



Mangroves Under Demographic Pressure and Salt Production Threats in the Municipality of Ouidah (Benin)

Sehouevi Mawuton David Agoungbome¹(✉), Estelle Gbenontin²,
and Moussa Thiam³

¹ African Institute for Mathematical Sciences,
Mbour km2 Road of Joal, Mbour, Senegal
sehouevi.m.d.agoungbome@aims-senegal.org

² Ecole d'Agriculture de Kétou, Université d'Abomey Calavi, Ketou, Benin

³ Department of Civil Engineering, University of Ottawa,
161 Louis Pasteur Office A113, Ottawa, Canada

Abstract. Three coastal villages in the municipality of Ouidah (Djébadji, Avlekete, and Houakpe-Daho), well-known for their salt production activities, are experiencing a substantial challenge regarding protection and conservation of the mangrove forest, a key component of their ecosystem. The increasing growth of these communities (more than 200% between 1992 and 2016) has led to the progressive destruction of the mangrove trees needed for firewood. This situation has dramatically threatened the sustainability of the whole ecosystem of the mangrove forest on which many other species rely on. In this work, we investigated the historical development of the situations from a demographical aspect and the possible consequences for the communities and future generations. It's has been shown based on the community growth rate that salt production which is the main activity in the region and employed more than half of the population (women and men) is the main cause for the destruction of the mangrove forest. Therefore, the town-hall services led discussions with the salt producers to find a more sustainable solution. Actions have then been taken to reduce the impact of these activities on the ecosystem, and propose some alternative solutions to the salt producers such as improved stoves which use palm nut hulls as the source of energy for their main activity.

Keywords: Mangrove forest · Ecosystem services · Salt production · Improved stoves · Ouidah

1 Presentation of Ouidah

1.1 History of Ouidah

Located in Benin (West Africa), Ouidah is a historical town that belongs to the Atlantique department (Rep. of Benin). The name Ouidah was etymologically given by the Kingdom of Abomey men who called people of the area “Xwéda”. This name had been written in a different manner according to the colonizers of the area during that period. It finally becomes Ouidah with French in the XIII^e century.

The population is mainly composed of Fon, Nago (Yoruba), Xwéda and Mina (Adja). The Xwéda were the first occupants of the area followed by the Fon coming mainly from Abomey to conquer the area during the reign of King Agadja and in 1727 made Ouidah their maritime gate. As Ouidah played an important role in the Bight of Benin as the main coastal gate during the Blacks slavery period, many other tribes arrived through TransAtlantic Trade. Nago and Haoussa tribes from Nigeria also came during that migration period and slave trade [1, 2].

Since 1999, the decree “Loi 97-028 du 15 Janvier 1999, portant organisation des communes en Rep. du Benin” had redefined the administrative organization, and Ouidah then obtained the status of Municipality, led since August 2017 by Mme Celestine Adjanohoun. According to the last general census of population and habitat of 2013, the different communities are distributed as follows: 69.8% of Fon, 16.5% of Adja, 9.0% of Yoruba, 0.5% of Bariba, 0.4% of Dendi, and others [2].

In terms of administrative distribution, Ouidah is divided into 10 districts which are Ouidah I, II, III, and IV, Pahou, Savi, Gakpe, Djegbadji, Avleketé and Houkpe-daho as shown in Fig. 1.

1.2 Geographical Condition of the Area of Study

Ouidah lies between latitudes 2°N and 2°15'N and longitudes 6°15'E and 6°30'E and covers an area of 364 km². It is one of the eight Municipalities of the Atlantique department in Rep. of Benin (Fig. 1) and is about 40 km west of Cotonou, the main town of the country [2]. The sub-equatorial climate of Ouidah is soft and characterized by two rainy seasons (April to June and September to October) alternated with two dry spells of unequal duration. The average temperature and annual precipitation are 27 °C and 1 200 mm respectively [3, 4]. Ouidah is considered as part of the agro-ecological zone VIII named the fishing zone. The land cover types include grassy savanna, swamp, and mangrove forest mostly located in the coastal part. The soil profile in the township is composed of hydromorphic and mineral soils or little humus-bearing with pseudo-gley which are favorable for growing cassava, tomatoes, maize, watermelon, and vegetables. The land cover shows a high proportion of agricultural areas, with some wetlands mainly located near the Atlantic ocean [5, 6]. There are also many palm trees (1660 ha) and coconut trees (600 ha) plantations in the district of Gakpe, the reforested plantation of *Acacia Auriculiformis* (500 ha) and a natural forest

(225 ha) in the district of Pahou. The majority of the households are located in the urban districts of Ouidah and Pahou. However, some groups of small villages are agglomerated in Savi, Gakpe, Djegbadji, Houakpe-Daho, Avlekete, where people are still living and working traditionally.

1.3 Societal Distribution and Activities

The population of Ouidah has significantly increased over the past three decades. The population grew from 64 433 inhabitants in 1992 to 162 034 inhabitants in 2013, an increase of 151.48%. From 2013 to 2016, the projection of the population was estimated to reach 197 720 inhabitants, with a total increase rate of more

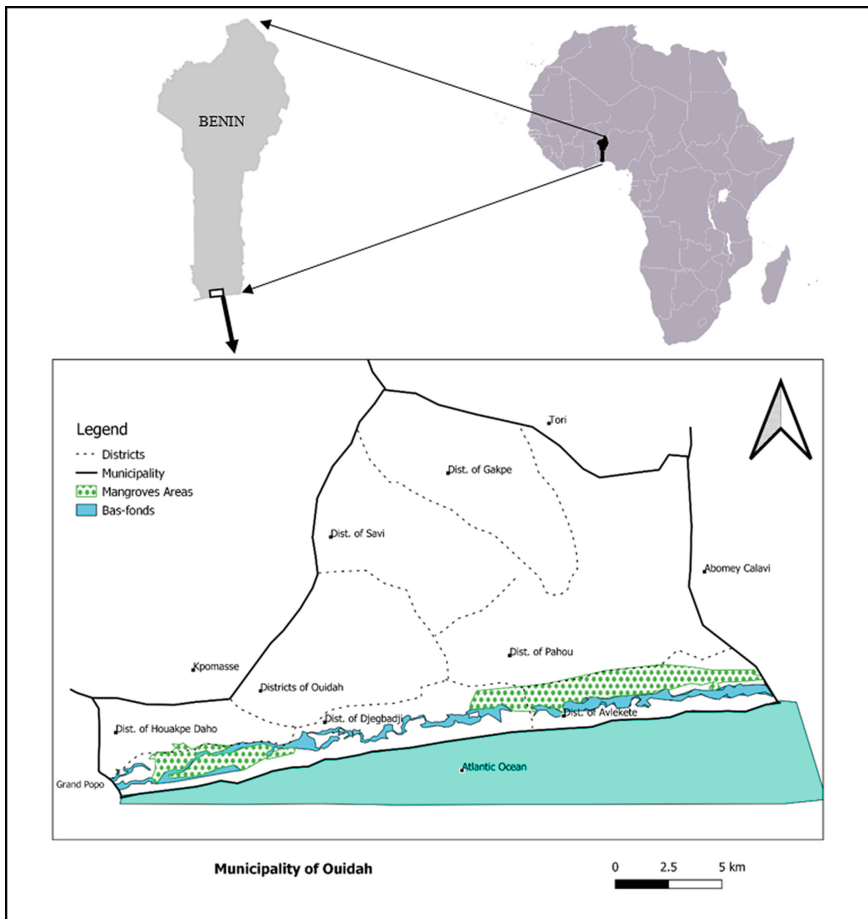


Fig. 1. Administrative map of Ouidah (Source: Township Development Plan 3, 2017–2022).

than 200% since 1992 [7]. This evolution of the population is shown in the table below per district and gender.

Table 1. Population of Ouidah from 2002 to 2016 in the 10 districts and per gender. (Source: Plan de Développement Communal 3ème Génération, 2018–2022)

District	^a RGPH3, 2002			RGPH4, 2013			^b Pro, 2016		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Avlekete	2725	2911	5636	5624	5829	11453	6863	7113	13976
Djebadi	2072	2098	4170	2444	2553	4997	2982	3115	6097
Gakpe	2258	2518	4776	3091	3145	6236	3772	3838	7610
Houakpe	1454	1487	2941	1748	1725	3473	2133	2105	4238
Pahou	6877	7559	14436	38097	40377	78474	46488	49270	95758
Savi	3848	4340	8188	4890	4895	9785	5967	5973	11940
Ouidah I	6186	6670	12856	4493	4731	9224	5483	5773	11256
Ouidah II	4652	5228	9880	6375	7335	13710	7779	8950	16729
Ouidah III	3120	3603	6723	7320	7887	15207	8932	9624	18556
Ouidah IV	3477	3472	6949	4514	4961	9475	5508	6054	11562
Tatal	36669	39886	76555	78596	83438	162034	95907	101815	197722

^aRGPH: Recensement General de la Population et de l'Habitat

^bPro: Projected population

The table shows that almost half of the population of the municipality lives in the district of Pahou, which is the biggest in area. With the districts of Ouidah I, II, III and IV, Pahou hosts the main commercial activities centers and markets, and they form the urban area of the municipality, where more than 75% of the population lives. This distribution also points to the massive exodus of the population from rural to urban areas where the economic activities take place. The district of Avlekete just follows in term of demography and with its long coast and water bodies offering the possibility for sea and lake fishing and also for Tourism. When considering the gender distribution in Ouidah, one must notice that women are slightly larger (51.50%) than men, mirroring the national gender distribution at the country level. This highlights the position of women in our society and the importance of improving gender equality as women are a large component of our communities.

The Institut National de la Statistique et de l'Analyse Economique (INSAE) (2016) reveals in its report that trading, small-scale manufacturing industries and farming accounts for 32%, 15% and 12% respectively of the major economic sector in the municipality of Ouidah. The major crops grown are cassava, maize, palm tree, tomatoes, watermelon. However, other intermediate activities are present such as fishing, livestock, tourism, and some agribusiness cooperative groups which produce palm oil and various food products [7]. Salt production mainly undertaken by women is considered to negatively affect the coastal ecosystem. Dossou et al. (2010) reported that the activity started on Benin coasts

between 1420 and 1550 and has been practiced in the districts of Avlekete, Djegbadji, and Houakpe-daho since Xwéda communities arrived in the area [8]. With the withdrawal of water from the lagoon, the production chain begins with the collection of a salted sand crust which is then mixed with the lagoon water and filtered through a traditional filter built locally, to obtain finally the brine, water with a high concentration of salt (Fig. 2).



Fig. 2. Traditional filter composed of a first layer of braided mangrove branches, then a second layer of thin clothing superimposed as a filter, into which the salted sand crust and the lagoon water are poured. The filter also has a pipe at the base to collect the brine (source: Nouvelle Afrique Magazine 2018/03/26).

Salt production is based on a chemical process called crystallization in which salt solution evaporates, precipitates, settles and forms the sodium chloride. The brine collected from the filtration process is crystallized by burning in mangrove woods. On average, the preparation uses 53 kg of woods to produce 3.5 kg of rough salt.

Referring to Table 1, the current evolution of the population of these three villages which doubles in the last 20 years (from 12 747 in 1992 to 24 311 in 2016), will certainly modify the environment especially the management of land cover and land use. In the three villages, mangrove trees (*Rhizophora racemosa* and *Avicennia Africana*) are the main source of energy for the fire. The past decades have witnessed increasing exploitation of mangroves for cooking as well as for energy utilisation in salt and palm oil production and also fish smoking. These populations have exploited a large domain of the mangrove forest inducing the destruction of the species if nothing is done. Continuous pressure on

mangrove forests will likely increase the risks on the remaining tracts of forest, compromising wider ecosystem functionality and impacting on surrounding human populations.

That is why salt production has been the focus point of many studies, which strive to analyze their impact on the ecosystem. Many environmental institutions and some local associations such as Eco-Ecolo and Eco-Benin, highlighted the destruction of the mangrove forest due to the daily needs of the communities of these three villages who have been using the mangrove trees for many years now.

2 Mangrove Ecosystems in Ouidah

On a global scale, mangrove ecosystems have experienced risks of destabilization or even pronounced risks of extinction due to several natural and above all anthropogenic factors [9]. The recent population growth and the related activities to support human well-being have mainly contributed to increasing the over-exploitation of many natural resources. In this section, we will review the current state, the threats and the possible consequences.

2.1 Mangrove Ecosystem

The term mangrove refers to a wetland ecosystem at low tide in the intertidal zone of tropical and subtropical latitudes. The mangroves are unique plants that have evolved and adapted to survive in the interface between lands and ocean in tropical humid climate regions. They are described in various ways as coastal woodland, tidal forests, and mangrove forest, which grow as trees up to 40 m high, or as shrubs below the high spring tides level. They have developed intelligent mechanisms to cope with high salt concentrations and regular flooding over their root systems by rising tides [9]. Mangroves require freshwater inflow, which brings nutrients from upstream and silt as a support substrate. Acting as a key component in the environment of 26 Sub-Saharan African coastal countries, there are composed of 17 species that do not thrive in stagnant water. African mangroves are widespread along the western coast from Senegal to Congo and occur locally in East Africa, interlinked with highly productive coastal lagoons, tidal estuaries, and deltas. They provide these areas with essential organic nutrients as well as critical breeding grounds and nurseries for larval and juvenile stages of important fisheries species [10]. Historically mangrove has been regarded as swampy, mosquito-infested, muddy wastelands and has been cleared in the past, for the interest of public health or for conversion into other uses for high profit but short-term gains. However, it has emerged that mangroves are among the most productive terrestrial ecosystems and natural renewable resources [9].

Throughout Sub-Saharan Africa, the livelihoods of coastal populations depend heavily on access to natural resources. Mangroves fulfill important functions in terms of providing wood and non-wood forest products, coastal protection, conservation of biological diversity, provision of habitat, spawning grounds

and nutrients for a variety of fish and shellfish, and salt production. Mangrove forests provide the nutritional inputs to adjacent shallow channel and bay systems that constitute the primary habitat, spawning and breeding grounds for many aquatic species of commercial importance [6, 9].

2.2 Ecosystem Services Provided by Mangrove

The Millennium Ecosystem Assessment categorized environmental services into four groups [9, 11]. Examples of the services provided by mangroves are the following:

- Regulation - shoreline protection: the complex three-dimensional structure of a 200 m band of mangrove branches, trunks, and roots can absorb 75% of the energy generated by wind-generated waves, atmospheric and climate regulation; human disease control, water-processing, flood control, erosion control;
- Provision: Use of timber for fuel (cooking, fish processing, salt production); charcoal; construction, fishing, gleaning for shellfish; and extraction of chemicals (e.g. tannins, saponins, alkaloids, flavonoids) for craft and medicines, glues;
- Cultural: Amenity, recreational/tourism of mangroves is not yet well developed (except in some areas of Angola), but it's been explored elsewhere in the world, taboo/sacred areas, education and research;
- Support: Cycling of nutrients, fish nursery habitats, sediment trapping, filtering of water, treatment of waste (e.g. sewage), biochemical, absorbing toxins.

It has been proven that the presence of mangrove ecosystems on coastline save lives and property during natural hazards such as cyclones, storm surges, and erosion [12, 13]. These ecosystems are also well known for their economic importance. A recent estimate suggested on a global scale that the annual values of the benefits and services provided by one kilometer of mangrove range from US\$ 200 000 to 900 000 [9]. In terms of related biodiversity, mangrove forests provide habitats for a host of animal species from endangered mammals to reptiles, amphibians and birds, and spawning grounds for a variety of fish and shellfish, including several commercial species. Mangrove forests also provide nutrients to coastal marine waters, often resulting in high fisheries yields in waters adjacent to them [9]. In Ouidah (Fig. 3), mangrove is mainly known for providing firewood to households and salt production activities especially in our study areas [2]. However, the reduction in fish species and the diminution of their size have been linked with the destruction of mangrove forests.



Fig. 3. Mangrove in Ouidah.

2.3 Threats on the Mangrove and Its Ecosystem

2.3.1 Global Scale Threats

Rivers are dammed, their waters diverted and the intertidal zone extensively developed for agriculture or aquaculture, resulting in the destruction of mangrove forests. Large tracts of mangrove forests have also been converted to rice fields, fish and shrimp ponds, industrial, urban and tourism development and other non-forest uses. Mangrove areas are further exploited for fuelwood and charcoal. In overpopulated and acute fuelwood-deficient areas, even small branches and saplings are removed primarily for domestic fuel [9]. Salt is produced by villagers by boiling brackish water in clay bowls on fire made using mangrove trees; this technique requires huge quantity of woods, so places a heavy demand on the mangroves. On a larger scale, salt is harvested from evaporation ponds or shallow brine-filled pits, usually built-in cleared mangrove areas. The mangroves in West Africa also face many of the conservation and development challenges emblematic of the continent as a whole. Four major drivers of change can be identified across the continent [9], (i) population growth and urban development in the coastal zone (ii) economic and political trends, (iii) climate change, (iv) changes in upstream habitat.

2.3.2 Local Threats

At Ouidah, the mangrove ecosystem has never been threatened as it is this last two decades. The population rate is increasing, and with more women and men in need of fuelwood. In 2014, according to the World Food Program study, the poverty rate in Benin rural areas (39.7%) was ahead of the urban area (31.4%) in 2011 [14]. Households in villages like Djegbadji and Avlékété, face many challenges to cope with their daily needs. The average living cost is under 1 USD per day per person (500F CFA/Jour/Person). Therefore, it is quite difficult or almost impossible to witness household using gas cookers. This implies that the population of these areas mainly relies on mangrove woods for fuelwood. But recent studies have shown that population use more and more mangrove, a situation which has drastically induced the state government to take a decree that prohibits the destruction of mangrove trees and moreover any ecosystem in the wetland close to the sea. Thus, at the present rate of destruction, the United Nations Environment Program – World Conservation and Monitoring estimated that 15,000 m³ of mangrove trees had been exploited per year in Benin in the past. Furthermore, they observed that the quarter of the mangrove area generally in Africa had been cut-off between 1980 and 2006 and that we shall observe the deforestation of about 70% of the total area of mangrove in Africa if no action is taken [9].

2.4 Consequences of the Destruction of the Mangrove Forest

Obviously, the impact of human activities clearly affects the mangrove ecosystem in Ouidah. Bearing in mind the key role played by mangrove in wetland, it appears that all the surrounded species (fishes, birds) of the ecosystem are under high vulnerability risk and more specifically species that rely on the mangrove in their life cycle. At the first level, the mangrove forests are recognized for excellent carbon sequestration and storage in the soils that surround mangrove roots and then contribute to reducing greenhouse gases effect on our planet. Secondly, the mangrove roots constitute the appropriate environment for many fish species reproduction. The local communities admit that the size and the number of fishes have decreased over the past years. This condition will get worse because of the fishing system named Acadja which functions as an artificial system of enhancing fish production by providing, through branches fixed on the bottom of the lake, additional substrate for the development of plants and animals which will serve as fish's nutrients. This system is known for reducing the depth of the body of water and decreasing the fish fauna biodiversity because few species can adapt to these new conditions [15]. Moreover, some migrant birds (*terns*) who usually migrate and dwell in the mangrove trees in their season seldom arrive in the region. This will contrast the efforts of the town-hall to promote ecological tourism and inhibit the attractiveness of regional eco-tourism.

Mangrove roots are also known to have the ability to trap sediment particles drawn from upstream channels and stabilize the coastline [9]. Its destruction leads then to the filling of the lagoon which causes the reduction of the depth of the water body and therefore causes flooding events to occur in case heavy rains.

The high illiteracy rate of those communities mainly composed of fishers and farmers makes them more vulnerable to flood events and their capacity to cope with it is then compromised. The 2010 flooding events which affected the region caused many financial losses (crops, livestock, houses, education equipment, etc.) and even humans death [2].

It then appears that the destruction of the mangroves by the population of these three villages impacts not only the mangroves and its ecosystem but also affect the community's sustainability, livelihood, and well-being. The need for adequate programs and policy, elaborated in accordance with them is urgent. Some alternative solutions moreover need to be proposed at affordable prices in such a way to effectively address the problem.

3 Ongoing Initiatives to Conserve the Mangrove Forest

Attempts have been made to restore the mangrove forest in Benin, between 1998 and 1999. Two hundred thousand *Rhizophora racemosa* and *Avicennia Africana* trees were planted with a survival rate of 62% after 12 months [9]. Later in 1999, a further 470 000 mangrove trees of both species were planted, although the survival rates are not reported. Supporting activities included awareness-raising and information provision to local communities living in the target areas will be beneficial and contribute to the success of such programs.

Many projects and activities had also been initiated to address the problem of destruction of mangrove trees in Ouidah, and more generally in Benin. At the national level, laws and decrees had been voted by the parliament to limit the abusive exploitation of woods in most of the forests. The risk is so high that the government decree forbids the destruction of the mangrove, an offense punishable by judicial sanctions up to imprisonment. Then, the population felt that their primary needs for firewood have not been taking into consideration because no option was given to them. In response, some NGOs and institutions have promoted alternative solutions that continue to enable economic activities, but in a manner that does not threaten the mangrove ecosystem. Some NGOs, propose new activities such as oil production, and the latest is a new and improved stove as an alternative to this community. Mainly, the alternative solutions aim to address salt production which is the major activity in the area by focusing on some types of stoves that function without woods as input. The observation is that any solution that fits with this activity could then be easily adapted to other sector or activity and replicated according to their local available materials as input.

3.1 Solar Salt Solution

The solar solution is a process that relies on the sunshine and its heat to evaporate the water vapor from the brine. This solution had been proposed to the population of Ouidah by UNIVER-SEL in 1998 as an alternative to cooking it. Some challenges were reported: (i) the process duration can take about 2–3 days to produce what is produced in half a day and it mainly depends on the weather

and some other natural parameters (wind, humidity, ...), (ii) the system is affordable except only the system tarpaulins (5 m × 2 m) which was estimated to 10 USD, (iii) the solution is an extensive process which requires a large surface of production to dry the brine, (iv) a training was required in order to arrange the tarpaulins in a way to foster a good production and the manipulation of tools needed for harvest or collection of the salt is special; (v) and these women considered that drying the brine will not eliminate pathogenic microbes in the salt and then cause a bad quality of salt comparing to their traditional process.

However, the project failed to bear fruit because once the project's staff left the communities, the salt producers returned to their traditional way of doing.

3.2 Improved Stoves

The most appreciable alternative to these communities remains the improved stove which combines local products in replacement of the mangrove woods. The objective of the improved stove is to create alternative stoves using local products but without mangrove woods or limited amounts. Until now, a total of four (04) stoves have been proposed each with its own challenges.

- Traditional stove: this is the first type of stove that the women and the population of the villages have been using for salt production. It is made with clay collected from the bottom of the lagoon and has a shape of an empty cylinder. It has one orifice for wood at the basis and has also 3–4 openings for bowls (Fig. 4). This stove uses 25 L of brine and 53 kg of wood within 120 min to produce 3.5 kg of rough salt.



Fig. 4. Structure of the traditional stove (source: Nouvelle Afrique Magazine 2018/03/26).

- The Ofedi stove is the same as the traditional one but the clay here is mixed with palm kernel cake. Training is required in order to master how to use it effectively. This type of stove does not address the mangrove issue and did not get the approval of the population. However, the main issue raised by the users is the longer duration to produce the same amount of salt and more energy as a matter of fact.
- Action plus stove: this stove was produced using red clay and cement to shape the stove in the parallelepiped-shape. This combination with cement stabilizes the clay and gives it more resistance. It has two orifices for woods with two openings for bowls. The users reported that this stove is less resistant than the other and also consumes more energy and takes longer to produce salt. For instance, it requires on average 62 kg of wood to transform 25 L of brine into 3.78 kg of salt within 412 min.
- Mafoubu stove also uses clay to produce the stove in a cylinder-shape. It has only one orifice and one opening. It didn't get also the approval of the population because of the long duration of salt production. This stove uses 25 L of brine and 48 kg of wood within 325 min to produce 3.7 kg of salt.
- Mivo stove: this type of stove is the last generation of stove proposed to these communities. It has been proposed base on the prototype that the township is working on and funded by the United Nations Development Programme (UNDP). In fact, to avoid the destruction of the mangrove, the mayor in collaboration with her technical advisors try to link the palm oil production chain and it dusts which can be a good input in the replacement of the wood. Then, the system presented below, consists of the reuse of waste from a chain in other-chain as an important input. The stove is made of metal components and has a solar system for ventilation. It has four (04) openings where the palm nut hulls are dropped off as input (Fig. 5).



Fig. 5. Mivo stove structure using solar panel as energy source and palm nut hulls.

This solution is a good approach to the mangrove and its ecosystem conservation. As for disadvantages, this stove requires the continual presence of the user for adding the palm nut hulls. However, the Mivo stove will definitely help to address the main issue of the destruction of the mangrove.

3.3 Recommendation for Policy and Management

The benefits and services provided by mangrove trees are enormous and everything needs to be gathered to protect and conserve it. The mangroves forests need to be preserved in order to sustain the surrounding ecosystem. At the country level, we recommend that the law and decrees for ecological protection in general and mangrove forest, in particular, should be reinforced and made known to the general public and the people living in those areas through sensitization campaigns. Locally, the town-hall services need also to continue collaborating with the communities in order to get their input to improve the different versions of the stoves. Emphasis should be given to increase the efficiency of the stove by reducing the time duration, no or minor consumption of wood, and the resistance of the proposed stove. Moreover, a plantation of acacia auriculiformis and eucalyptus camaldulinsis should be implemented in those villages to supply additionally woods.

4 Conclusion

In summary, Ouidah hosts a valuable mangrove forest located in the three coastal villages of Djegbadji, Avlekete, and Houakpe-daho. Due to the actual growth of these communities coupled with the urgent demand of wood for salt production, the mangrove forest ecosystem has been enormously threatened. The services provides by such an ecosystem are many, and more actions need to be implemented to conserve it. Beyond laws and decrees, the state government needs to sensitize the communities and fund alternative solutions for salt production. Concerning the improved stoves which aim at replacing the input (mangrove woods) by palm nut hulls, new versions must include the insights of those communities in order to improve them for their well-being and moreover to preserve the ecosystem of mangrove forests.

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