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Oil exploitation, fisheries resources and sustainable livelihood in the Niger delta, Nigeria

Olanike Kudirat Adeyemo[1], Oniovosa Eloho Ubiogoro[2] and Olufemi Bolarinwa Adedeji[3]

Summary

Mangroves, the coastal forests of the tropics, have traditionally provided a variety of plant products, fish and shellfish for local communities. They also provide services such as coastal stabilization, and food chain support for near-shore fisheries. This study assessed the status of the coastal area of Niger Delta, Africa's largest delta. In the Nigerian coastal environment, large areas of the mangrove ecosystem have been destroyed. The mangrove forests were once a source of both fuelwood for the indigenous people and a habitat for the area's rich biodiversity, but are now unable to survive the oil toxicity of their habitat. The harmful effects of oil spills on the environment are many. Oil kills plants and animals in the estuarine zone. Oil settles on beaches and kills organisms that live there; it also settles on ocean floor and kills benthic (bottom-dwelling) organisms such as crabs and disrupts major food chains. It also covers birds, impairing their flight or reducing the insulative property of their feathers. Oil endangers fish hatcheries in coastal waters and contaminates the flesh of commercially valuable fish. In many villages near oil installations, even when there has been no recent spill, an oily sheen can be seen on the water, which in fresh water areas is usually the same water that the people living there use for drinking and washing. Hence, the public health implication is grave. Several oil spill management policies and efforts are in place to reduce the menace of oil spill incidents in the country. However, most are poorly implemented and laws are usually not enforced. We therefore propose constant monitoring for oil spillage, stringent enforcement of laws and other policies and remediation efforts geared towards restoring the environment of the Niger Delta.

Introduction

The Niger Delta is located in Southern Nigeria and is Africa's largest delta and the third largest world mangrove forests. It covers about 70 000 square kilometers. About one-third of the delta consists of wetlands (Spalding *et al*, 1997). The Niger Delta is unique in Nigeria because it is the home of Nigeria's oil industry, with its attendant environmental hazards such as water, land, air pollution, etc., which pose great challenges to economic development of the Niger Delta. Pollution in the Niger Delta region is largely due to industrialization: petrochemical industrial waste discharge, oil spills gas flaring etc. Exposure to oil or its constituent chemicals can alter the ecology of aquatic habitats and

[1] Olanike Kudirat Adeyemo. *Fish and Wildlife Unit, Department of Veterinary Public Health and Preventive Medicine, University of Ibadan, Ibadan, Nigeria. Tel: +234-805-545-45440. E-mail: olanikeadeyemo@hotmail.com ; olanike.adeyemo@mail.ui.edu.ng*

[2] Oniovosa Eloho Ubiogoro. *Fish and Wildlife Unit, Department of Veterinary Public Health and Preventive Medicine, University of Ibadan, Ibadan, Nigeria. Tel: +234-805-545-45440. E-mail: olanikeadeyemo@hotmail.com ; olanike.adeyemo@mail.ui.edu.ng*

[3] *Olufemi Bolarinwa Adedeji. Fish and Wildlife Unit, Department of Veterinary Public Health and Preventive Medicine, University of Ibadan, Ibadan, Nigeria. Tel: +234-805-545-45440. E-mail: olanikeadeyemo@hotmail.com ; olanike.adeyemo@mail.ui.edu.ng*

the physiology of marine organisms. When oil pollutes the water, some of its components are degraded and dispersed by evaporation, photochemical reactions, or bacterial degradation, while others are more resistant and may persist for many years, especially in shallow waters with muddy sediments. Accumulation of contaminants to hazardous levels in aquatic biota has become a problem of increasing concern (Idodo–Umeh, 2002, Adeyemo, 2003, Adeyemo, 2008). It is of paramount importance that a constant assessment and monitoring of the health of the aquatic system in Niger Delta be carried out. This study focuses on the impact of oil exploitation on the mangrove forests, fisheries resources, public health and sustainable livelihood in the Niger Delta, Nigeria.

Oil Exploitation Leading to Loss in Niger Delta

Moffat and Olof (1995) observe that despite existing, abundant natural resources, the region's potentials for sustainable development remains unfulfilled while the crisis there is exacerbated by environmental degradation. The imprints of the multi-national oil corporations operating in the Niger Delta are visible throughout the region. Some of the oil industry activities that have led to mangrove vegetation clearance include construction of flow stations, pipelines, and seismic lines. Mangrove vegetation clearance causes many problems, the vegetation in the Niger Delta will take between 30 to 40 years to regenerate once removed. Very little documented information is available about the quantity of oil that is spilled by the oil industry's offshore jetties. Indirect evidence from oil washed onto coastal shorelines and beaches in the area suggest, however, that the pollution is significant. Their coastal location makes mangrove forests vulnerable to marine oil spills and on-going pollution from offshore rigs, as observed in Figure 1.

Figure 1: Urie River in Igbide-Isoko in Delta State, note the oil pollution

The oil spills in mangrove habitats permeate exposed tree trunks, accelerating the rate of decay of these precious plants and, as a consequence of their disappearance, will lead to shoreline erosion. They will also devastate fauna and other flora, organisms big and small that depend on mangroves for survival. The destructive will spiral continue down the food chain as fish populations diminish as do the fishermen´s catches. There is a need for careful and continuing environmental monitoring, the more so because of the increasing importance of fish as a source of protein for human populations and the interest in understanding the accumulation of heavy metals and polyaromatic hydrocarbons (PAHs) at the different trophic levels of the food chain, (Greig *et al*., 1978; Obasohan and Oronsaye, 2004).

Impact of Oil Exploitation on the Mangroves

Generally, mangrove forests provide a wide range of beneficial natural ecosystem goods and services for man (Nwilo and Badejo, 2005). Oil spills are a serious concern in regard to the health of Nigeria´s remaining mangrove forests. Leaked oil permeates the coastal waters and streams, coating the exposed, air breathing roots of the mangroves. It is difficult, if not impossible, for the plants' breathing lenticels to perform their essential functions when covered in oil thus, in effect, they are slowly suffocated. Massive mangrove die-off is a common phenomenon plaguing the mangrove regions where coastal oil exploitation occurs. Because oil spills often occur in remote regions, many frequent accidents may go undetected for long periods of time, and are not cleaned up in an effective and timely manner. Oil spills in the Niger Delta are attributed to oilwell blow-outs, sabotage, corrosion, equipment failure, and operator or equipment maintenance errors. In 2006, an independent team of experts from Nigeria's Ministry of Environment, World wildlife fund (WWF), UK and the IUCN Commission on Environmental, Economic and Social Policy in their preliminary findings reported that an estimated 9 million – 13 million barrels (1.5 million tons) of oil has spilled in the Niger Delta ecosystem over the past 50 years, representing an amount equivalent to about one "Exxon Valdez" spill in the Niger Delta each year, while the financial valuation of the environmental damage was estimated to be tens of billions of dollars. In the present study, we identified rapid urbanization, wood extraction, dredging activities, oil industry operations, and threats from invasive species to be the primary drivers of the loss in the mangrove forests across the Niger Delta. In addition, over 200 000 poles and wooden items are reportedly extracted annually from the mangrove forests (Figure 2).

Figure 2: Ethiope River in Sapele showing on-going logging activities

Impact of Oil Exploitation on local communities

Nigeria flares more natural gas associated with oil extraction than any other country on the planet, with estimates suggesting that 3.5 billion cubic feet (100 000,000 m^3) of associated gas (AG) is produced annually, of which 2.5 billion cubic feet (70 000,000 m^3), or about 70%, is wasted via flaring. AG wasted during flaring is estimated to cost Nigeria US $2.5 billion per year (World Bank, 1995; Nwilo and Badejo, 2005). Along with the inefficiency of gas flaring, another problem which gas flaring poses is the release of large amounts of methane, which has very high global warming potential. Methane losses are accompanied by another major greenhouse gas escape, that of carbon dioxide, of which Nigeria was estimated to have emitted more than 3 438 metric tons of in 2002,

accounting for about 50% of all industrial emissions in the country and 30% of the total CO_2 emissions. Gas flares can have potentially harmful effects on the health and livelihood of the human communities in their vicinity, as they release a variety of poisonous chemicals. Combustion by-products include nitrogen dioxides, sulphur dioxide, volatile organic compounds like benzene, toluene, xylene and hydrogen sulfide, as well as carcinogens like benzapyrene and dioxin. Humans exposed to such substances can suffer from a variety of respiratory problems, which have been reported amongst many children in the Delta but have apparently gone uninvestigated. Flares located close to local communities portend a high public health risk (Figure 3).

Figure 3: A community around Uzere creek, with on-going gas flaring.

Impact of Oil Exploitation on Sustainable Livelihoods

During this study, human populations in the Niger Delta were found to be predominantly farmers and fishermen, living off the rich alluvial farm lands and abundant surface water-web that characterizes the basin. It is a universally known that mangrove forests act as nursery grounds for many marine fish. The Niger Delta is bordered by a deep belt of mangrove forests, which protects vast areas of freshwater swampland in the Inner Delta. The trees and roots provide rich habitats for a wide variety of flora and fauna, much of which is only just beginning to be known and understood. The Niger Delta also has the greatest extension of freshwater swamps in Africa. The region's brackish creeks, bays and tidal pools are breeding grounds for the marine life upon which many people depend for their livelihoods. It has been estimated that 60% of the fish in the Gulf of Guinea breed in the mangrove forests of the Niger Delta. Oil spillage has been found to be impacting the fisheries resources adversely (Akpofure *et al*, 2000). Aworawo (2000) commented that the economic conditions in the Niger Delta reflect unequivocally that poverty is endemic in the region and that it is getting worse as a result of oil pollution of the coastal water that provides fish consumed by the people. According to the members of communities interviewed, there has been over recent years massive reduction in fish catches by fishermen. We also observed in the present study that in rivers polluted by oil spillage, some fishes were severely coated with crude oil, making them inedible, while some others were found floating dead on the surface (Figure 4).

Figure 4: Some fishes recovered from oil polluted Uzere creek, note the oily sheen on the dead fishes.

Women and children are the worst hit, because mangrove swamp fisheries such as hand-picking of periwinkle (*Tympanotonus* spp and *Pachymenalia* spp) are mostly a job of the womenfolk in the Niger Delta. On the average, fish constitutes 40% of the animal protein intake in Nigeria. The percentage of fish consumption is generally higher for residents of the Niger Delta region. A decline in fish availability will have serious consequences on the nutritional status of the people, especially children who require adequate fish intake their development. Because of economic incapacitation, inhabitants of the Niger Delta are today living in poor health conditions and in an environmentally polluted atmosphere that constrain a good standard of living. According to WHO; "an urgent need exists to implement mechanisms to protect life and health of the regions inhabitants and its ecological system from further deterioration" (World Bank, 1995).

Sustainable Use of the Mangroves of the Niger Delta

Non-sustainable use of the mangrove ecosystems can lead to loss of the whole mangrove habitat, and associated losses of shoreline organic matter production and the disappearance of species dependent on the habitat and mangrove-based food chains.

Appropriate responses needed to ensure sustainability of the mangroves forests of the Niger Delta include:

- Stabilization and protection of shorelines;
- Filtering, trapping and removal of water-borne pollutants;
- Maintenance of nursery and feeding grounds for numerous species of finfish and prawns and habitat for crabs and molluscs;
- Provision of nesting sites for sea and shore birds.

Conclusion

Oil development occurred in the Niger delta of Nigeria without a comprehensive, strategic plan which would have protected its natural resources. Many of the oil facilities and operations are located within sensitive habitats - including areas vital to fish breeding, sea turtle nesting, mangroves and rainforests; that have often been severely damaged, contributing to increased biodiversity loss and poverty. The damage from oil and gas operations is chronic and cumulative, and has acted synergistically with other sources of environmental stress to result in a severely impaired coastal ecosystem and compromised livelihoods and health of the region's impoverished residents. Sustainability of mangrove forests and coastal ecosystems depends on collaboration by all stakeholders to introduce adjustments to industrial processes, oil spill

prevention, response preparedness; restoration framework and implementation plan. Corporate Social Responsibility (CSR) and Environmental Stewardship should be required of the oil exploitation industries and enforced by the federal government.

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Livelihoods in Cameroon mangrove areas: finding a balance between conservation and sustainable use in a fragile ecosystem

Oumarou Njifonjou[1], Mvondo Ze Antoine[2] and Ondo Sylvie Carole[3]

Summary

A socioeconomic study was conducted in the two mangroves of Cameroon with the objective of identifying all the activities and livelihoods of populations and subsequently record their impact on the conservation and sustainable management of this ecosystem. The Rio Del Rey mangrove in the South-west region (Bakassi area) and the Cameroon estuary mangrove in the Douala region, include seven species that form the wood and non-wood floristic base in this environment. These comprise six indigenous mangroves species and one species introduced from Asia, the Nipa palm (Nypa fructicans). The study underlines a multitude of sectors including those of halieutic (fishing) products, agricultural products, wood, shopkeeping and sand. Measures to manage the anarchic development of Nipa palm are suggested. For a sustainable management policy of Cameroonian mangroves, it is urgent to have laws and regulations specific to that ecosystem.

Introduction

With an estimated surface area of 277,000ha, Cameroon mangroves include three large groups: (1) the Rio Del Rey mangrove in the Bakassi area (150,000ha) stretching from the Njangassa village to the Nigerian border, as well as all the islands of the Rio Del Rey estuary; (2) the Cameroon estuary mangrove (120,000ha) stretching from the Sanaga estuary to the Bimbia Cape; and (3) the Southern mangrove (about 7,000ha) located in Campo at the mouths of the Nyong, Lokoundjé and Ntem rivers. It should be noted that this mangrove has been excessively exploited here and there, especially for young trees cut as poles and exported to Nigeria.

The coast's equatorial maritime type of climate, the differences in annual rainfall from the south to the north (4,000mm in Douala, 11,000mm in Debunscha, and 6,000mm in Rio Del Rey), a relatively high air temperature (28°C), and a low salinity (<5‰), are all favorable factors for the development of these mangroves. They are also conducive for the installation of human communities in these environments, and for economic activities that potentially have negative impacts on the biodiversity of that ecosystem. Apart from the known natural functions of mangroves, in Cameroon they are often the basis for significant economic exchanges. The economic operations thrive on the dynamics of the demand from urban areas in Cameroon as well as exchanges with neighbouring counties such as Nigeria and Equatorial Guinea.

[1] *Oumarou Njifonjou. IRAD/SRHOL Research station; PMB 77 Limbe. Cameroon ; Tél. +237 761 91 49 ; Email : njifonjou@gmx.fr ; inter_ezphone@yahoo.fr*

[2] *Mvondo Ze Antoine. Hydro soil Department, University of Dschang, Cameroon; Tel.+237 77 51 85 35; Email: mvondoze@yahoo.fr*

[3] *Ondo Sylvie Carole. IRAD Research Station, Kribi, Cameroon; Tél. +237 781 86 82 ; Email : sylondocarlo@yahoo.fr*

Universally known as an unstable and fragile ecosystem, Cameroon has adhered to the protection of mangrove ecosystems through a framework law n° 96/12 dated 05/08/96 and its Article 94. In the overall framework of defining a sustainable development policy for Cameroon's mangroves, a multidisciplinary study focusing on the participatory management and conservation of the biological diversity of mangroves was carried out during the year 2005. This paper presents a number of results of the socioeconomic aspect of the study, with a view to identifying all the activities and livelihoods of communities in mangroves areas of Cameroon, and recording their impact on the preservation and sustainable management of that ecosystem.

Materials and method

Site and materials

The study considers the Rio Del Rey estuary mangrove and the Cameroon estuary mangrove. Several villages were visited except those on the Bakassi peninsula (Idabato and Diamond) that were still experiencing armed conflicts at that time. Site visits were carried out using a 4x4 pickup vehicle and a small boat. The light equipment includes a GPS, a camera, hydrographical and tides maps, pieces of strings and survey sheets.

On-site data collection strategy

A multidisciplinary team including a socio-economist in fishery, a mangrove developer, a hydro-pedologist, a lawyer and the survey staff, was formed to conduct a participatory analysis in the communities living in the region under study.

The collection of information was primarily done at the level of the administrative centre of localities visited, after consultation with local institutions for information on the large-scale dynamics affecting the overall mangrove ecosystem. Local institutions consulted included administrative authorities, representatives of relevant technical ministries, NGOs, fishermen associations, fish traders, logging companies and lumberjacks; and sand operators. Information was collected in villages systematically visited and geo-referenced:

- At the level of focal groups and village institutions (Village Chief, heads of socio-professional associations, youth and women groups, fishing post managers, School headmaster, hospital nurse, etc) to collect information on the various aspects of communities livelihoods;
- Participatory discussions with the various socio-professional categories (fishermen, fish traders, farmers, loggers, transporters, sand and gravel operators, etc.) in 20% of villages visited. The sample embraced all the types of villages (small, average, large). The data collected enabled the team to grasp the village dynamics as regards access to resources and related conflicts, income generating activities, actors' perceptions on sustainability, environment preservation and protection, etc.

The approach used was interactive and deductive with the use of the main MARP (Methode Acceleree de Recherche Participative) tools which facilitated an identification and inventory of the floristic biodiversity and enabled detection of areas where the mangrove ecosystem is in a state of advanced deterioration. MARP (a French acronym) is very similar to Participatory Rural Appraisal (PRA).

Results and discussions

Vegetation and floristic composition of mangroves

The majority of mangrove species in Cameroon belong to three (3) families: *Rhizophoraceae,* A*vicenniacea* and *Combretaceae*. The associate or volunteer species are highly varied and amount to more than 19 families. Seven species are predominant, including six indigenous species gathered under the term 'mangrove' and one introduced species, the Nipa palm originating from Asia (Table 1). The 'associate species' are mainly: *Drepanocarpus lunatus, Dalbergia ecastaphylum, Hibiscus tiliaceus, Phoenix reclinata, Acrostichum aureum, Pandanus candelabrum, Raphia palma pinus*, etc. *Rhizophora spp.* is the predominant species in Cameroon with about 80% of mangrove vegetation followed by the Nipa palm (*Nypa fructicans*) with about 13%.

***Table 1*: The main mangrove species in Cameroon**

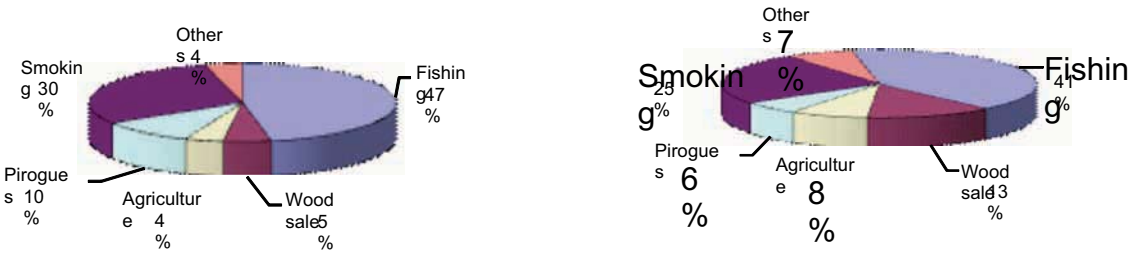
Mangrove species	Abbreviation	Family
Rhizophora racemosa	***Rr.***	***Rhizophoraceae***
Rhizophora mangle	***Rm.***	***Rhizophoraceae***
Rhizophora harrisonü	***Rh.***	***Rhizophoraceae***
Nypa fructicans*	***Np.***	***Arecaceae***
Avicennia Germinaans	***Av.***	***Avicenniacea***
Laguncularia racemosa	***La.***	***Conbretaceae***
Conocarpus erectus	***Co.***	***Combretaceae***

****Introduced species*** ***Source: Thomas, D.W. & Check M., 1992***

Livelihoods in the mangroves of Cameroon

The analysis of data collected on site (Njifonjou, 2005; Mbog, 2005; Mvondo Ze, 2005) underlines a great number of activities often performed seasonally. Even though the same activities are found in the entire area, some of them are more important in the Southern mangrove in view of the presence of large towns.

In Rio Del Rey, at the border with Nigeria (Figure 1.a) fishing is the most important activity (47% interviewees) followed by fish smoking (30%) and the manufacturing and repair of dugout canoes (10%), wood sale (5%), agriculture (4%) and other activities (house building, petty trading, transport of goods).



a) Bakassi area *b) Cameroon estuary*

Figure 1: Distribution of populations' activities in the southern part of Cameroon

Fish smoking, manufacturing of dugout canoes, house building, and wood selling represent 48% and are all the activities related to the exploitation of mangrove wood, confirming its importance in the area under study. Wood sale is less important and located around the Bekumu fishing grounds of which the main activity is catching the small shrimp (*Nematopaleamon hastatus*) (popularly called Njanga in Cameroon) which is sold dried-smoked.

At the Cameroon estuary (Figure 1b), fishing also remains the most important activity within that mangrove ecosystem. However trade in wood (13%) is gaining importance in view of the nearness to large urban centers of Douala and Tiko (especially in Bilongue, Bonaberi and Avion Beach neighbourhoods). Fishing grounds such as Yoyo I, Youme, Cap Cameroon, Kange, Mabeta, etc. are big centers for fish smoking.

All the activities related to logging (smoking, woodwork, building) represent 46%. This confirms once again the excessive logging occurring in Cameroon mangroves in general and testifies to the need to undertake an urgent action to preserve that ecosystem. Agriculture is also more important in the south (8%) of villages located near dry land. The other activities (6%) are spread between sand exploitation (2.5%), house building and woodwork (2.0%), transport of goods and persons (1%) and trade (1.5%).

Levels of exploitation

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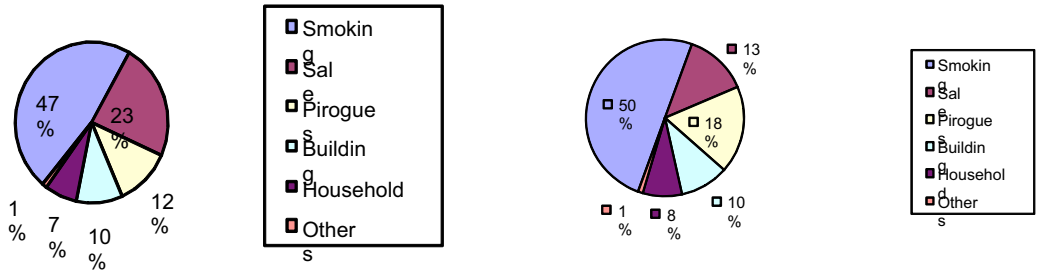
Human activities in the mangrove forests of Cameroon are more focused on logging; however some species such as rattans and palms near or inside mangrove ecosystems, are also subjected to intensive harvesting. Mangrove logging has become the second activity after fishing in mangroves. Red mangrove (*Rhizophora spp.)* is by far the most solicited species: used for fuel wood, fish smoking (wood and fruits), timber. Figure 2 presents the distribution of wood use in the mangrove areas of (a) the Cameroon estuary, and (b) the Bakassi area.



a) Cameroon estuary *b) Bakassi area*

Figure 2: Categories of wood-use in the mangroves of Cameroon

There are small and large scale loggers. Regarding the small-scale loggers, the cutting is done with machetes or sometimes axes and mainly involves small areas. This system leads to the reduction of young trees of 10 to 20 cm diameter (1 to 5 years old) sought after for their easy use and transport (fish smokers, housewives, shelter builders).

The large-scale loggers use motorized chainsaw and cut big trees to be sawn as planks and used for fuel. This is an intensive and profitable exploitation even though illegal. Loggers are sometimes organized in associations (operating illegally) like the 'Firewood Cutters Union' of Cap Cameroun Village. At Rio Del Rey, mangroves suffer from excessive cutting of poles directly exported to Nigeria for use on various building sites.

Agricultural logging

In Cameroon, agriculture is secondary and highly scattered in mangroves area. It concerns only a few villages such as Ekoumamindo, Bekumu, Bamousso in the northern part of the area; Tiko, Mabeta, Manoka, Mouanko in the southern part; and these are villages benefiting from the nearness to dry land. However, there are large rubber tree and oil palm plantations belonging to the agro-industrial company Cameroon Development Corporation (CDC) that occupies large surface areas at the outskirts of the mangrove area. Rice production is missing and unknown and backyard (homestead) gardens are widespread in the villages with fruit trees and various types of food crops.

Exploitation of sand quarries

Sand exploitation is one of the important activities in areas covered by mangroves, and at the same time near large towns. Sand quarries are visible everywhere in the Cameroon Estuary, particularly around the city of Douala (Modeka Bay, Youpwe, Bonabéri neighbourhoods) where the annual mangrove sand production is estimated at 90,000 m^3. That activity is increasingly spreading in the Cameroon Estuary because of the ever increasing demand for large grain river sand exported to Equatorial Guinea.

Impact of industrial, urban and entertainment activities

The effects of urbanization and its consequences are more perceptible in the Cameroon Estuary mangrove. The perpetual increase of the population of Douala causes a systematic invasion of mangrove areas, both by populations and new factories. The result is industrial and household pollution with the dumping of waste materials such as phosphate, heavy metals (Pb, Zn, Cu, Cd, etc.), solid waste and organic matter in the environment. Hydrocarbon pollution is perceptible in the entire area, especially with the

frequent dumping of oil in the sea (e.g. refinery wastes, platforms, waste oil from fishing boats, etc.)

Impact and development of Nipa palm (Nypa fructicans)

Originating from South-East Asia and typical of swampy estuaries, Nipa palm was introduced in the Gulf of Guinea from the Calabar region where the species spreads its seeds along the Guinea current. The multiplication and development of *Nypa fructicans* species in the areas disturb the optimal development of various indigenous mangrove species and became a plague in the entire region. In Asia, the plant has multiple uses (building material, basketwork, sweet sap used to prepare sugar and alcohol, kernel often consumed, etc.). In the Bakassi region and in Calabar where the palm found a good growing environment, populations use it only to build houses, weave mats and baskets, etc.

Prospects for the sustainable management of mangroves in Cameroon

Since the participation of Cameroon to the Rio de Janeiro Earth Summit (United Nations Conference on Environment and Development, 1992), the protection and conservation of the mangrove ecosystem is henceforth included in the list of priority tasks for ministerial, decentralized and other authorities. Among the current projects: the review of the legal framework for fishery and aquaculture (Project (A) : the TCP/CMR/2908(A) Project on participatory management and conservation of mangroves biological diversity, the research programme N°3-2007/IRAD/SRHOL on destruction strategies of the Nipa palm (manual destruction of fruits and sabotage of the heart of Nipa to stop its growth) and in Nigeria, funding of a demonstration project on Nipa monitoring through its use at the University of Calabar, by the Project 'Gulf of Guinea Large Marine Ecosystem (GCLME).

Conclusion and recommendations

These studies contributed to the diagnosis of the situation of major mangrove ecosystems in Cameroon, through the evaluation of mangroves resources and their potential to contribute to food security and income generation. The mangroves were exposed to a double pressure from endogenous and exogenous factors. They were subjected to various uncontrolled actions by local coastal populations, and to continuous changes of the coastal environment as well as to pollution by urban and maritime waste. Many activities were thus carried out, notably fishing and related activities, wood cutting for various uses (more than 60% of activities revolve around wood cutting), agriculture, sand extraction; and the multiplication of Nipa palm added up to the long list of the causes of the drastic reduction of the extent of mangroves surface areas. Cameroon is thus faced with mangrove ecosystem that is anarchically exploited, not rationally managed or protected and little developed. This situation will further compromise the ecosystem's vital functions.

The results have made vital information available. Therefore the country should formulate its development plan, put in place mangrove-specific legislation and regulations, and adapt them to the latest developments that occurred in that ecosystem both at national and international level. As the primary beneficiaries of the ecosystem, local resident populations should be sensitized to make sustainable use of the mangrove ecosystem. Actions to embrace should include selective tree cutting for fish-smoking, the use of more

efficient fish smoking wood-kilns, the use of young Nipa fruits to slow down its development, and the non-use of destructive practices in nursery areas, etc.

Although some initiatives have been launched on the sustainable management of the mangrove ecosystem in Cameroon, it would be advisable that concerted actions be carried out to realize the activities of the GCLME Mangrove Demonstration project on each side of the Cameroon-Nigeria border.

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Human activities; the key threat to the rich Tana delta mangrove forest in Kenya

Geoffrey Murithi Riungu[1]

Summary

In Kenya, mangrove swamps cover an area of about 53km^2(53,500 hectares) along the coast, with sixty percent, or about 33, 500 hectares, found in the Lamu Archipelago. There are ten species of mangrove along the Kenyan coast, found in estuaries such as Mida Creek, and Gazi bay. Despite the diversity of benefits attributed to mangrove, the uncontrolled exploitation and habitat destruction are reducing their coverage at alarming rate. This paper seeks to underscore the ecological role and the benefits of mangrove forest to the Tana Delta communities of kenya, the main drivers to the destruction of Tana Delta mangrove and the possible interventions to arrest future ecological collapse of this unique ecosystem.

Introduction

The Tana River Delta (Figure 1) is arguably one of Kenya's unique natural and human environments located in a semi-arid area of Garsen, Tana River district, Coast Province. It is one of the six deltaic areas off Eastern Africa and is Kenya's largest deltaic zone. It is estimated to be about 130,000ha of which 69,000 are regularly inundated. The striking feature of the Tana Delta is the prodigious variety of its wetland habitats and the richness of its biodiversity thanks to the Tana River.

Figure 1; Map of Tana Delta (source: Multiple land use model for Tana Delta)

The Tana River is the longest river in Kenya being over 1000km long and it has a catchment area of 95,000km^2. It discharges an average of 4000 million m^3 of fresh water and about 4million tones of sediments annually into the Indian Ocean. Before entering the Indian ocean, about 30km upstream of Kipini, the Tana River forks and forms the complex of tidal creeks, flood plains, coastal lakes and mangrove swamps known as the Tana Delta.

[1] *Geoffrey Murithi Riungu, Kenya Wetlands Forum c/o East African Wild Life Society P.O Box 20110,00200 Nairobi, Kenya. Tel: +254(020) 3874144. Email: geoffrey@eawildlife.org ; wariungu@yahoo.com.*

There are mangroves along the main river course of the Tana River between Ozi and Kipini (including large areas with tall *Heritiera littoralis* - about the only place in Kenya where these are found) and in the tidal delta south of the main river (dominated by *Avicennia marina, Rhizophora mucronata, Ceriops tagal, Bruguiera gymnorrhiza, Xylocarpus granatum, Sonneratia alba)*. Other mangrove areas include Tunza, Tudar Creek, Funzi bay, Mtwapa creek, Shimoni, Majorani, Vanga-Jimbo, Ozi, Mteza and Mwache creeks.

Social, economic and ecological importance of Tana Delta mangrove

Mangrove forests in the Tana River area are of significance spanning from social-economic to ecological importance especially to the local indigenous people who over the years have created intriguing relationships with the local environment. Mangrove ecosystems have been recognized as an important food source in food chains for fish and the value of mangroves for fisheries is five times greater compared to alternative uses. Aksornkoae (1993) observed that mangrove contributes nutrients to the ecosystem, provide shelters and nurseries for fish and help support extensive aquatic species. Tana Delta is tremendously rich in fish with more than 40 species recorded in it some of which are endemic such as the feather-barbelled squeakers (Swara Newsletter, 2001). Fishing is an important source of food and employment. The local fisher folks (Malakote minority community) depend on the delta fish for their livelihoods. In Kipini, fish is consumed in almost every meal and very early, before dawn, you will see fishermen with their night fish catch walk into the village across the mangrove trees, some to their home and others to the market places but not before preserving the fish through smoking, using as fuel *Bruguiera grmnorrhiza* and *Avicennia marina* mangrove tree species.

The local indigenous people have over the years used mangrove trees as fuel wood and building materials. The most commonly used species are *Avicennia marina* and *Ceriops tagal*. These and other tree species also provide poles and rafters for the construction of traditional huts, which are commonly round in shape and made of mud. Traditionally, the mangrove tree species *Xylocarpus granatum* has been used by local medicine men to remedy various human diseases. Its stem pulp is applied to cure skin infections and rashes, and its seeds are used in treating stomach problems and in inducing abortion. However, as observed by Aksornkoae (1993), the traditional medicinal value of mangrove has not received much scientific investigation and experiments.

Other non-monetarily measurable benefits of mangroves at the local level include the provision of habitats to animals and birds and branches for beehives siting especially the *Avicennia* and *Ceriops* species. The leaves of *Avicennia marina* are used as fodder for goats, camels and cattle. They, further, offer good sites for educational and scientific research programmes and support recreation and eco-tourism activities due to their aesthetic value. Moreover, mangrove helps to stabilize shorelines of Indian Ocean and estuaries by protecting them against tidal bores and soil erosion. Other indirect benefits include filtering of nutrients, and protection of hinterlands from salt intrusion (currently witnessed in the Tana Delta due to reduction of mangrove cover).

Threats to mangrove survival

Despite the Tana Delta's value and benefits, the diversity and richness of its mangrove vegetation has faced threats of degradation and continues to be a hot spot for

unsustainable commercial and sectorial economic development. In the early 1990s, a multinational company was allocated land in the Tana Delta to develop shrimp farms by the government. This allocation was followed by a wide and organized protest by the local communities and environmentalists, who referred to the negative effects this could cause to the mangrove ecosystem and which announced that this would abuse traditional land rights of indigenous local communities. The Kenyan government acknowledged these pleas and, through a Presidential decree, stopped the project. Litigation between the company and the government remains however unresolved, and there are fears that the company might restart the shrimp farm project in the future.

During the same period, a lot of mangrove forests were cleared for the development of rice plantations. Although the impacts of this activity were not established at the time, this has no doubt had negative effects on the natural ecological setup. The rice growing scheme was discontinued after the 1998 El Niño catastrophe, the severity of which has been largely attributed to climate change. Recently however the government has made plans to re-establish the rice growing scheme to remedy growing food insecurity in the country.

Further serious threats to the coastal mangrove ecosystems in the Tana River area arose in 2004 with the earmarking of the delta as prime land for two large-scale multi billion dollar sugar cane projects. In mid 2007, the *pro* conservation lobby and local communities went to court to stop one of these projects, but on 18th June 2009, the Malindi High court ruled on technical grounds in favor of the project. The contesters have expressed fears that the project will have grave negative effects, as it will result in massive clearing of mangrove forests and other natural coastal vegetation in the area and in the use of the waters of the already shrinking Tana River and related wetlands to irrigate more than 2000 km^2 of sugar cane plantations. The activities are bound to negatively impact the already economically marginalized indigenous communities and to cause adverse effects on the ecological systems downstream. Among the biodiversity that will be negatively affected are; marine turtles, sharks (3 species listed as endangered by CITIES) and birds.

Currently, a large mangrove area in the coastal province has been cleared for salt production. To-date, the area covered by the salt pans exceeds 6,500 ha, and this area shows an increasing trend. The situation in this area will further deteriorate if a proposed Titanium mining and oil exploration project in the Tana Delta were to be realized.

In addition, due to legislation inadequateness, the rampant indiscriminate illegal harvesting and unsustainable use of the Kenyan mangrove resource go uninhibited. For instance, whereas mangrove and terrestrial forest are put together under the Kenya Forest Act 2005, the Kenya Forest service puts more emphasis on terrestrial forests than the mangrove forests which are thus neglected. Mangroves of the Tana Delta are particularly vulnerable because unlike others of Kiunga, Shimoni, Vanga and Mtwapa that occur within marine protected area, they do not have a protected status.

The future of Tana delta mangrove

Unsustainable development of this region will have negative impacts on mangroves ecosystems, and may be further aggravated by effects of climate change. In this regard, unless urgent action is taken to reverse present trends, the fragile mangrove ecosystems

which have been slowly recovering from the El Niño phenomena of 1998, will be affected severely by both possible climate change impacts and anthropogenic interference.

Consequences include de *facto* reduction in river stream flow and changes in water PH, negative effects from the clearing of vegetation to give way for sugar cane and other monoculture plantations, solar salt pans, and agricultural and industrial pollutants from unsound development schemes. The livelihood of indigenous and minority communities who have over the years lived and depended on the dynamism of the rich Tana Delta ecosystems will suffer as a consequence. Equally at stake is the conservation of a rich mangrove flora and fauna, which includes some species, listed as vulnerable and threatened.

There is hope on the ongoing designation of Tana Delta as a Ramsar site spear headed by the Kenya Wildlife Service. This may help in protecting this ecological region from the growing human interferences especially in curtailing the establishment of commercial plantations. This not withstanding, there is critical need for a multiple land use development master plan incorporating communities and other stakeholders' interest. The master plan should offer the guidelines in sustainable development of Tana Delta and its resource as well, respecting the rights of all groups. Contrary to such stakeholder concessions, Tana Delta will continue to be a battle field and as the old Swahili saying goes; *wapiganapo fahari wawili, siumiazo ni nyasi* (whenever bulls fight, it is the grass which suffers most). The rich resources of Tana Delta, its mangrove ecosystems included, will bear the brunt.

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Developing a technique to plant *Avicennia africana* at *La Somone* lagoon (Senegal)

Jean Pierre Ngor Ndour[1], *Cheikh Mamina Diédhiou*[2] *and Mamadou Fall*[3]

Summary

At La Somone, the deterioration of the mangrove is related to the recurrent drought in the 1970s and the closure of the Lagoon in 1987 (Ndour et al., 2002). In order to rehabilitate the ecosystem, combat engineering intervened to reopen the lagoon in 1987 while women had planted Rhizophora mangle in 1995. Recently, the State and its partners, including the International Union for Conservation of Nature (IUCN) and the Japanese Cooperation (JICA) have collaborated to develop a technique for planting the species. This required the selection of a site where Avicennia africana grows on sandy loam mud flats just like Avicennia officinalis in Vietnam (Untawale, 1996). However, the species also grows on sandy-clay mud flats in La Somone (JICA, 2004). The diaspore(seed) germination test resulted in 100% for the set of planting techniques. The survival rate (94.7%) of 1.5 month-old seedlings at weaning is comparable to survival rates (80 to 90%) obtained with Avicennia marina (Saenger, 1996). The growth of the species is similar to that of Avicennia officinalis according to Siddiqi and Khan (1996). The results obtained are a sign of a good extension of the technique and of important ecological and socio-economic impacts.

Introduction

The experimental site is located in the Senegalese coastal area (Figure 1) where it is still possible to observe sources during the rainy season between the dry land and the mangrove. The climate there is dry with a wet season lasting three months. The species of mangrove are *Rhizophora mangle, Avicennia africana* and *Conocarpus erectus.* In Senegal, the degradation of mangroves has reached an alarming stage (Soumaré, 1992; IUCN, 1999; Ndour *et al.*; Ndour, 2005). Aware of this degradation, the Senegalese government, populations and development partners have undertaken to restore the mangroves. Together, they have put in place cooperation and intervention mechanisms and developed restoration techniques for the degraded areas. Women greatly contributed in restoring the *Rhizophora mangle* mangrove and it is believed that the *Avicennia africana* degraded stands could also be restored using a well developed planting technique. The optimism is based on the optimal salinity of the species which is between 10 and 70‰ and can exceptionally reach 90‰ in some conditions (Schenell, 1971).

[1]*Jean Pierre Ngor Ndour, Associate Lecturer, Research Professor at the Agroforestry Department of the University of Ziguinchor in Senegal. Email: ngor_ndour@yahoo.fr Tel: (221) 77 553 32 03*

[2] *Cheikh Mamina Diédhiou, Email : cheikhmamina@yahoo.fr* Tél : (221) 77 525 28 35

[3] *Mamadou Fall, Forestry Officer, Project management Advisor, Email: Ma_fall@hotmail.com Tél : (221) 77 555 33 25*

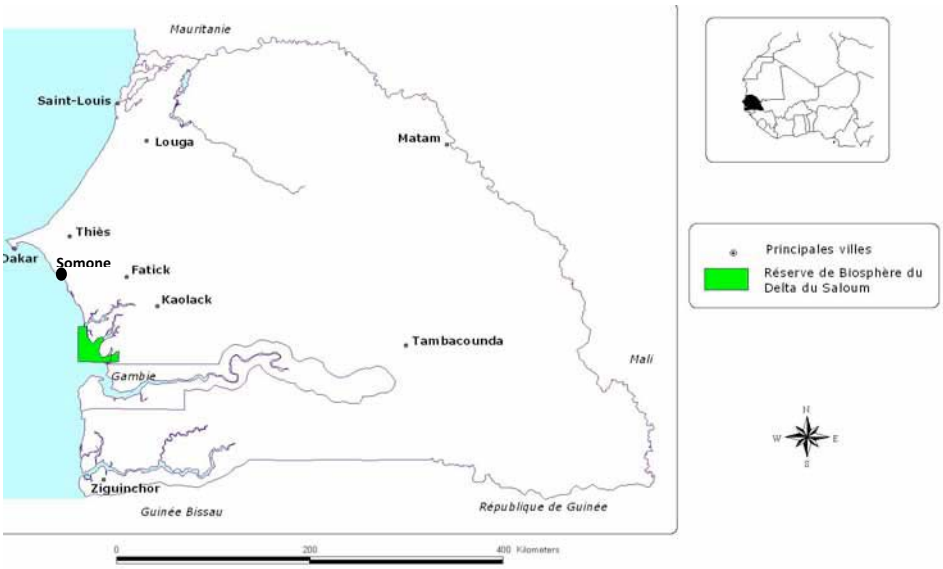

Figure 1: Geographical position of La Somone

Equipment, methods and results of the planting technique

Equipment and methods

The experimental site was selected on the basis of a study of the nature of mangrove landscape using aerial topography, water salinity measurements and observation of the frequency of mud flats submersion at various tides. The planting technique involves the establishment of a nursery at an area submerged by a high tide. The nursery should have a shade and should be fenced by a 12mm mesh net to keep fishes and crabs away from seedlings. The base of the net is buried at a minimum of 5cm depth in the mud. The seeds are then re-potted with mud up to 1cm from the edge (Roussel, 1995). This is done at least three days before sowing the diaspores (mangrove seeds) in order to facilitate the compaction and stabilization of the mud in sachets (Ndour *et al.,* 2003). Seeds are harvested between July and September, coinciding with the seed maturation period. During harvesting, the best quality seeds are selected based on their tegument color. They are then pre-processed by immersion of their water permeable content in the tidal land area for 4 to 7 days to trigger their germination. According to Evenari (1961), this procedure is justified by the fact that germination ends with the beginning of the extension of the radicle. Following the selection, seeds are sown inside pots in seed holes cut in the middle and having the same dimension with the radicle. The radicle is then pushed into the seed hole which is firmly closed to prevent the seed from being torn out by tides. Monitoring the nursery involves controlling the development of seedlings, recording the number of germinations, the constraints to germination and verifying the functionality of the nursery protection mechanism.

The weaning of seedlings was done 1.5 months after sowing (Figure 2) on a protected site by a net having the same dimensions with that of the nursery and with the same installation techniques. The reason is that the leaves of the seedlings are tender at that age and palatable to fish (carps) and oxen. The gap between seedlings and the lines is 2m

wide; while the height of the maximum submersion of planting sites is 35 cm. The forms of life and habitat on the sites are recorded in order to establish the baseline reference regarding bioecological conditions of the area.

Figure 2: Seedlings weaning at 1.5 months of age

Monitoring the planting involves checking the stability of the fence and recording the height and diameter of seedlings using a measuring tape every month during the experiment. The existing forms of life and the development of their population afterwards are recorded in order to perform a quality or quantity assessment of ecological impacts. The monitoring-evaluation of plantations also involves assessing the socio-economic impacts related to the development of mangrove resources. This monitoring-evaluation was organized two years after planting in the context of the support to research with funding from IUCN on behalf of the Institute of Environmental Sciences (IES) of the Cheikh Anta Diop University of Dakar (UCAD).

Results of the experiment

Mud flats on the planting site are sandy-clay and submerged during all high tides. The submersion which varies between 16 and 35 cm is often null during high tides in the dry season. The salinity of the river varies from 28 to 40 g/l. The highest values are recorded during the dry season. Quality seeds are characterized by a yellow tegument color that changes to grey after falling to the ground. When the tegument color changes to black, the diaspores' (seeds') viability reduces in view of the irreversible dehydration (Figure 3).

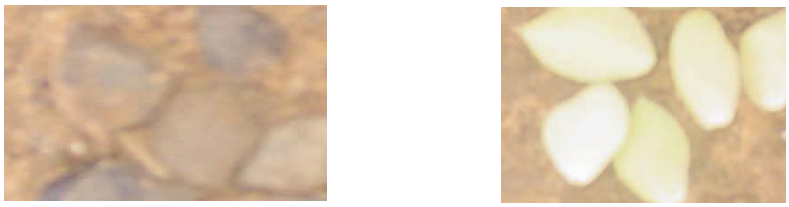

Figure 3: Black seeds on the left; yellow seeds on the right.

The germination of *Avicennia africana* diaspores in the above mentioned conditions resulted in a 100% success rate. The main constraints to the germination of seedlings are the sea currents which destabilize diaspores sowed in pots, while terrestrial crabs (*Cardisoma armatum*) pull or cut seedlings stems which subsequently die. The diaspores pulled out by sea currents are generally trapped by the nursery fence. Collected during the monitoring, they are once again sowed in the pots. Seedlings that escape these challenges

are grown in nurseries for 1.5 months. Their average size during transplantation in actual habitat was 16.2 cm and their survival rate was 94.7%. A stability index of more than 90% for the survival rate of seedlings was recorded 5 months after transplantation. The monitoring-evaluation performed in 2005 shows that seedlings reached an average growth of 51.1cm/year. With an average height of 1.18m, the appearance of the plantation's landscape begins to change (Figure 4).

Figure 4: Landscape of the Avicennia Africana plantation

Regarding ecological impacts, there is a proliferation of fiddler crabs (*Uca tangeri*) and land spiders in the area. There is also a proliferation of pneumatophores, creating a barrier conducive to the retention of seed of fertile root stocks. This facilitates the proliferation of the species given that the young stocks start yielding fertile seeds after one year (Figure 5).

Figure 5: Young fertile stock

The production of seeds by plants at 3 years of age, is a favorable result to the *in situ* regeneration of the species. Among other impacts, there is the compacting of mud flats by a creeping root system (pneumatophores) minimizing the erosion of mud flats on the plantation site. No socio-economic impact was recorded during the monitoring-evaluation. However, during the lean period, oxens visit the reforested sites to graze the leaves of the young seedlings. The teeth of cattle cause damages viewed as one of the major constraints to the success of plantations.

Discussions

The mangrove in La Somone plays the role of ecological niche for various species, spawning ground for fishes, and shelter and habitat for water birds. At socioeconomic level, it is a site for fishing and for the collection of cockles and oysters. It represents one of the main tourist attractions of the area with an ever-growing space in view of the plantations.

For purposes of comparison, *Avicennia africana* in Senegal grows on sandy-clay mud flats just like *Avicennia officinalis* which grows in the same type of environment in Vietnam (Untawale, 1996; Ndour *et al.*, 2004; IUCN, 2004; JICA, 2004). The maximum submersion height at which *Avicennia africana* was planted is 35cm. However, it reached 65cm at the beginning of plantation trials in 2002. It was concluded that the lower the mud flats submersion heights, the better the results. This situation corroborates the trend of the species to cover lower slope sites in mangrove areas. That preferential position inherent in the biophysical and anatomical nature of the seed, partly explains the distribution of the species in the mangrove ecosystems (Ndour *et al*., 2003). In Senegal, *Avicennia africana* seed should be harvested between the months of July and September. That period coincides with the harvest of *Avicennia alba* or *Avicennia officinalis* seeds in Vietnam according to Hong, 1996.

Regarding the quality of seeds, even though species are different, the identification criteria of good diaspores are almost similar in Senegal and in Vietnam. Goods seeds are identified by their yellow tegument when mature and their easy removal from the seed tree (Ndour *et al*., 2003; Hong, 1996).

The germination rate of seeds obtained in 2003 is 100% for all the plantation techniques. The survival rate (94.7%) of seedlings aged 1.5 months at weaning is similar to the survival rates (80 to 90%) obtained in Australia with *Avicennia marina* (Saenger, 1996). Regarding survival rates of seedlings before weaning, the various experiments show that the longer their stay in nurseries, the lower their survival rates during transplantation. Therefore, the technique of *Avicennia africana* plantation through raising seedlings followed by a transplantation of 1.5 month-old seedlings was the most successful technique. Among other techniques, there is the direct sowing, on mud flats, on balls and in pots followed by transplantation at more than 1.5 months (Ndour *et al.*, 2004).

Regarding height growth, the best results (49 to 51.1cm/year) were obtained with seedlings raised for 1.5 months before transplantation. The rates obtained with other techniques are more reliable (15 to 44.2 cm/year). According to studies by Siddiqi and Khan in 1996, these annual growth rates are close to those obtained with *Avicennia officinalis* (34 to 65 cm/year), Avi*cennia marina* (36 to 53 cm/year), and *Avicennia albida* (32 to 47 cm/year).

Other forms of life of apart from plants that appeared with the rehabilitation of the mangrove ecosystem are the seedling devouring grasshoppers and spiders that spin webs to catch and consume insects. This rehabilitation is also followed by the arrival of water birds.

Among the constraints to the restoration, could be mentioned tidal currents, predators (crabs and carps) and the cattle (oxen). Among other constraints, there are stony or sandy

soils that are not favorable to the survival of seedlings (Ndour et al., 2004). In spite of these obstacles, the results obtained are a sign of good prospects for the extension of restoration practices of the species on the coastal areas of Senegal.

Recommendations

The prospects of ecological and socio-economic impacts of plantations deserve a monitoring of plantations for at least 10 years for a better knowledge of the silviculture of species. In some cases, there is a need to examine the necessity to first restore the hydrographical network in order to improve the outcomes of mangrove plantations.

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Rehabilitation of mangroves between Fresco and Grand-Lahou (Côte d'Ivoire): Important fishing areas

Mathieu Wadja Egnankou[1]

Summary

Even though Côte d'Ivoire is one of the most botanically studied francophone African countries, mangroves are not well known. In spite of the important ecological and socio-economic role they play, they do not enjoy the attention they deserve and are deteriorating at a disturbing rate along the coastline. The mangroves lying between the cities of Fresco and Grand-Lahou play a vital role in supplying fish to the population centers of Abidjan (with about 5 million inhabitants) and Yamoussoukro. These wetlands which feed 60% to 80% of coastline communities are threatened with extinction by the indiscriminate logging and by poison fishing.

Twenty years ago, the mangroves between Fresco and Grand-Lahou boasted a surface area of 15,000ha. Today however, they hardly reach 6,000ha. Red mangroves (Rhizophora racemosa) and white mangroves (Avicennia germinans) tree formations are increasingly being replaced by a herbaceous stratum (Paspalum vaginatum) or shrub stratum (Drepanocarpus lunatus and Dalbergia escastaphyllum). In view of this deterioration, during recent years, there has been a reduction in fisheries productivity, exacerbating poverty among the communities, particularly among the youth and women.

In order to rehabilitate the ecosystem and restore fish stock, we carried out silvicultural activities on that section of the Ivorian coastline. These activities included enrichment planting.

Introduction

Known as mangroves, the forest ecosystems of tropical tidal areas are spread along the Ivorian coastline, from East to West, from Assinie-Mafia to Bliéron. They are located approximately between longitudes 2° 50' and 7° 59' west and latitudes 4° 30' and 5° 40' north.

They have played and still play an important role on the entire Ivorian coastline: their wood is used in building houses and in arts and crafts, in manufacturing tools for making fishing nets and especially as fuel wood. The bays and numerous channels are vital fish reserves. Water bodies and the rich biodiversity of these wetlands provide significant income through the development of tourist activities.

Unfortunately, the ecosystem is threatened with extinction by severe anthropogenic pressures: anarchic logging, poison-fishing and the closing of passages linking lagoons to the marine environment. In spite of scientific progress achieved in the knowledge of Ivorian forest ecosystems, mangroves still remain unknown. Indeed, authors such as Adjanohoun, 1962 and 1965; Guillaumet, 1967; Ake-Assi, 1982 and Paradis, 1988 have devoted a few 'studies' on the subject, but these were too few and limited to provide key

[1] *Mathieu Wadja Egnankou, Lecturer and Researcher, University of Cocody, Abidjan, Chairman of the NGO SOS- Forêts. 22 BP 582 Email: wadjaegnankou@hotmail.com*

information on the ecosystem. These authors studied the physiognomy of savannah formations, floristic composition of coastal forest and the development of aquatic and sub-aquatic groups. For example, the cartography that could have enabled researchers and natural resource managers to have an overview of its scope and consider adequate development has not been realized yet and the ecosystem is gradually deteriorating along the entire coastline.

Egnankou, 1985 and 1987 drew attention to the issue of extinction of the mangroves. The consequences of that potential extinction and the disorganization of physicochemical data on fisheries were studied in 1997 by the same author who also analyzed the possibilities for its development. The study underlined the predominant role of lagoons' outlet in the development of mangroves along that section of the Ivorian coastline. Actions carried out by the NGO SOS- Forêts from 2001 to 2003 have maintained the opening of the N'Gni Lagoon passage in Fresco up to this day. They still had to rehabilitate the tree cover in order to fulfill the needed ecological conditions for the restoration of biologic diversity.

This study is the first of a series the author has planned to carry out to improve the knowledge base of Ivorian mangrove ecosystem including those of its wildlife, fisheries and water resources comprising the rich bionetwork.

Geographic location of the study site

The study is about the section of the coastline between the cities of Fresco and Grand-Lahou. It is located approximately between longitudes 5° 38' and 4° 50' west and latitudes 5° 6' and 5° 20' north. (Figure1).

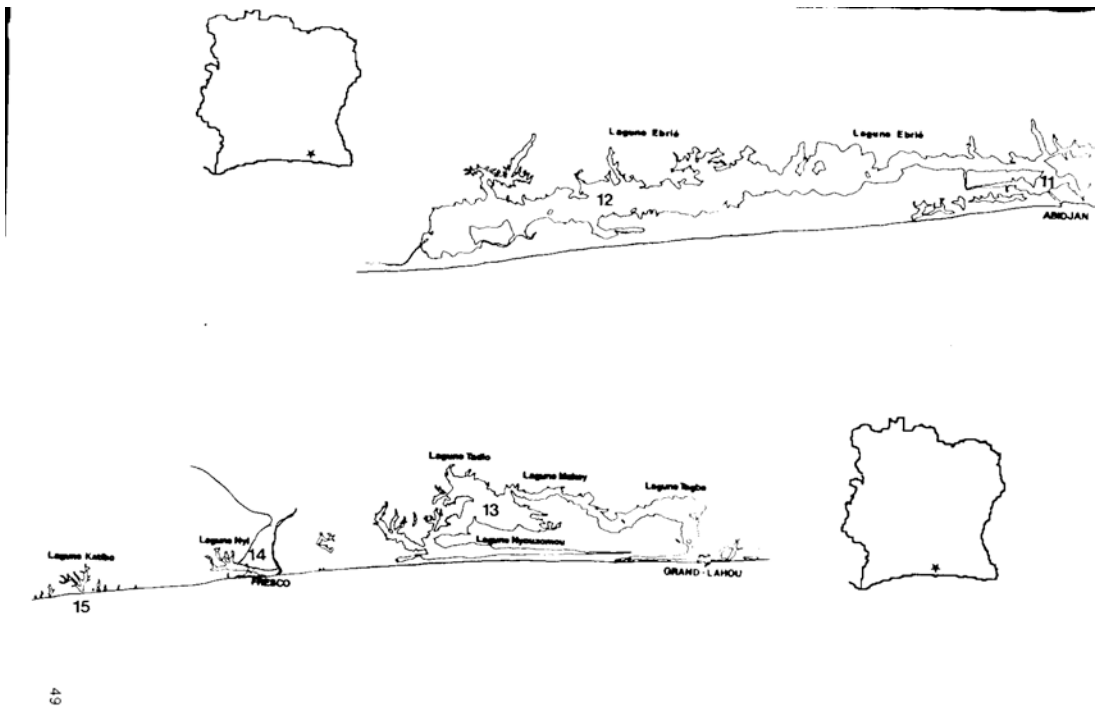

Figure 1. Location of study site: coastline between the cities of Fresco and Grand-Lahou in Côte d'Ivoire Scale : 1/1 000 000 Source : (Egnankou et al, 1989)

Equipment and methods

For successful silvicultural activities, basic data should be known and controlled. Data concerning the chemistry of the water and its physical characteristics, the vegetation and the hydrological network, were examined in a preliminary study. The equipment used was as follows:

- An Atago salinometer; 0 – 28% calibrated at 28°C at the Botanical laboratory. The water sampling is done with a syringe at a depth of 20cm. The interstitial water is also collected at a depth of 20cm but in holes dug in the mud.
- pH measurements were done with a pen-type pH-meter with a precision of more or less 0.5pH. The pH is directly obtained by dipping the pH-meter in the sampled water in conditions similar to those of the salinity measurement;
- The study of vegetation was done through the Duvigneaud topographic transect method. Sampling is done on each side of a rope stretched on the open water surface to the temporary or permanently flooded banks on a surface deemed sufficiently homogenous. The research team then identified all the plant species along the rope, by carefully sampling some of them for verification at the laboratory. The use of aerial photos the researchers took on board a CESNA single-engine aircraft enabled them to have data for drawing a map of the mangroves of that section of the Ivorian coastline.
- The sites for reforestation (enrichment planting) were chosen on the basis of their daily and regular submersions by brackish-waters;
- The red mangrove *Rhizophora racemosa* (Rhizophoraceae) was preferred to other mangroves [e.g. *Avicennia germinans* (Avicenniaceae) and *Conocarpus erectus* (Combretaceae)] because the harvesting of single-species mangrove involves only that species of which the excellent quality wood is used for various purposes;
- In view of the viviparity of *Rhizophora racemosa*, the harvesting, storage and/or transport of seedlings were carried out as follows: (i) Propagules are either harvested on the tree (according to a maturity index based on the color of the seed and especially on resistance to touch, because when mature, the seed falls when touched), or harvested while floating on the water; (ii) when transportation is over a long distance, the research team performs the first processing of the seeds and their storage in a shaded area subject to high tides and low tides during 5 to 15 days; seeds (germinating seeds or seedlings)are then sown at about 1m intervals. To assess the germination capacities of seeds, 5,000 seeds were directly harvested on trees; 3,000 of them were already germinating and were uprooted to be transplanted in experimental lots and 2,000 floating seedlings were collected.
- The monitoring of the plantation is done regularly through measurements and the counting of vegetative organs (e.g. leaves) and of the number of surviving seedlings.

Results

The results concerning the salinity, flora, vegetation and mangrove reforestation are as follows:

Water salinity

Water salinity is reported in Table 1 below. The pH is indicated in Table 2.

Table 1: Water salinity in the mangroves of Fresco and Grand-Lahou (in g‰)

Distance to the passage (in km)	IMMERSION WATERS		IMMERSION WATERS	
	Fresco	Fresco	Grand-Lahou	Grand-Lahou
	Dry season	Rainy season	Dry season	Rainy season
0.50	28‰	10‰	25‰	8‰
4.00	22‰	8‰	22‰	6‰
6.50	20‰	6‰	18‰	6‰
8.00	15‰	2‰	17‰	4‰
10.00	10‰	00	5‰	1‰
15.00	00	00	00	00
20.00	00	00	00	00

Table 2 : pH of waters

Distance to the passage (in km)	IMMERSION WATERS		IMMERSION WATERS	
	Fresco	Fresco	Grand-Lahou	Grand-Lahou
	Dry season	Rainy season	Dry season	Rainy season
0.50	8.00	7.29	7.00	6.00
4.00	7.20	7.18	7.00	6.00
6.50	7.00	7.90	7.00	5.50
8.00	7.00	6.55	5.50	5.00
10.00	7.80	6.90	5.00	6.50
15.00	7.90	7.00	6.50	7.00
20.00	7.90	6.20	6.20	7.00

A study of Table 1 shows that salinity decreases from the estuary of the water bodies or the outlets of lagoons towards more remote sites. On the other hand the pH variation is disorganized thus showing the possible influence of other parameters to be underlined by other studies.

Flora and vegetation

The study of vegetation through transects revealed 3 types of association between mangroves. These associations are as follows:

- A mono-specific mangrove of *Rhizophora racemosa* (Figure 2), a deteriorated mangrove of *Avicennia germinans* only accompanied by *Paspalum vaginatum* (Poaceae) and a mangrove of two species of *Avicennia germinans* following *Rhizophora racemosa* toward the land. These mangroves formations are found both in lagoon mangroves (all around Fresco and Grand-Lahou lagoons) and in estuarine lagoons (at the estuary of the Bolo, Niouniourou and Bandama rivers);
- A herbaceous formation where *Paspalum vaginatum* (Poaceae) represents, depending on the site, between 95 and 100% of the vegetation cover. This include: *Mariscus ligularis*, *Cyperus articulatus*, *Pycreus polystachyos* (Cyperaceae), *Ethulia conyzoides* (Asteraceae), *Echinochloaz pyramidalis* (Poaceae), *Sporobolus virginicus* *Fimbristylis thonningiana* and *Fuirena umbellata* (Cyperaceae) species;
- A *Drepanocarpus lunatus* and *Dalbergia ecastaphyllum* formation in upper-mangrove contains numerous shrubby and tree species among which are: the *hibiscus tiliaceus* (Malvaceae), *Acrostichum aureum* (Adiantaceae), *Ceasalpinia bonduc* (Ceasalpiniaceae), and *Nauclea latifolia* (Rubiaceae).

Figure 2: A mono-specific mangrove swamp of Rhizophora racemosa in Ebonou, west of Grand-Lahou lagoon complex (Photo EGNANKOU, 2007)

Reforestation

Concerning reforestation, five months after the seedlings had been transplanted, the following results were recorded:

- Of the 5,000 germinating-seeds harvested on trees, only 1,000 germinated and continued growing, representing a 20% success rate;
- Of the 2,000 floating-seedlings harvested on the water, 1,500 developed leaves during the first three months and continued growing, representing a 75% success rate;
- Of the 3,000 wildlings (seedlings growing on forest floor through natural regeneration) uprooted and transplanted on reforestation sites, 2,950 continued growing, representing a 95.66% success rate.

The best yields were obtained with seedlings growing wild on forest floor (wildlings) followed by the seedlings collected on the water surface (germinated seeds floating on water). In spite of their maturity and the precautions taken, germinating-seeds harvested on trees were only 20% successful, leading us to opt for the use of established seedlings. These seedlings are obtained either by natural regeneration (wildlings collected under trees) or by the establishment of nurseries (Figure 3). Thus, after installing experimental stations in the south of the N'Gni lagoon, the research team led the reforestation of a total of one hundred hectares of mangroves along the Ivorian coastline.

Figure 3: Rhizophora racemosa nursery at Fresco (Photo EGNANKOU, 2006)

Discussions

Ivorian mangroves in general and those lying between Fresco and Grand-Lahou in particular, are threatened with extinction due to a lack of knowledge. As a result of large-scale logging, entire stands have disappeared and have been replaced by *Paspalum vaginatum* grasslands. Others are in the process of disappearing; in the 1960s, the city of Grand-Bassam was characterized by huge forest ranges along lagoons mainly made up of 25 meters high *Rhizophora racemosa* red mangroves (Rhizophoraceae). The Azuretti mangrove near Grand-Bassam used to contain an important fringe of *Conocarpus erectus* grey mangrove (Combretaceae) in upper-mangrove and of beautiful *Avicennia germinans* white mangrove (Avicenniaceae) (Ake-Assi, 1987). Today these mangroves in the Eastern part of the Ivorian coastline are represented only by sparse red and white mangroves. The grey mangrove is absent in these regions where coconut groves and other building sites have considerably encroached on the mangrove ecosystem. In Fresco and Grand-Lahou, it is noted that the reduction of the mangrove ecosystem surface area has led to the reduction of fisheries resources in the zone through the reduction of catches by fishermen (Egnankou, 1989 and 1997).

The level of degradation of mangroves is now obvious in the coastline between Fresco and Grand-Lahou, and has led the author and his team to start rehabilitation activities by reforesting.

The high percentage of success achieved through the use of wildlings motivated the team to establish more mangrove nurseries with wildlings. Indeed, while more than 95% of wild seedlings uprooted and transplanted have continued growing, the germinating-seeds harvested on trees and seedlings harvested on the water (i.e. seeds germinated while still attached to tree, then falling into water for further development) have respectively yielded 20% and 75%. As suggested by Baglo, 1989, seedlings harvested on the water present above average germinative qualities, however, it is necessary to underline that the transition through nurseries can represent an efficient method in reforesting mangroves. It increases the germination rate and also enables the nursery worker to perform a first selection; poor quality seedlings are thus eliminated in the nursery. Moreover, nurseries have a double advantage: they not only enable to increase the success rate but are also an efficient method to preserve seedlings in all seasons for a large-scale and all-season reforestation.

Conclusion

Mangroves play a vital role for coastal communities. They ensure the richness of fisheries and provide communities with wood to build their houses and many other products. They are suitable for the reproduction of many aquatic animal species, be they marine or inland waters.

This highly productive ecosystem, however, is subjected to the negative effects of human activities in Côte d'Ivoire in general and in that section of the coastline in particular. These activities have eventually destroyed about 50% to 70% of these coastal wetlands.

In spite of numerous botanical studies on Côte d'Ivoire, mangroves are still not well known. They do not enjoy the protection they deserve and are gradually being degraded under the combined and constant pressures of over-logging and unsustainable use of aquatic resources.

With a view to restoring the biological diversity of the mangrove ecosystem in Côte d'Ivoire, the team carried out these research and reforestation operations. Today, about one hundred hectares of mangroves have been reforested. The research team intends to draw the complete cartography of all the mangroves in Côte d'Ivoire. Moreover, the team aims to establish a Geographical Information System in order to provide relevant biological information to policy-makers for the development of the coastline area.

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