West African Coastal Area: Challenges and Outlook

Jean-Jacques Goussard and Mathieu Ducrocq

Abstract

The Economic and Monetary Union of West Africa—WAEMU, instructed by its Conference of Environment Ministers, with the assistance of the International Union for the Conservation of Nature—IUCN, the consultancy firm EOS.D2C and the Coastal Ecosystems Group of the Commission on Ecosystem Management, undertook a vast diagnostic and prospective study on coastal risk study including the formulation of proposals for rethinking the development of the West African coastal strip, from Mauritania to Benin (SDLAO, UEMOA–IUCN 2011). This study highlights the general trends that will characterise these coastal systems by 2030 and 2050. These trends are based on the fragility of coastal systems, urban and industrial developments, and uncertainties related to climate change in a context where the sedimentary deficits are compounded by large dams and growing demand for construction materials. The importance given to green infrastructure and soft, natural solutions, assuming their conservation, and sometimes restoration, was emphasised in the conclusions of the study, as was the necessity of building capacity in terms of observation and anticipation, in order to steer development decisions on different scales, from regional to State to local authority. The complexity of the mosaic of estuarine habitats determines their sensitivity to any changes in the environmental conditions and positions the estuarine zones, which are generally populated, as sentries for the marine environment, but also for the management of the upstream river basins. The subtle geography of the estuaries and, more generally, of fluvio-marine systems (lagoons, deltas, etc.) should also teach us how to better employ the various dimensions of the rich notion of coastal area and lay the foundations of a kind of development and planning that is integrated into the natural land matrix, buoyed by it and respectful of it.

Keywords

Coastal spatial planning • Coastal erosion • West Africa • Ecological services • Coastal risk management

The myth of a predominantly continental Africa "with its back turned to the sea (Pelissier 1990)" would appear to have worn rather thin. The development, in colonial times, of major urban centres, practically all on the coast, subsequently relayed by post-independence developments, and the migrations consecutive to the droughts in the 1970s and 1980s have given the West African coastline all the appearances of a veritable pioneering front.

J.-J. Goussard (✉) · M. Ducrocq
Coastal Ecosystems Group of the Commission on Ecosystem Management, IUCN, Gland, Switzerland
e-mail: jj.goussard@eco-evaluation.org

M. Ducrocq
e-mail: mathieuducrocq@gmail.com

S. Diop et al. (eds.), *The Land/Ocean Interactions in the Coastal Zone of West and Central Africa*, Estuaries of the World, DOI: 10.1007/978-3-319-06388-1_2,

While certain segments of the West African sea front have long been settled by traditional maritime peoples (the Balante in Guinea Bissau, the Lebou in Senegal, the Imraguen in Mauritania…), this is where colonial history left its mark, first of all through the trading posts, motivated by the mining of the natural and geological resources of the hinterland.

Until today, this exploitation of natural resources and customary usage values have been the main drivers of the development and use of West African coastal areas. Today, the need to protect people and goods, in a concept of security and social progress, imposes to revisit the relation between African societies and their coastal lands; this is true in particular for estuarine areas, interfaces between maritime trade and continental resources, which were historically the pioneer centres of coastal settlements and of the investments of the major economic sectors.

The acceleration of the building of new facilities, the urban extensions and densification with associated environmental deterioration, arouse the fear that part of the development potential associated with coastal ecosystem services will deteriorate over the coming decades. Furthermore, against a background of climate change which no longer leaves any doubt as to the eventuality of a gradual rise in sea level, the question of the risks of natural catastrophes in coastal areas becomes more strident.

The Economic and Monetary Union of West Africa—WAEMU, instructed by its Conference of Environment Ministers, with the assistance of the International Union for the Conservation of Nature—IUCN, the consultancy firm EOS.D2C and the Coastal Ecosystems Group of the Commission on Ecosystem Management, undertook a vast diagnostic study of the situation including the formulation of proposals for rethinking the development of the West African coastal strip, from Mauritania to Benin (SDLAO, UEMOA–IUCN 2011).[1] The importance given to green infrastructure and soft, natural solutions, assuming their conservation, and sometimes restoration, was emphasised in the conclusions of the study, as was the necessity of building capacity in terms of observation and anticipation, in order to steer development decisions on different scales, from regional to State to local authority.

[1] http://www.iucn.org/fr/propos/union/secretariat/bureaux/paco/programmes/programme_marin_et_cotier__maco/projets/thematique__amenagement_integre_du_littoral_/erosion_cotiere_et_schema_damenagement_du_littoral_ouest_africain/

Human Land Use Rapidly Becoming More Dense in the Coastal Areas

Sub-Saharan Africa is the last region in the world to undergo demographic transition. This process implies a population multiplied by a factor of almost ten between 1950 (approximately 180 million) and 2050 (more than 1.7 billion according to United Nations forecasts). The total population growth rates rose from 2.3 % in 1950 to 2.6 % in 2000. Forecasts predict a rate of 2.2 % in 2025 followed by a decrease to 1.7 % in 2050. This tenfold increase in the population of Sub-Saharan Africa will be differential and heterogeneous, with some desert areas or areas already densely populated to the point of saturation being evidently less concerned. Human land use in the coastal areas expresses the diversity of the living systems and systems of production (Fig. 1).

The current human footprint on these coastal areas appears to be dominated by the concentration of population and economic stakes related to the (i) urbanisation and its forerunners (communication routes, alleviation from isolation, electrification, recent changes in artisanal fishing strategies, etc.); and (ii) rapid development of tourism and residential areas, often on the periphery of urban areas. Access to water in dry areas also constitutes a key factor in organisation and distribution and in the growth of human settlements. The acceleration of the often anarchic and spontaneous use of coastal land is all the more pronounced as land ownership control often remains unclear, given that such areas were still rural a short time ago, where legal pluralism prevails in terms of land ownership (customary law and modern law). This human land use of the West African coastal areas is expressed in different ways:

Development of Built-up Areas and Urban Areas

A remarkable fact is that the coastal zone (arbitrarily defined here at a width of 25 km inwards) concentrates slightly more than half of the total urban population of the coastal countries in around one-twentieth of the total surface area of these countries. This proportion seems to be very gradually declining, from 57 % in the 1960s to 53 % in 2010. As an order of magnitude for West Africa, the average standard is 150 m^2 urbanised space per urban inhabitant (excluding parks, water features, land where building is not authorised, or which is not yet developed or inhabited). However, the footprint of the agglomerations is greater than built-up land area alone. According to the AFRICAPOLIS study, the total surface area occupied by agglomerations in 2000 was in the order of 200–300 m^2 per capita, and an average 210 m^2 per capita for the coastal agglomerations identified from Mauritania to Benin, if

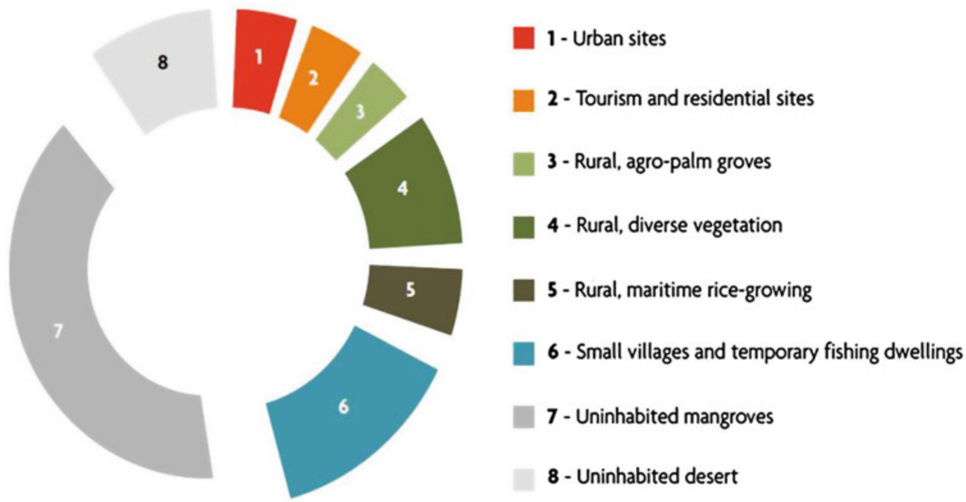


Fig. 1 Distribution (percentage of the coastline) of different forms of human land use in the first kilometre from the coastal strip inwards—the high percentage of mangroves is related to the high fractal dimension of the shoreline along these seaboards (SDLAO, UEMOA–IUCN 2011)

Abidjan, which is said to have an abnormally low rate of space consumption, is not included.

> The AFRICAPOLIS report states: "The average density of agglomerations did not increase from 1950 to 2000 as far as we can estimate in the current state of our work based on a sample of 97 towns for which we have the surface area in 1960. This sample accounts for 1/9th of the total agglomerations with populations of more than 10,000 in West Africa but 44 % of the urbanised land. This primarily concerns the largest agglomerations… Between 1950 and 2000, the urbanised area of our sample increased from 766 to 6,381 km^2, the average annual extension of urbanised land was therefore 5.1 % compared to 4.3 for the population."

Spread: The first thing that stands out about the growth of agglomerations is the horizontal spread of built-up areas, with the evident consequence of considerable land use, rising cost of facilities (roads, power, sanitation, etc.), accentuated by the often low-lying, flat topography of the littoral areas occupied by coastal agglomerations. These are often situated on the edge of a lagoon, in situations that complicate the collection and evacuation of waste waters and rainwater... Spread is often also responsible for the "exiling" of population groups in a precarious economic situation to peripheral areas far from the centre. Note that the historical centres of the largest agglomerations are typically located in proximity to the sea front.

Corridorisation: Agglomerations usually spread in corridors following the busiest communication routes. This corridor development can take on considerable dimensions in some cases, evolving into a long conurbation, as is the case between Keta (in Ghana) and the border with Togo, or between Lomé and Cotonou, in both cases along the coastal interstate road. In the case of Ghana, the model differs somewhat, with a mesh of "micro-centres", hub crossroads and small agglomerations in satellite positions around the major cities. These growth centres have a tendency to join up in the long term. In Senegal, there is an intermediate situation, where corridor concentration is sometimes weighted (except in the case of the Dakar peninsula) by a regular and relatively balanced road grid with tentacles stretching towards the different expanding secondary towns.

Apart from the situation of the consolidated districts (historical, partly) of urban centres, the dynamics of extension to peri-urban areas or areas in proximity to the sea is organised succinctly around for basic types:

- Extensions related to industrial activities, with, in particular, the attractiveness of harbours, which constitute business and investment centres.
- Precarious (or random) residential districts close to the centres and often located in areas highly exposed to risks and often historically unoccupied.
- Peri-urban extensions for residential purposes (seaside residences) or tourism, often along the main coastal roads, on north sides of the main agglomeration, the rapid development of which often follows speculative dynamics.
- The fishermen's districts located very close to the shore and canoe landing areas, in more or less precarious settlements.

These urban developments also imply the mobilisation of building materials leading to extractions and quarries on natural sites. The extraction sites are logically located as close as possible to the sectors being extended and concern fragile coastal formations, such as dune rims, for the extraction of sand. In other cases, rocky materials are employed either in blocks, or crushed, as is the case in Togo for the beach rock freed by erosion, an effective natural protection for a coast that is under threat, today subject to exploitation. Generally, regulatory measures eventually ban the practice, but either these come late or they are difficult to apply as long as viable economic and environmental alternatives have not been identified and possibly accompanied by public action.

To summarise:

- The coastal zone today concentrates 31 % of the total population and 51 % of the urban population of the coastal States.
- The total urban population of the coastal area in the 11 countries may well double, from 18 to 36 million between 2000 and 2020, while the rural population is expected to grow by half.
- From 2020 to 2050, the urban population of the coast could increase from 36 to over 80 million under the business-as-usual scenario and to 74 million under the moderate "controlling disparities" scenario.
- Almost all the administrative and/or economic capitals are situated there.
- The level of urbanisation on the coast is twice as high as in the hinterland.
- The current average population density is 260 per km^2, with maxima of 1,000 per km^2 in Togo and Benin and zones with less than 10 per km^2 in Liberia or Guinea Bissau. These densities could exceed 2,000 people per km^2 in certain countries in the Gulf of Guinea, such as Benin, for example. Certain areas remain unoccupied in the desert regions or large mangroves.
- The coastal fringe today accounts for approximately 56 % of the GDP of the coastal countries.

Growing Demand for Coastline

The generalisation of a global residential and leisure model confers particular appeal on the coast, which is expressed through (i) urban sprawl on coastal areas, followed by (ii) the densification of building in peri-urban and/or interurban coastal areas. The most attractive segments of coast (not isolated, with the right exposure, possessing a heritage of attractive beaches preferably not too far from the urban centres) are experiencing rapid growth related to the expansion of a tourist clientele mainly international initially, but increasingly regional and national as various more or less wealthy middle classes emerge. The stability of the coastal areas "under tourism" in this way is threatened:

- By the facilities built on the rim and on the backshore, depriving it of its sediment reserves and the exchanges that ensure its equilibrium.
- By disrupting the coastal drift, either through the building of leisure facilities affecting the beach, or even the intertidal zone, or even more so by individual or "spontaneous" anti-erosion structures put in place by owners anxious to preserve an heritage of beach exposure, when it is already deteriorating.

A further consequence of the intensification of tourism resides in the specialisation of the functions of the coast, breeching its multi-functional equilibrium, with the emergence of conflicts over use on the beaches which are gradually contracting because of erosion, in particular with the activities related to fishing (canoe landing, fish processing, smoking, etc.) (SDLAO, UEMOA–IUCN 2011).

The multiplication of spontaneous individual coastal defence and protection actions turns out to be completely counter productive and aggravates the sediment deficits observed globally. This is also a factor that reinforces inequalities, for the attempts at localised solutions implemented by owners with sufficient means triggers an acceleration of erosion downstream of coastal drift currents, affecting the more modest properties of poorer population groups or even traditional villages, when these alternate with major hotel infrastructure, as on the Petite Côte in Senegal. This "privatisation of the sediment heritage" is only one of the signs of the accelerated privatisation of the coast in sites that are "under tourism", which also leads to the public being denied access to the beaches in front of the seaside hotels and residences, or by the closure (walls and building) of sea views from public tracks and areas. The future demand for seaside leisure resorts, in particular in the major metropolises, and the respect of the landscape identity of all the coastal sites, should as an imperative be anticipated through a "back to basics" approach regarding the inalienable nature of the public maritime domain.

Economic and Infrastructure Growth

The prospective study that was carried out in the frame of the SDLAO (UEMOA–IUCN 2011) also forecasts a probable acceleration of economic growth in West Africa, with rates exceeding 5 % over the long term. This growth will support the pace of urbanisation throughout the region, which will see a reinforcement of the concentration of economic activity along the coast, with the building of heavy industrial plant and the development of agro-industrial production. Pressure on the raw materials market is also already being expressed through different projects to build ore ports, mainly oriented towards the estuaries, as in Guinea Bissau and Guinea. We were able to observe how in Maritime Guinea, the port of Kamsar caused a village to grow to the second largest city in the country in under 20 years.

In this favourable growth context in the sub-region, most African ports have already begun to undertake work to

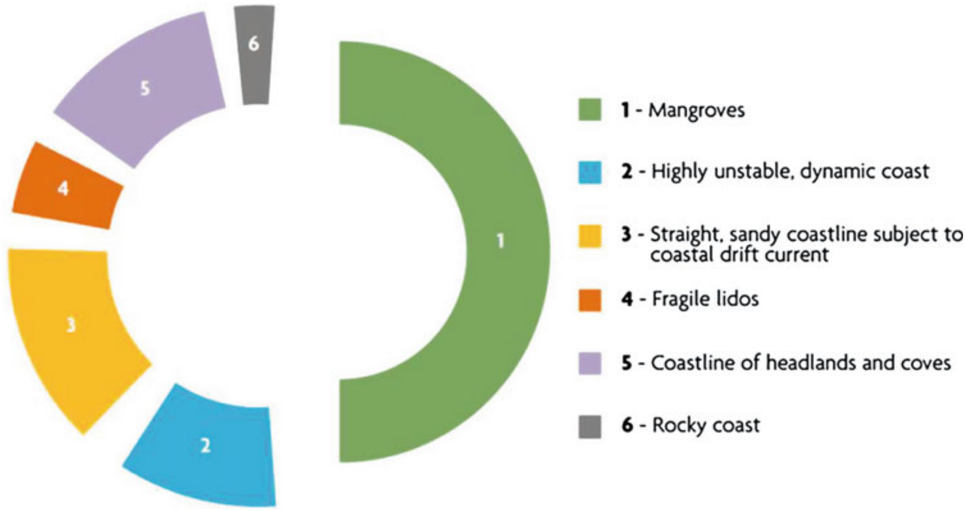


Fig. 2 Proportion of length of shoreline according to the different coastal facies (SDLAO, UEMOA–IUCN 2011). *Note* the high proportion of mangrove coasts, also related to the highly fractal dimension that characterises the shoreline in these milieus

extend their capacity, or will do so in the near future. The increasing penetration of the private sector in the management and even building of ports (for ore ports) should act as an incentive to the States to be vigilant in taking into account the environmental and coastal impacts of these new facilities.

A Fragile, Dynamic Coastline

> On the coasts constituted of sedimentary accumulation, which are by far the most common in West Africa, the mobility of the shoreline largely depends on the local balance of supply and removal in the sediment budget. Removal operates under the action of natural agents (coastal drift, ocean waves, wind, etc.), which are also partly responsible for sediment supply. Removal may also be the result of human activity, either directly (extraction from the beaches of raw materials for building activities, for instance), or indirectly (the creation of surfaces that reflect wave energy or installations that disrupt the operation and the exchanges between the different sediment compartments of the beaches or that disturb the coastal drift parallel to the shore). The dams situated on the catchment areas also constitute traps for continental sediment which no longer reaches the coast, increasing the sediment deficit, particularly at the level of the estuaries and mouths of rivers.

Of the estimated less than 6,000 km of coastline (at a scale of 1:75,000) from Mauritania to Benin, rocky coasts represent fewer than 3 % of the coast line. These coasts are made of rock that is often altered and fractured, subject to landslides and erosion. There are, however, a few rock outcrops that structure this coast in headlands that are less soft but often fractured and fragile, and especially few in number:

- Basalts and other rocky formations on the Cape Verde Peninsula (Senegal).
- Rock outcrops at Cap Verga and the Conakry peninsula (Guinea).
- Breakwater at Freetown (Sierra Leone).
- Relict of sandstone or hardpan spared by erosion (sandstone on the Senegalese Petite Côte, the Bijagos and around the periphery of Accra).
- Granites and metamorphic rocks presents on all of Liberia, Western Côte d'Ivoire and the central part of the coast of Ghana.

The remainder of the coast line is composed of:

Unstable and/or very dynamic coasts

- Sand banks, estuaries, river mouths, spits and islets by nature also very unstable and dynamic (12 %).
- Mangroves, continuously evolving (48 %).
- Sandy formations of lidos, thin sandy rim between a lagoon and the sea shore, also unstable and highly changing (7 %).

Less dynamic coasts, but still subject to natural episodes of erosion and accretion outside of human intervention.

- More or less straight sandy coasts, fashioned by the coastal drift currents, relatively stable but subject to cyclical phases of erosion and accretion, also very sensitive to nay disruptions of the coastal drift (16 %).
- Stepped coasts or headlands and coves, where the coves are compartments more or less separated by rock outcrops or less soft. Their stability strongly depends on the orientation in relation to the ocean waves and currents (14 %). The sediment stocks here are often very limited (Fig. 2).

> The whole of this coastal system is first of all conditioned by the sediment legacies dating from the last transgressions and remobilised by the morphogenic agents (currents, winds and ocean waves). Continental fluxes, whether aeolian or fluviatile, only partially contribute to maintaining the legacy stocks. This is nonetheless a hypothesis which has not yet been confirmed.

Fig. 3 Continental shelf from Mauritania to Benin (blue shading from 0 to 300 m)

A Narrow Continental Shelf

The landform is, on the whole, not very rugged. The continental shelf is narrow in the main, around 30 km on average, except from Guinea Bissau to the Sherbro islands in Sierra Leone, where it widens considerably to 200 km. This continental shelf is marked by some major deep features: the Khayar canyons in Senegal to the North of the Cape Verde Peninsula, and the deep canyon ("Trou sans fond" (Bottomless pit)) that cuts through the shelf perpendicular to Abidjan in Côte d'Ivoire. For certain authors, these bathymetric features contribute to trapping the sediment transported by the coastal drift current parallel to the coast (Fig. 3).

Circulation and Redistribution of Sediment

The propagation of ocean waves affects the whole of the two major sea fronts along this coastline, west and south, with an orientation that is generally oblique, which contributes to the generation of a significant coastal drift current more or less parallel to the coast.

The circulation and redistribution of sediment is governed on the major part of the coast by this coastal drift current, which is subject to annual variations, but the resultants of which are globally north–south all along the western sea front (from Mauritania to Guinea Bissau) and west–easterly along the Gulf of Guinea. In certain cases, these variations are considerable: the drift is reversed seasonally on the Grande Côte of Senegal, and the resultant observed through the physiography of river mouths and estuaries indicates an east–west orientation for a large part of the coast of Liberia and Sierra Leone.

In the portion of coast between Guinea Bissau, Guinea, and the north of Sierra Leone, called the Southern Rivers region, sediment circulation and redistribution is primarily governed by tidal removal currents, combined with river spates in these regions with high seasonal rainfall. The role of the mangrove estuaries in trapping sediment and building sediment accumulations, which are partially expelled in periods of spate, contributes strongly to modelling the facies of this portion of the West African coast. It should be noted that the tidal ranges are very wide in this zone, exceeding 5 m in places, while the average for the whole coastal area studied is in the order of 1 m. In these regions where rainfall determines important annual spates, the dams built across rivers can reduce these spates and restrict the expulsion of the mud plugs, an important source of sediment supply usually put into circulation in the coastal waters during these episodes.

Five Major Coastal Profiles

There are five distinct major coastal profiles from north to south:

- *The straight coastal regions from Mauritania to the Cape Verde peninsula* composed for the most part of sandy formations subject to the direct action of the coastal drift. In the immediate proximity of and behind the ridge/sandbar, there are vast expanses of low-lying salt marshes situated below sea level in places.
- *A coastal region with headlands and softened coves from Cape Verde peninsula to Basse Casamance* structured by

the major estuaries of Sine Saloum and the Gambia. This coast is structured by rocky outcrops of sandstone and badly deteriorated, fragile ferruginous cuirass.

- *The mangrove coastlines associated with the estuaries in the Southern Rivers region from Sine Saloum in Senegal to the Sherbro islands in Sierra Leone.*
- *A coastal region highly structured into rocky headlands and sandy coves from Liberia to the West of Coast d'Ivoire.* This same profile is also to be found in the central part of Ghana.
- *From the west of Côte d'Ivoire to Benin* stretches two large sediment basins of soft coastline (Côte d'Ivoire and Dahomey basins) also characterised by important lagoon and channel systems parallel to the coast and situated behind a sandbank that is very narrow in places (lidos). These two large sediment basins are separated by the Three Points Cape in Ghana and a few adjacent formations that are more or less rocky (sandstone) or in headlands, right to the mouth of the Volta.

The major part of the coast in West Africa has a high sensitivity to coastal erosion related to (i) the nature of the materials (mobile sandy sediment or highly altered and fractured rocks; (ii) the circulating sediment fluxes which remain limited either due to continental or river mouth trapping, or due to the coastal sediment partitioning that can be observed on coasts that are more predominantly structured in headlands and coves.

The developments and infrastructures that disturb a coastal drift that is typically parallel to the shore create observable direct impacts: siltation upstream and erosion downstream of the portions of the coastal region that have undergone human artificialisation, in particular through structures placed perpendicular to the shore and the coastal drift current (ports of Nouakchott, Lomé, Cotonou, etc.).

In the stepped coasts, or in headlands and coves, the diversity of the situations in relation to the predominant ocean waves and the coastal drift current requires a case-by-case analysis of the sensitivity to erosion, which is largely conditioned by the local configuration.

Biodiversity and Ecological Services

The biodiversity of the coastal ecosystems of West Africa is directly related to the variety of types of coast and to the steep bioclimatic gradient characteristic of the region, covering the Saharan, Sahelian, Sudanese and Guinea-Congolese zones (White 1983). The extensive wetlands, corresponding to the morphology of flat, low-lying topography of the major part of the coast and to the interpenetration of fluvio-marine influences, in particular in the estuarine areas, constitute the striking characteristics of this maritime façade.

Major Natural Areas

There are four major, extensive, more or less protected natural areas along this coastline: the Banc d'Arguin National Park in Mauritania, the Delta of the River Senegal, the Bijagos archipelago and the Sherbro-Robertsport complex between Sierra Leone and Liberia.

Between these major units, some of which have already been subject to conservation measures for some time (Arguin, Bijagos), is an interspersed network of natural areas that are still relatively preserved, some of which are subject to local protection measures (RAMSAR sites, marine protected areas in Senegal, the national network of marine and coastal protected areas in Guinea Bissau, etc.).

Dense Guinea-Congolese forest

The last relicts of the Guinean coastal forests (Guinea Bissau, Guinea) are today largely deteriorated, or have simply disappeared. However, a few dense forest areas remain in places, in particular in Liberia, with little data available on the actual status and distribution of these formations. Secondary forests from the recolonising of plantation areas that were previously artificialised are better represented from Liberia to Ghana. Note that the dense, evergreen Guinea-Congolese forests extend from Cap Palmas to Cape Coast in Ghana, at some distance from the coast. These formations extend to Nigeria after an interruption (Dahomey gap), due to the bioclimatic reasons from Keta in Ghana to Benin inclusive. There is practically no forest remaining on the actual edge of the coastal area.

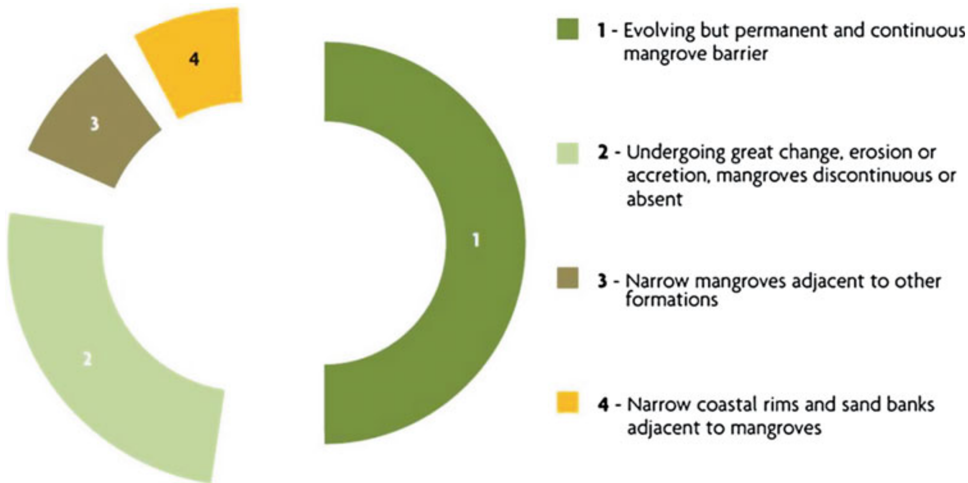
These hinterland forest facies vary depending on the edaphic conditions (rock outcrops and cuirasses, wetland depressions, leached sand on coastal terraces), orographic conditions (reliefs), bioclimatic conditions (duration of the dry season) and the intensity of human intervention (fires, conversions and secondary regrowth after plantation or slash-and-burn).

This coastal evergreen Guinea-Congo rainforest is recognised as exceptionally rich with a diversified flora including a notable proportion of endemic species. Like the dense coastal forests of Guinea, these forest entities are also highly threatened.

Mangroves

The mangroves of West Africa are completely different in their composition from those in East Africa. The seven main species they comprise (*Rhizophora mangle, R.*

Fig. 4 Proportion of coastline according to physiography of mangrove stands (the whole of the study area) (SDLAO)



harrisonnii, R. racemosa, Avicennia germinans, and Laguncularia racemosa, Acrostichum aureum, Conocarpus erectus) are also distributed on the eastern coasts of tropical America. These mangroves grow in the intertidal zone. They cover approximately 14,000 km^2 in the zone under study and are subject to the influence of various factors: oceanographic, sedimentary, geomorphologic, but also and increasingly, anthropic.

Not very diversified from a floristic point of view, these mangrove communities nonetheless play a vital role for the coastal ecosystems as a whole, in particular by the high net production that characterises them, which is exported to marine milieus and enables a rich and diverse piscifauna to be maintained. Their physiographic characteristics (shallow gradients, the cryptic nature of milieus that are crowded with the roots of the mangrove trees) also make them essential reproduction zones for a high proportion of fish species that make up the region's fishing stocks. The small areas of estuarine mangroves in the Gulf of Guinea, particularly in countries like Togo and Benin, are extremely threatened and specific protection measures are required. The pressure on the mangroves and on these coastal ecosystems is increasing today. A distinction should be made between:

- *Biomass removal*: wood for energy (supplying the nearby urban concentrations for smoking fish or producing salt in Guinea), for services, fisheries and the gathering of attached organisms, molluscs and crustaceans, removal of bark and of various species in traditional pharmacopeia.
- *Conversions and clearance*: artificialisation for rice production, salt production, or shrimp farming, which is expected to expand in the future, in particular in Guinea. The surface area occupied by mangroves in the region is thought to have decreased by a quarter between 1980 and 2006 (Corcoran 2009)

The changes in the surface areas of mangroves (contraction or expansion) are, however, also governed by continental drought cycles or, on the contrary, abundant rainfall. These systems are particularly dynamic and sensitive to changes in mud banks, the physiognomy and topography of which are under the influence of coastal hydro-sediment forcing.

Preserving these original systems also conditions that of the veritable ethno-ecosystem that characterise these areas and their population which was largely dependent on a daily basis on resources valorised locally through complex production systems adapted to these particular milieus. The contribution of these ecosystems to the subsistence strategies of certain coastal societies (in Sine Saloum, Casamance, the Gambia, Guinea Bissau, Guinea and Sierra Leone) is fundamental, as much at the level of food, food security and pharmacopeia as from a cultural point of view (Figs. 4 and 5).

Five West African governments (Mauritania, the Gambia, Guinea, Guinea Bissau and Serra Leone) have ratified a charter that commits them to cooperate for the protection of the mangrove in the sub-region. This mangrove protection charter also comprises detailed plans of action specific to each country.

Estuaries

Estuaries constitute areas of particular importance for the interpenetration of marine and fluvial environments, favouring different ecological processes and the exchange of nutrients, which, depending on the season, are used by a wide variety of fishes and crustaceans species, some at specific stages in their life cycle. The estuaries of West Africa are home to the major expanses of mangroves, which are reputed for their biological productiveness and their role

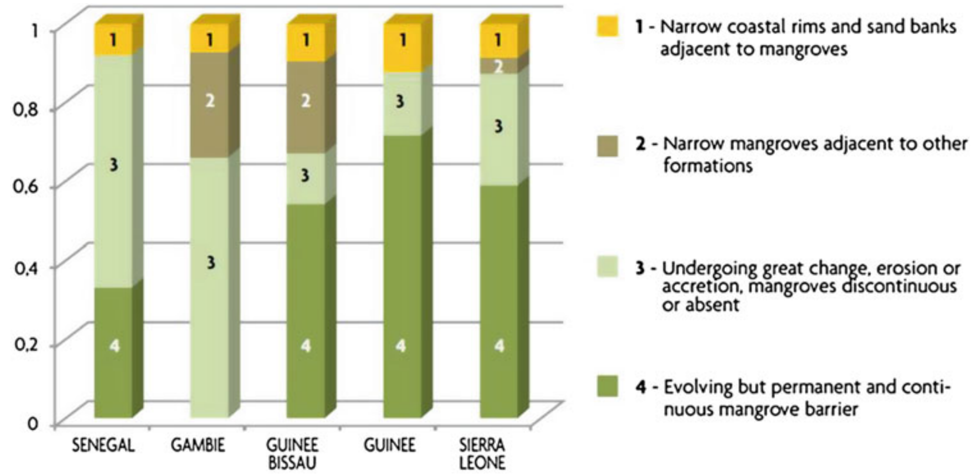


Fig. 5 Proportion of coastline according to the physiography of mangrove stands (by country) (SDLAO, UEMOA–IUCN 2011)

of being nurseries and feeding areas for large numbers of marine species and water birds.

Beyond the mangrove area associated with the major estuaries and the archipelago estuary of the Bijagos, the string of small estuaries from Sierra Leone to Côte d'Ivoire also represents a network of extremely rich ecosystems, sheltering a fluvio-marine and brackish water fauna the diversity of which remains relatively unexplored and unknown. As far as fish species are concerned, the estuaries are home to relatively diverse communities that are uniform on a regional scale, with low seasonal variations compared to adjacent marine waters.

The biological diversity and ecological processes associated with the estuaries relates to the multiple gradients (salinity, temperature, bathymetry and topography of the banks and coastal lagoons, conditions and sediment dynamics and local current systems) which characterise these milieus, whose conservation certainly constitutes a priority on a regional scale, in particular given their richness, their sensitivity to pollution and the risks associated with the development dynamics of harbour and urban infrastructure.

The dramatic effects of dams on coastal areas:

Hydrologic constraints have led to the building of dams on the majority of large rivers, often for hydroelectric power (50 % of dams), but also for agricultural purposes. In certain cases, there are several purposes, the Senegal River Basin Development Organization for example tries to reconcile agricultural production goals with the production of hydroelectric power and navigation. There are approximately 150 dams in West Africa, with several more scheduled. This number is relatively low when compared to Southern Africa, however, which has the majority of dams (there is a total of 1,300 dams in Africa and 45,000 worldwide). The two largest dams in West Africa are the Akosombo on the Volta in Ghana, built in 1964, which stands 134 m high (4th highest in Africa) and has a capacity of 150 billion m^3 (3rd in Africa) and the Kossou on the Bandama in Côte d'Ivoire, which has a capacity of 28 billion m^3 (6th in Africa).

The consequences of these developments are multiple, in particular in terms of conserving biodiversity, but also in reducing sediment load and the speed of flows particularly during flood peaks. The consequences in the coastal zone and the deltas are often major: salinisation of soils and surface waters, erosion provoked by sediment deficits, accretion and delta formation related to energy reduction when annual expulsion of silt plugs should normally occur.

With the exception of special cases such as the Gambia and Senegal, which have regional river development organisations (OMVG, OMVS), the majority of these dams were designed at national level, and therefore often without taking into account in depth the remote impacts of the developments, which should be considered on a sub-regional scale.

Coastal Conservation and Natural Infrastructure

The natural coastal milieus in West Africa, and in particular the estuary systems and fluvio-marine connections, contribute directly to producing ecological services that are useful or even indispensable to the coastal societies, perhaps even more so in the context of climate change on the agenda today. These ecological services procure identifiable benefits on every scale, including global: carbon sequestration by the mangroves, sea grass beds and coastal marshlands, the importance of which is recognised.

- *Self-maintenance services*: constitution of habitats and of the milieu. Maintaining of energy flows and nutritional cycles through primary production, inter- and intra-ecosystem services and functions, reproduction, nourishment, etc.
- *Provisioning services*: fisheries (artisanal, staple, and commercial), agriculture, firewood, ligneous and non-ligneous gathered food products, aquaculture, crafts, building (materials and service wood), pharmacopeia, genetic resources, etc.
- *Regulation services*: climatic (carbon sequestration), sediment trapping and coastal protection against marine erosion and extreme marine weather events, treatment and recycling terrigenous and effluent input from human activities, waste water purification, protection against floods from continental waters, stabilisation of mobile dunes, etc.
- *Cultural services*: landscape appeal and environmental quality (formation of beaches, islands and coastal landscapes), leisure activities (urban beaches for example), research and education, cultural and religious heritage (sacred sites, customs, traditional ways of life, artistic expression), etc.

Not all of these ecosystem services, which strongly contribute to the development potential of the coastal countries, are subject to systematic economic valorisation to date, except for a few sectors such as fishing. This also implies that these services are globally still functional. Nonetheless, the concerns related to coastal erosion show that functional deficits in these natural systems can have a considerable economic impact. The numerous instances of deterioration observed along the West African coastal zone are generally attributable to inappropriate development practices implemented with no concern for the anticipation of how the natural systems will respond (SDLAO, UEMOA–IUCN 2011).

Fishing: A major sector of activity, weakened by fish stocks depletion

With an EEZ of more than two million km^2, and the existence of upwellings (essentially in Mauritania, Senegal and the Gambia) rendering the waters highly productive, fishing livelihoods are an essential component of the development strategies of the coastal States of West Africa, not only in building their GNP, but also in the struggle to attenuate poverty and malnutrition. Fishing is an important sector for employment (approximately 600,000 jobs in Senegal, more than 500,000 in Ghana).

The competition for access to these fishing resources is intensified in a global context of increasing demand, and access to pelagic resources (but also to a lesser extent, demersal resources) is coveted by foreign fleets—European fleets through fishing agreements, but also Asian (Korea, China) and Eastern European fleets. The way these foreign fleets respect the access conditions is sometimes relative, and the fiscalisation of the activity remains very unequal, depending on the states and their foreign partners.

While total catches have increased regularly since 1950, this growth should also be compared to the regular increase in fishing efforts and the efficiency of fishing units. The observed depletion of certain stocks of demersal species, associated with the reduction in the diversity of the communities, the sensitivity and fluctuations recorded in certain specific fisheries, such as cephalopods, closely dependent on the conditions of the milieu (in particular of the upwelling), certainly attests to a deterioration in the composition, structure and organisation of marine biological communities.

Climate: Facing the Possible Futures

The uncertainty that characterises the future of these coastal systems in a context is subject to climate change, which will very probably have significant impacts on the state of the coastal sea and the coast area.

West African Climate Models

There are systematic biases in the simulation of the African climate by most of the climate models that contributed to the 4th report of the IPCC (Intergovernmental Panel on Climate Change). A total of 90 % of these models overestimate the precipitations on a large part of the continent (Christensen et al. 2007). The temperatures simulated also show bias, but this is not significant enough to call into question the credibility of the projections. The intertropical convergence zone simulated is moved towards the equator in most of these models. The surface sea temperatures are overestimated by 1 to 2° on the Gulf of Guinea. A large part of these models have no monsoon, as they cannot properly reproduce the northward movement of precipitations on the continent. Only 4 of the 18 global ocean-atmosphere models in the 4th IPCC report examined by Cook and Vizy (2006) are able to produce quite realistically the interannual variability of surface water temperatures in the Gulf of Guinea and the dipolar structure of precipitations between the Sahel region and the Guinean coast.

Future Projections to 2050

Temperatures: The projections for Africa show temperature rises that will very probably be well above the average global rise, with an accentuation on the arid zones (ACMAD, in SDLAO, UEMOA–IUCN 2011).

Precipitations: The global ocean-atmosphere models have more difficulty simulating precipitations than temperatures. In several regions of the world, these models agree on the rise or fall in precipitations, but they diverge greatly in their projection of precipitations in West Africa and the signal for variations in precipitations on the Sahel and Guinean coast remain uncertain. The overall average of the various models presents a downward trend in precipitations in JJA (June July August) on the West African coast to the north of the 10th degree of latitude, which is approximately the domain of the maritime trade wind and the north of the Liberian–Guinean domain. This decline would be accompanied by an increase in the intensity of precipitations and a decrease in the number of rainfall events (Tebaldi et al. 2006). In the south, on the domain of the permanent Atlantic monsoon, the models do not agree on the signal of change, even though the average presents a slight upward trend.

> The increase in the intensity of precipitations and the reduction in the return periods of certain extreme events could cause the flooding of coastal zones and aggravate erosion phenomena (which could in certain specific cases lead to increased siltation). The global reduction of rainfall in the course of the twenty-first century would cause a decrease in the flow rates of the major rivers such as the Senegal and the Volta, which would be accompanied by a sediment deficit and an aggravation of coastal erosion. To this should be added the influence of works such as dams on these watercourses, which only aggravate the trend/phenomenon.

Frequencies of Extreme Events

Among the most important extreme events affecting the coasts of West Africa, the episodes of intense precipitations, depressions and tropical storms can cause considerable damage. There is disagreement between the different studies on the projected the frequency of extreme events (including cyclones) as a result of global warming. There seems to be more of an agreement on their increase in intensity because of a perceptible rise in the temperature of marine surface waters. Furthermore, storm surges depend greatly on local conditions, in particular bathymetric and related to tidal regimes. This means studies of storm surge statistics are specific to each region and cannot be generalised.

Significant Wave Height

There are a limited number of studies on wave climatology projections (Weisse and von Storch 2010). These studies nonetheless allow for a considerable increase in the significant height of waves in the North Atlantic, consistent with the deviation of storm paths towards the poles. These studies do not predict an upward trend in low latitudes. For West Africa, the change will therefore come especially from the increase in the frequency and duration of tidal wave events, in particular related to extreme marine weather events.

Higher Sea Level and Storm Surges

The fact that sea level is rising seems to have been largely confirmed. *The historical tide gauges show that in the course of the past 100 years, the level of the sea has risen by an average 20 cm*. The current estimations are between 20 and 50 cm by the end of the century. Much more dramatic estimates evoke (on a conservative hypothesis) a rise of 3.3 m according to a number of possible scenarios, such as, for example, the complete disintegration of the West Antarctic ice sheet (Bamber 2009).

The spatial distribution of the sea rise signal is nonetheless far from uniform. First of all, the surface of the oceans is not regular and for example, in the subtropical Atlantic, we note a convex area of approximately 1 m in elevation. This spatial distribution also depends on climate variability and the hazards of marine circulation. These spatial disparities were already observed in the data for the decade 1993–2003.

At regional level, this rise can significantly deviate from the global average due to little known local factors such as land subsidence, change in atmospheric circulation and wind regime, the redistribution of atmospheric pressure or the unequal distribution of thermal expansion. Our current state of knowledge does not allow more accurate estimations.

According to the IPCC's 2007 report, in 2090–2099 average sea level will have risen by around 18–59 cm compared to 1980–1999. By 2050, the rise will be in the order of 10–20 cm. This rise does not take into account the probable acceleration of ice melt, which could add a further 10–20 cm. There is a lot of uncertainty surrounding these values, which could be exceeded (Meehl et al. 2007).

Alarming Conclusions

The erosion and flooding (submersion) of coastal areas which largely contributes to the receding shoreline will be aggravated in the course of the twenty-first century following an increase in average sea level.

Africa is one of the regions in the world whose coastal zones, estuaries and deltas are the most exposed to risks of flooding related to the rise in mean sea level (Nicholls and Tol 2006). This rise in sea level, combined with increased intensity or frequency of extreme events, will have serious consequences for the development of the coastal zone. Many coastal or island areas will be submerged or subject to increasingly frequent flooding, causing considerable damage.

In West Africa, although this rise cannot be estimated accurately, a rise greater than the global average is expected. There could be dramatic consequences for certain areas, such as around Nouakchott, an area which is already below sea level. Major conurbations are greatly at risk. *The destructive effect of this rise in water level will lead to an increase in the frequency of storm surges and their submersion potential, particularly in the estuaries and river deltas. There will be more frequent intrusions of saline waters which may gradually make aquifers unfit for consumption and agriculture (the advancement of the salt-water wedge, alteration of freshwater lenses and surface aquifers).*

The consequences remain, however, extremely difficult to evaluate and should only be envisaged through *a detailed study of local situations.* The hypothesis of a rise in sea level of 1 m would cause a considerable aggravation in coastal hazards, first of all, reaching the low sandy coasts and mangroves, as well as coastal zones composed of easily erodible sandstone or marno-limestone cliffs. The major lagoon systems will also be affected. The lowest-lying sectors will be subject to increased erosion or temporary or permanent submersion.

To complete these hypotheses, it should be added that natural coastal systems are not in fact passive with regard to the rise in sea level, and there are numerous threshold effects, for these systems also react and adapt to the new configurations. For example, in the case of submersion hazard, coastal plant formations can trap sediment, river flow rates can be modified by the variability of continental precipitations, lagoon or estuary outlet streams can be partially closed by the advance of sand spits, etc. Any evaluation of the impacts of the rise in sea level should therefore remain cautious and avoid swinging into simplistic, reductionist or "mechanical" calculations or representations, in particular in the field of economics. The submersion hazard, when the stakes justify this, can only be properly considered through a detailed local hydraulic approach.

- *Sandy coastline*: increasing erosion of sandy systems is expected, aggravating the risks of submersion. The receding of the shoreline already observed should accentuate.
- *Dune ridges and lidos*: lidos and dune ridges will migrate inland, at least for the narrowest lidos. Certain lidos will become fragmented. A tracking programme should enable local identification of the lidos able to migrate and those likely to fragment.
- *Lagoon systems*: the hydrology of lagoons comprises exchanges with continental waters, but also with the sea. In addition, these are located at a height close to sea level. The ecology of lagoons is based on two main parameters: depth and salinity. While the former is not expected to change much,[2] the salinity is expected to change (i) following the rise in sea level; (ii) by the salinisation of aquifers; (iii) by a possible decrease in the freshwater supply consecutive to a reduction in rainfall and therefore in flood peaks. On the other hand, the tendencies for lagoons to fill in by terrigenous supply could be partially counteracted. Note also that the multiplication of dams, by removing the very small spates, may contribute to reducing the salinity of certain brackish waters.
- *Closing of lagoon outlets*: the closure or strangling of lagoon outlets due to the development of spits and local accretions leads to the eutrophication of the aquatic milieus concerned. The filling in of these outlets also implies flooding in periods of spate.
- *Estuaries*: the way estuary systems work could also be profoundly modified, in particular in relation to changes in sediment supply, but also to the distribution of salinity, the surface temperatures of the waters, etc., all parameters which strongly determine the biological potential of the gradients that characterise these very specific milieus. The impact of the decisions made in the management of the major dams will also be largely as important as trends cause by climate change.

These different elements of climate forecast must, however, be balanced by the recognition of the non-linear and chaotic nature of the dynamics under

[2] The migration of lagoons, if this is possible, should conserve the initial depth gradient in most cases, even if the depth of the lagoons increases slightly.

consideration, and the threshold effects that characterise the different manifestations of climate change. The combination of permanent shoreline monitoring with the monitoring of changes in climate conditions should enable the production of scenarios to be updated regularly, in order to reduce the uncertainty that today besets any forecasting in terms of climate.

Estuarine Sentries

In West Africa, the concentration of social and economic stakes on the coastal strip, along with the multiple rapid changes already underway, calls for the implementation of forward-thinking, deliberate land planning policies, in order to preserve the fragile coastal interface on which the future depends—the future, not only of the coastal States, but also, partially, of the Sahelian States (population mobility; economic exchanges).

Interconnecting the inland areas with the coastal sea, the estuaries aggregate these stakes. Historically and geographically, estuaries are structural components of the West African seaboard, and are today in the front line of exposure to the general trends affecting the entire coastal complex.

The complexity of the mosaic of estuarine habitats determines their sensitivity to any changes in the environmental conditions and positions the estuarine zones, which are generally populated, as sentries for the marine environment, but also for the management of the upstream river basins.

The subtle geography of the estuaries and, more generally, of fluvio-marine systems (lagoons, deltas, etc.), should also teach us how to better employ the various dimensions of the rich notion of coastal area and lay the foundations of a kind of development and planning that is integrated into the natural land matrix, buoyed by it and respectful of it.

References

Bamber JL (2009) Reassessment of the potential sea-level rise from a collapse of the West Antarctic Ice Sheet. Science 324:901–903

Cook KH, Vizy EK (2006) Coupled model simulations of the West African monsoon system: twentieth-and twenty-first-century simulations. J Clim 19:3681–3703

Corcoran E et al (2009) Les mangroves de l'Afrique de l'Ouest et centrale. PNUE—Programme des Mers Régionales

Meehl GA et al (2007) Global Climate Projections

Pelissier P (1990) Post-scriptum à Rivages. L'Afrique tourne-t-elle le dos à la mer? Cahiers d'Etudes Africaines 117(XXX-1):7–15

Tebaldi C, Hayhoe K, Arblaster J, Meehl G (2006) Going to the extremes. Clim Change 79(3):185–211

UEMOA–IUCN (2011) Schéma Directeur du Littoral d'Afrique de l'Ouest—SDLAO

Weisse R, von Storch H (2010) Marine climate change: ocean waves, storms and surges in the perspective of climate change. Springer, Berlin

White F (1983) The vegetation of Africa, UNESCO

Christensen JH et al (2007) Regional climate projections

Nicholls R, Tol R (2006) Impacts and responses to sea-level rise: a global analysis of the SRES scenarios over the twenty-first century. Philoso Trans A 364(1841):1073

Springer

http://www.springer.com/978-3-319-06387-4

The Land/Ocean Interactions in the Coastal Zone of West and Central Africa

Diop, S.; Barusseau, J.-P.; Descamps, C. (Eds.)

2014, XXII, 210 p. 133 illus., 122 illus. in color., Hardcover
ISBN: 978-3-319-06387-4