainfall induced flooding and higher temperature caused by global warming and climate change.

**Fig. 7.5** Harvested mangroves for sale in a Market in Ghana

**Fig. 7.6** Artisanal fishing landing sites along a mangrove shoreline of Ghana

- **Bush Fires**: Slash and burn is one of the common farming practices in West African. With this farming technique, the farmers clear the land through slashing the vegetation with a cutlass, wait for the weeds to dry, and then burn the dry slashed vegetation before planting. In recent times, due to the rise in temperatures, most peripheral part of the mangrove wetland dry up during the dry season. In most cases, the fire trespass from the burning of the slashed farmlands to the dry mangrove forest areas and destroyed them. This problem is becoming rampant. Thousands of hectors of mangroves in West Africa are burnt during the dry season through the activities of farmers.

## 7.5 Vulnerability and Impact of Climate Change on West African Mangroves

The vulnerability of both mangrove ecosystems and societies is interlinked (Pramova et al. 2015). This is because coastal communities depend on ecosystem services of mangroves for subsistence, livelihoods and coastal protection. Therefore, factors that negatively impact on mangrove ecosystem services and make them vulnerable, will inevitably make coastal communities vulnerable as a result of the loss of ecosystem services from the mangroves (Gilman et al. 2008; Ellison 2015). In addition, the impacts of the loss of ecosystem services on socio-economic systems could lead to unsustainable mangroves exploitation and management due to possible displacement and loss of livelihood associated with depletion of resources and livelihood. The unsustainable management of mangroves would increases their vulnerability. Thus there will be no win situation in those situations.

This implies that climate change and associated forces affecting communities living in coastal areas in West Africa are comparable to the ones affecting mangrove ecosystems. Sea-level rise, coastal storms and changes in precipitation will cause severe impacts on settlements, economic sectors, livelihoods, health, and well-being (IPCC 2014). However, local communities and economic sectors will be negatively impacted by changes in the ecosystems, which in turn affect the flow of ecosystem services that societies depend on. This will renders coastal societies even more vulnerable to climate hazards and change.

Sea-level rise will impact on people and economic sectors through land loss and inundation resulting from rising seawaters. This will force the shoreline to retreat and will decrease the land available for settlements, economic activities such as tourism, agriculture and livelihoods. Sea-level rise will also intensify coastal erosion, which is already a major problem in many low-lying coastal areas of West Africa (Ellison 2015). Salinity intrusion will decrease agricultural production by decreasing fresh water content in the soils. Sea-level rise will also increase the risk of coastal flooding, especially in combination with stronger tides, storms and precipitation. All these factors will force people to migrate landwards or elsewhere, which could lead to conflicts and further resource degradation.

According to Gilman et al. (2008), Pramova et al. (2015), and Ellison (2015), the main climate change related stressors that impact on mangrove ecosystems are: sea level rise, increase temperature, storms surge, and changes in precipitation, especially in relation to decreases in rainfall.

### 7.5.1 Sea-Level Rise

Sea-level rise is considered to be the biggest threat to mangrove ecosystems (Pramova et al. 2015; Gilman et al. 2008). According to Boateng et al. (2017), relative sea-level rise per year over the next 100 years would be about 3 mm/year in the region. Mangrove systems do not keep pace with changing sea level. Already, several of the anticipated impacts of accelerated sea level rise identified by the IPCC (2014) have been experienced in Ghana and other countries in the ECOWAS sub-region (Boateng et al. 2017). In fact, climate change and associated impacts of rising sea level, increased storm and torrential rainfall and flooding are already having impacts on coastal mangroves. This is because the changes have led to increased erosion and weakening of root structures of mangroves. There are also increases in salinity and frequency/depth of mangrove inundation beyond mangrove tolerance levels. In order to maintain the preferred hydro periods and salinity, the mangroves will need to migrate landward so that they can maintain their preferred condition. However, the success of the mangroves landward migration will depend on factors such as the availability of land/space and the slope at the back shore to allow the migration, ability of individual species to colonize new habitats at required rates (relative to sea-level rise) (Alongi 2008). The increase coastal population in West Africa, which began from the trading with Europeans from the fourteenth century and the associated development in the coastal zone has led to urbanisation in the coastal zone, coastal protection structures and development in the coastal areas that restrict the landward migration of mangroves in most places.

### 7.5.2 Increased Temperatures

The African Centre of Meteorological Application for Development (ACMAD) (2016) has projected that warming of the African continent will be 1.5 °C by 2050 and could rise to about 3 °C by 2100. This will aggravate the effects and intensify the impact of climate change on the continent. These could increase the intensity and frequency of tidal wave and storm and potentially cause inundation of the low-lying coastal areas through tidal waves induced by temperature and pressure imbalances between the land and the sea. The impacts of increased temperature is expected to cause changes in species composition, changes in the timing of flowering and fruiting, change in the mangrove productivity and expanding mangrove ranges to higher latitudes (Ellison 2000).

### 7.5.3 Storm

The southwest Monsoon winds and tidal waves develop tidal waves, as a result of atmospheric pressure imbalance between the land and the sea. These waves can have an impact on mangroves as they induce larger and more intense waves, increase wind speed, and cause changes in water levels. Climate change is increasing the intensity of these storm systems and their impact on mangroves. The negative impacts of storms on mangroves include defoliation, uprooting and mortality (Gilman et al. 2008; Pramova et al. 2015). Tidal surges, coastal flooding and strong wave currents induced by storms also impact sediment elevation through soil erosion or compression, and soil deposition (Alongi 2008). The intense rains events caused by the southwest monsoon winds will lead to flood causing erosion and debris flow to accumulate in the habitat of mangroves. These effects will increase vulnerability of mangroves due to the changes in hydrology and sediment elevation.

### 7.5.4 Precipitation

Globally, rainfall is predicted to increase by about 25% by 2050 in response to climate change (Gilman et al. 2008). In West African sub-region, it is anticipated that climate change will cause extreme dry seasons (haematin) and wet seasons (monsoon rainfall) in West Africa (IPCC 2014; ACMAD 2016). Changes in precipitation are expected to affect mangrove growth and distribution (Ellison 2000). Increases in rainfall will lead to mangrove area expansion, as mangroves will be able to colonise previously unvegetated areas at landward fringes in tidal wetlands. Areas with higher rainfall have also been shown to have higher mangrove diversity and productivity in comparison to areas with less rainfall, due to the higher supply of fluvial sediment and nutrients and reduced exposure to salinity and sulphate (Pramova et al. 2015). However, decreases in rainfall and increases in evaporation associated with hammattan will lead to increases in salinity due to lower groundwater tables and less surface freshwater input in to the mangrove ecosystem. This will lead to net losses of peat, as increases in seawater sulphate augment the anaerobic decomposition of peat. This effect will increase mangrove vulnerability to relative sea-level rise even further. Increases in soil salinity will also decrease net primary productivity and growth, as mangroves will experience increased tissue salt levels. Seedling survival will also be compromised, resulting in changes in competition between mangrove species.

## 7.6 Management and Adaptation Policies for West Africa

At a regional level, there has been some effort to conserve and protect mangrove forests from further destruction. Many West African countries have signed international conventions, including the Ramsar Convention on the Conservation of Wetlands, the Convention on Climate Change, the Convention on Biodiversity, and the Convention on Ozone Layer. Mangrove restoration efforts have been conducted in almost all the coastal nations along the West African coast to help communities restore Mangroves and sustainably harness their ecosystem services.

Despite these efforts there is still inadequate policy, law and institutional provision for mangrove forests management and adaptation. Many countries in West Africa have no clearly defined mangroves management structures or plans and tend to place mangrove forests under many institutions with conflicting roles. For instance, in Ghana it is under the responsibility of many ministries including Ministry of Forestry and Wildlife, Ministry of Environment and Ministry of Fisheries. National and international Non-Governmental Organisations also contribute through different community projects on the restoration, conservation and sustainable management of Mangroves. Besides the conflicting institutional role, the institutional framework for managing Mangroves in the sub-region tends to be top-down instead of bottom-up or lateral/collaborative (Boateng 2006). The top-down institutional framework applied in this region tends to make policy implementation ineffective at the operational/local level. This happens because the resources users at the local level are not invited to participate in the policy making. This normally either creates inefficient policy or poorly accepted policy. In most cases it leads to misunderstanding and conflict between the policy makers at the top and the resource users at the bottom/local level.

The key adaptation option for mangroves are:

(i) **Reduce anthropogenic impacts**: This policy focuses on reducing current anthropogenic stressors that are depleting mangroves ecosystem services and increasing vulnerability. Anthropogenic responses to climate change have the potential to exacerbate the adverse effects of climate change on mangrove ecosystems (Gilman et al. 2008; Ellison 2015). For example, human response to sea level rise could lead to increase in the construction of seawalls and other coastal erosion control structures adjacent to mangrove landward margins. The hard defence structures may cause erosion and scouring of the mangrove immediately fronting and down-current from the structure. The reduction of the human impacts on mangroves such as hard coastal defence structures, deforestation, burning during dry season, conversion for aquaculture and pollution will increase the overall ecosystem health and resilience and thus reducing the vulnerability on mangroves to climate change.

(ii) **Catchment management**: The impacts of sea-level rise on mangroves can be adapted by managing mangrove catchment area to minimize reductions in sediment supply. These can include, for example, limiting the development of impervious surfaces within the mangrove catchment and managing rates and locations of groundwater extraction (Pramova et al. 2015). Such activities can reduce alterations to natural groundwater recharge, which influences mangrove elevation. Limiting human activities that reduce mangrove soil organic matter accumulation, such as deforestation and pollution inputs, can contribute to maintaining relatively natural controls on trends in sediment elevation. Depending on the tree species and nutrient added, nutrient enrichment can also have a positive effect. Enhancement of mangrove sediment accretion rates, such as through the beneficial use of dredge spoils, could also augment mangrove sediment elevation to enhance resilience.

(iii) **Maintain coastal buffer zone (manage retreat)**: Unlike in the developed countries where coastal towns are built very close to the sea and buildings are protected by concrete structures, many coastal areas and towns in West African have buffer lands between the sea and the developed area. Though population growth and urbanisation have led to severe pressure and squeeze on the coastal buffer lands (setback zones), there is still opportunity for West African countries to protect coastal buffer zones from development pressures (Boateng 2009). This can be achieved through coastal landscape planning. The coastal buffer zones will allow the long-term landward migration of both the mangroves ecosystems and the coastal development to accommodate future impact of climate change.

(iv) **Artificial landward migration and refugia**: Protected areas can be established and managed to maintain mangrove representation, replication and refugia. Ensuring representation of all mangrove community types in a protected area network and replication of identical communities to spread risk can increase the chances of mangrove ecosystems surviving climate change and other stressors (Gilman et al. 2008; Pramova et al. 2015). Protected area selection can include mangrove areas that act as climate change refugia, which means selecting communities that are likely to be more resilient to climate hazards, such as mature mangrove communities. Protecting refugia areas that resist and recover quickly from disturbance can serve as a source of recruits to recolonize areas that are lost or damaged. Protected area networks should also account for likely movements of habitat boundaries and species ranges over time under different climate change scenarios, and also consider the role of ecosystems in the adaptation of society. Facilitated landward migration of mangrove may be necessary, as discussed in the previous point, and the connectivity between coastal ecosystems, including mangroves, should be protected to enhance overall resilience and maintain functional links.

(v) **Restoration**: Finally, mangrove restoration in areas where mangrove habitats previously existed can offset losses by climate change and consistent monitoring activities could help assess gradual changes (Coberly 2014). Regional networks, sharing of best practices using standardized techniques will enable the separation of site-based influences from global changes for a better understanding of mangrove responses to different stressors and enhance overall adaptive capacity in coastal socio-ecological systems.

(vi) **Regional monitoring and regulation**: There are some uncertainties in climate change projections and anticipated impacts (IPCC 2014). Therefore some of the predicted response of mangroves ecosystems may be misjudged. There is a need for continuous monitor changes on both local and regional scale. To achieve this, there the need to develop a regional regulation and standard techniques for assessing and establishing mangrove baselines, and monitoring changes using regional standardised tools and regulation to develop a better understanding of mangrove responses to sea-level and global climate change. This will facilitate the development of progressive adaptation and mitigation measures based upon the monitored changes.

(vii) **Education and local participation**: to achieve a successful implementation of any adaptation policy, there is the need to educate the local coastal communities, the impacts of climate change on mangroves the potential consequences if they do not apply or abide by the adaptation policies. There is the need to develop in the locals' knowledge and understanding of the present changes and their personal observations about the dwindling resources from the mangrove through community participation in the monitoring and the decision-making processes. Community participation can increase the support for adaptation actions. According to Gilman et al. (2008) education and outreach programmes are an investment to bring about behaviour change and attitudes by having a better-informed community of the value of mangroves and other ecosystems.

## 7.7 Conclusion

This chapter has assessed the status of West African mangroves and identified that over 20% of the mangroves have been lost over the last century through exploitation and other anthropogenic activities. The existing mangroves are still contributing to the economic development and the sustenance of the local coastal communities whose livelihood still depends on the mangroves. It has been identified that harnessing various services and benefits from the mangroves poses a varying threats to the mangrove ecosystem (Table 7.4). However, the combined effects of the anthropogenic threat and climate change impacts may have deleterious effects on coastal mangroves if adaptation measures are not developed and implemented well in advance to reduce, if not to prevent some of the anticipated catastrophic impacts of the combined effects of both anthropogenic and climate change impacts on coastal mangroves. Some of the adaptation measures suggested include reducing anthropogenic impacts, maintaining coastal buffer zones, restoration of mangroves, catchment management, establishing regional monitoring and regulations. There is also the need for education and local participation in the formulation and the implementation of the mangroves adaptation policies.

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