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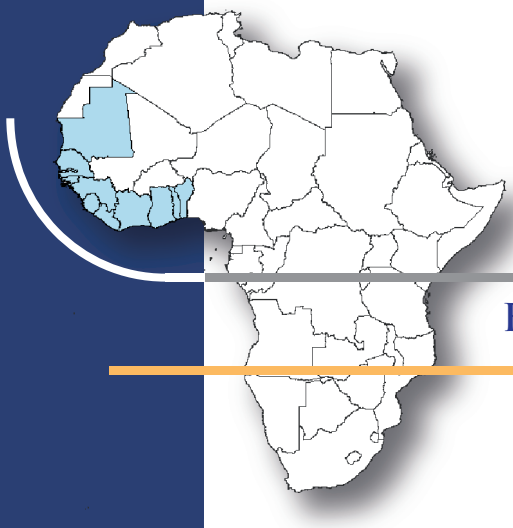
Cartography



REGIONAL SHORELINE MONITORING STUDY AND DRAWING UP OF A MANAGEMENT SCHEME FOR THE WEST AFRICAN COASTAL AREA

CARTOGRAPHY INFORMATION

UEMOA

IUCN

2010

The regional study for shoreline monitoring and drawing up a development scheme for the West African coastal area was launched by UEMOA as part of the regional programme to combat coastal erosion (PRLEC – UEMOA), the subject of Regulation 02/2007/CM/UEMOA, adopted on 6 April 2007. This decision also follows on from the recommendations from the Conference of Ministers in charge of the Environment dated 11 April 1997, in Cotonou. The meeting of Ministers in charge of the environment, held on 25 January 2007, in Cotonou (Benin), approved this Regional coastal erosion programme in its conclusions.

This study is implemented by the International Union for the Conservation of Nature (UICN) as part of the remit of IUCN's Marine and Coastal Programme (MACO) for Central and Western Africa, the coordination of which is based in Nouakchott and which is developed as a thematic component of IUCN's Programme for Central and Western Africa (PACO), coordinated from Ouagadougou.

UEMOA is the contracting owner of the study, in this instance through PRLEC – UEMOA coordination of the UEMOA Commission. The work has been carried out under the supervision of:

⇒ **The PRLEC[1]-UEMOA Regional Steering Committee** set up to improve the orientation of the different projects and oversee their diligent and efficient execution. This is presided over by the State, which holds the presidency of the Council of Ministers of UEMOA.

⇒ **The PRLEC- UEMOA Regional Scientific Committee,** established with a view to assisting the UEMOA Commission in validating the technical and scientific contents of projects initiated within the framework of the implementation of PRLEC. This committee also expresses a technical and scientific opinion on all the reports drawn up within the framework of the implementation of this programme.

Supervision: Malick Diallo, UEMOA, Director of the Environment and of Water.
Papa Goumba Lo, President of the Regional Scientific Committee of UEMOA Regional Programme to combat Coastal Erosion.

Overall coordination: Mathieu Ducrocq, IUCN, marine and coastal Programme Regional Coordinator for Central and West Africa:

Technical and publications coordination: Jean-Jacques Goussard – EOS.D2C / EAM-GEOME

[1] Programme to combat Coastal Erosion, UEMOA (West African Economic and Monetary Union).

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The mapping data associated with the development scheme is divided into three complementary documents:

- ⇒ Geodynamic analysis mapping at a 1:500,000 scale.
- ⇒ Human land use issues mapping at a 1:500,000 scale.
- ⇒ The mapping of development scheme representation at a 1:500,000 scale.

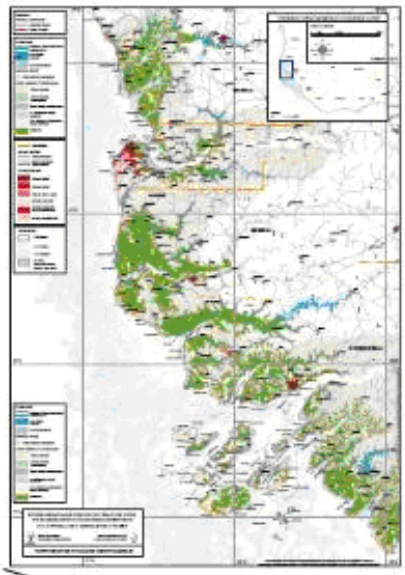
Some of the subjects mapped are common to the three documents, while others are specific to a particular document. The table below shows the distribution of the mapped data common to the three documents.

Grid system: a 1 degree grid system is used. This is not shown on the development scheme mapping in order to enhance legibility.

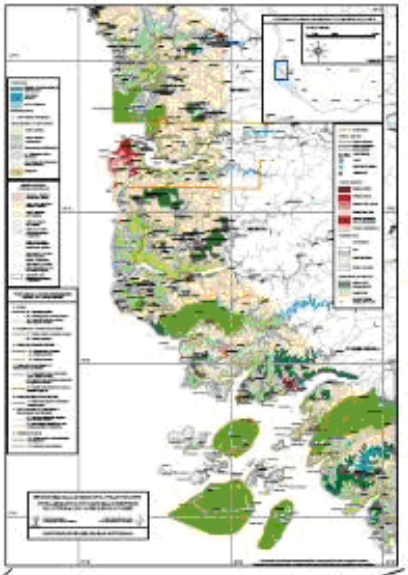
Scale and segmentation into sheets: the geodynamic analysis mapping was initially produced at a scale of 1:250,000 (14 A0 sheets). This scale turned out to be largely inadequate, in particular regarding the difficulty of obtaining an overview of the entire area mapped. The A0 format also turned out to be difficult to handle. All the final deliverables are therefore presented at a scale of 1:500,000 in A1 format (9 sheets). The segmentation into sheets is the same for the three mapping documents. This segmentation represents a compromise between (i) the necessity of limiting the whole to nine A1 sheets; (ii) the aim of producing a fraction of the shoreline considered on each sheet with a more or less consistent profile; (iii) the opportunity of optimising the areas of intersection between each sheet; (iv) the necessity of reserving sufficient space on each sheet to place the information related to the reference boxes and the management scheme.

The metadata corresponding to the different layers should be added as an appendix when the work is completed.

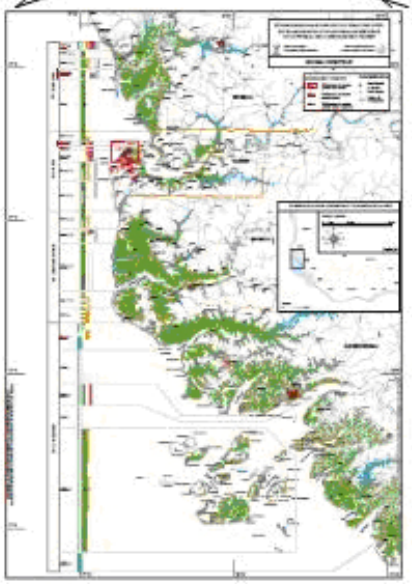
Geodynamic analysis mapping



Stakes and human occupation mapping



CROSSINGS



Management scheme

1. COMMON THEMATICS

Name	Primary data sources	Treatment	Typology and/or hierarchy	Type of representation
WATER SYSTEM				
Watercourses	Vmap 1 and 0 vector data, topographical base maps on paper, high resolution images, USGS Hydrosheds data	Merging, verification and correction of primary data from (i) existing, fixed topographical base maps; (ii) high resolution images; (iii) Landsat satellite imagery. Manual hierarchy.	3 levels	Vector
URBAN STRUCTURE AND TRANSPORT SYSTEMS				
Urban structure	See elements provided below	See elements provided below	6 levels	Vector
Roads	Vmap 1 and 0 vector data, topographical base maps on paper, high resolution images, Landsat images.	Merging, verification and correction of primary data from (i) existing, fixed topographical base maps; (ii) high resolution images; (iii) Landsat satellite imagery. In certain cases the network was validated by discrimination of axial urban spots.	3 levels	Vector
Miscellaneous				
National borders	Public data	Resetting on rivers where necessary (from the water system)	None	Vector
Hypsometry	Curves generated from the digital terrain model SRTM (CGIAR-CSI)[2] from 90 metres	Generation and vectorisation of contours at different elevations.	None	Vectors
VEGETATION				
Mangroves	Landsat Images	Interpretation of Landsat images. Generation of contours from digital terrain model SRTM 30.	None	Polygons
Shoreline	NOAA (scale 1:75,000)	Completion of the layer by photo interpretation on the segments with missing information.	None	Polyline

1.1. URBAN STRUCTURE

The urban database was built using the Africapolis data as a starting point. The Africapolis team drew up a vector layer of the agglomerations in West Africa with populations over 10,000 using the high resolution images available via Google Earth (and other statistical and cartographic data). When high resolution data was not available, the agglomerations are nonetheless mentioned without detail, in the form of a red dot (identified on the topographic base maps) or a pale pink area, if the area is extensive but discrimination into density classes was impossible. In these cases, the Africapolis contours were conserved without correction.

Using the National Oceanic and Atmospheric Administration (NOAA) shoreline, a 25 km-wide buffer zone was created, and within this zone the agglomerations in the Africapolis database were extracted from Mauritania to Benin.

[2] The quality of this digital field model was confirmed by a CIAT study: *Comparison of SRTM derived DEM vs. Topographic map derived DEM in the region of Dapa*.

1.1.1. CORRECTION OF AFRICAPOLIS DATA

Corrections were made to some of the polygons digitised by the Africapolis team, in order to improve the accuracy of the contours of the urban perimeters. In certain cases, areas of bare soil with low vegetation within an agglomeration have been deleted. In the opposite case, peripheral urban areas which were not included in the agglomeration have been added.

Particular case: the Accra - Tema conurbation

In the Africapolis database, certain polygons correspond to conurbations of agglomerations such as Lomé and Aflao (separated vectorially because of the transborder location), or Dakar and Rufisque, Accra and Tema.

The conurbations identified have not been modified, for the aim was to obtain a perimeter identifying the urban areas as a whole, with these perimeters being subsequently broken down into further detail.

It was nonetheless necessary to correct the Accra – Tema conurbation, for the poor quality Google Earth images (mosaic of images from different dates and different resolutions with thick cloud coverage) were updated. On the last images, the city of Accra is seen to be surrounded by a network of small agglomerations (dense urban hubs are visible) constituting a loose but continuous urban fabric along a stretch of many kilometres. This urban fabric was not integrated into the conurbation, but its boundaries were drawn in new polygons.

In the end, this conurbation represents a unique case in this study area, but it was corrected by determining the following criterion: for a conurbation, beyond a built-up area of 20km, the boundary of urban sprawl is placed on a visible natural break (bare soil, forest, etc.) and the boundaries are drawn for a new urban area for the built-up areas beyond.

1.1.2. ADDITION OF NEW AGGLOMERATIONS

In addition to the case of the periphery of Accra, other areas of urban expansion have been added to the Africapolis database. This database only contains agglomerations with populations over 10,000, which does not include certain towns and villages with fewer inhabitants, which may nonetheless constitute built-up areas that should be taken into consideration in characterising the organisation and dynamics of urban expansion on the coast of West Africa. For the 11 countries considered, 271 agglomerations were added in the 25 km-wide buffer area measured from the shoreline, which has been extended for Senegal, Gambia and Guinea Bissau along the river Gambia, Casamance and Rio Cacheu rivers.

These agglomerations correspond to villages that have a built-up density that is identifiable when flicking through the images. The identification on the very high resolution images focused on the villages situated on the coast, in mangrove areas (areas that are largely blank in the Africapolis database), on the branches of the major rivers, or in the satellite villages around the principal agglomerations. We also tried to identify all the **hub intersections** of the main communication routes, by crossing the high resolution images with the vectorised, hierarchical layer of the regional road network.

1.1.3. CLASSES OF URBAN DENSITY

Inside the identified urban sprawls, areas have been marked out, corresponding to four possible levels of built-up density:

⇒ **DENSE URBAN FABRIC**: areas where no vegetation (beyond an isolated tree) and/or bare soil is visible between buildings. This class of density is typified by a tight mesh of buildings and communication routes. This category contains the centres of the major agglomerations and of certain urban hubs, informal settlements and certain villages where buildings are highly concentrated. The central industrial zones in the major agglomerations have been included in this class, even though the density of buildings they present is slightly lower.

⇒ **LOOSE URBAN FABRIC:** areas where the buildings are farther apart and separated by bare soil or vegetation correspond to unbuilt spaces in the basic plots. The mesh is composed of practically equal parts of buildings and unbuilt land. This category includes the peripheral zones of the agglomerations, which mostly correspond to residential areas.

⇒ **URBAN FABRIC THAT IS VERY LOOSE BUT SERVICED**: areas where bare soil and planted areas predominate over buildings. This class constitutes the very loose mesh urban zones, which are nonetheless serviced by communication routes. It includes villages with sparse housing and the

scattered peripheral areas around agglomerations corresponding to recently urbanised zones, or where building is in progress at the time the available pictures were taken.

⇒ **INTRA-URBAN OPEN AREAS**: areas that are planted or bare soil with no built-up areas greater than 0.02 km². This class comprises all the types of undeveloped land that can be used as a reserve, as well as parks and developed woodland, the areas surrounding aircraft runways, etc.

⇒ **INDISTINCT URBAN SPRAWL**: this category comprises areas of urban sprawl which are not distinct either because they are too small or because pictures of a sufficiently high resolution were not available.

Comments

- For the urban sprawls to be found in low resolution images (the minority), the category of surface areas in low resolution was determined in continuity with the part in high resolution. These parts have generally been classified in the intermediate level of density, or loose urban fabric.

- Airport complexes have been classified taking account the degree of urban mesh in the surroundings.

- Small plots that are disconnected from the principal agglomeration have been classified in the 'Urban fabric that is loose but serviced' category.

Creation of the layer of communication routes structuring the agglomerations

This layer of data comprises the main communication routes that cross the identified agglomerations. This work was carried out for all the agglomerations, irrespective of the resolution of the available pictures. The communication routes can in fact be seen even in the low resolution images. In addition, other data on routes was available on the existing topographic base maps. To build this database, the following criteria were selected:

⇒ All trunk roads that cross an agglomeration are shown as structural routes.

⇒ For small agglomerations, one or two structural routes are identified, even if these are dirt tracks.

⇒ When a route extends out of an agglomeration, this means it continues outside the agglomeration. But if the route is limited to within the agglomeration, this means it is structural within the agglomeration only.

Creation of the layer of hub intersections

This data layer comprises all the urban hubs already identified, whose existence is largely justified by the situation of the agglomerations located at the intersection of several communication routes. The criteria selected for building this layer are the following:

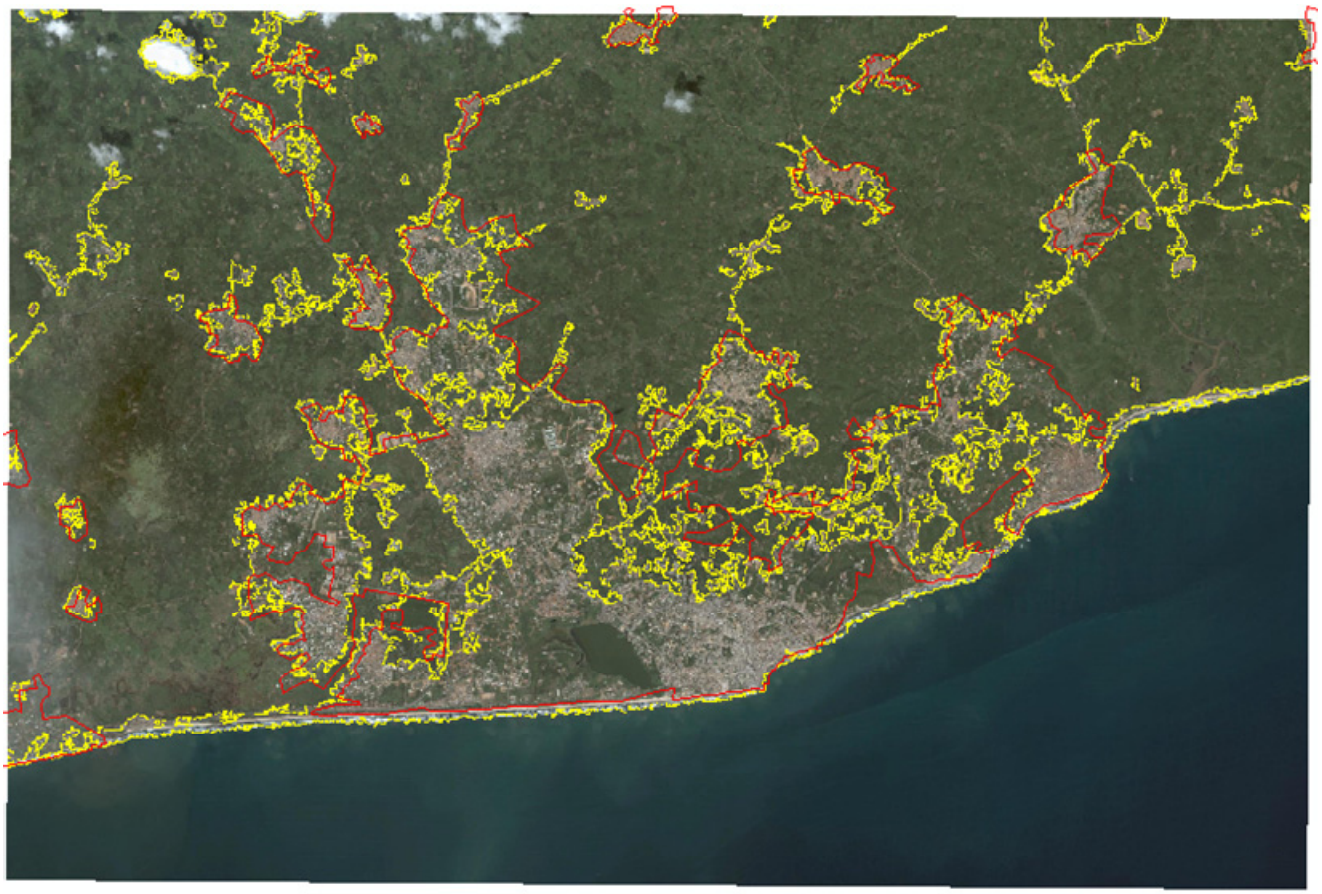
⇒ At least two communication routes must cross within the agglomeration, or in proximity to the agglomeration within a radius of 1km.

⇒ All the road routes are taken into account, whatever their level in the vectorial road database.

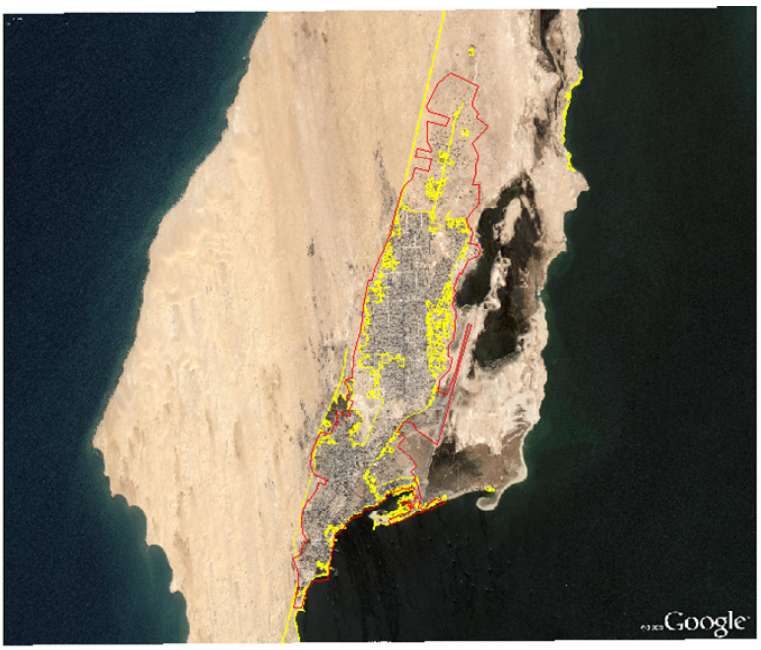
⇒ An agglomeration can be considered a hub intersection if the communication routes are clearly identifiable on the high resolution images, even if these routes are not included in the vectorial road database.

⇒ Extensive agglomerations (on a regional level) are not taken into account in this data set, because even if these agglomerations were built in the past on the sites of intersections, their existence today is no longer mainly determined by this factor.

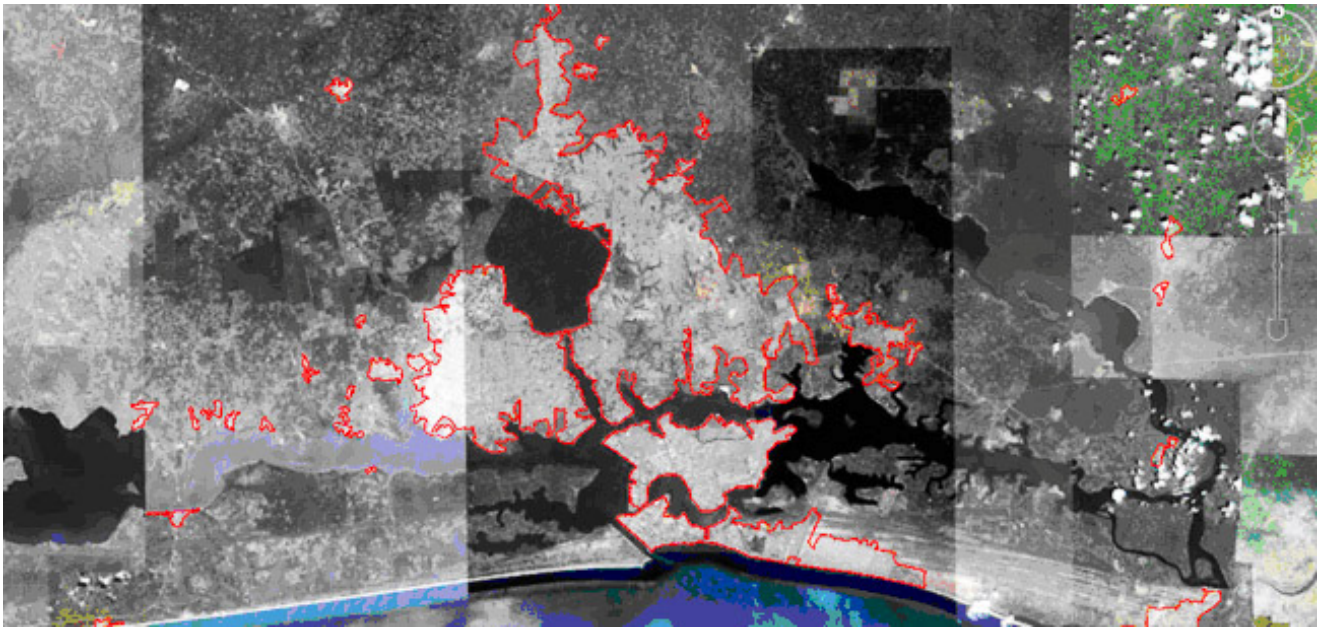
⇒ The urban cores that are satellites of major agglomerations are not taken into account in this layer, since here again their existence is not principally justified.



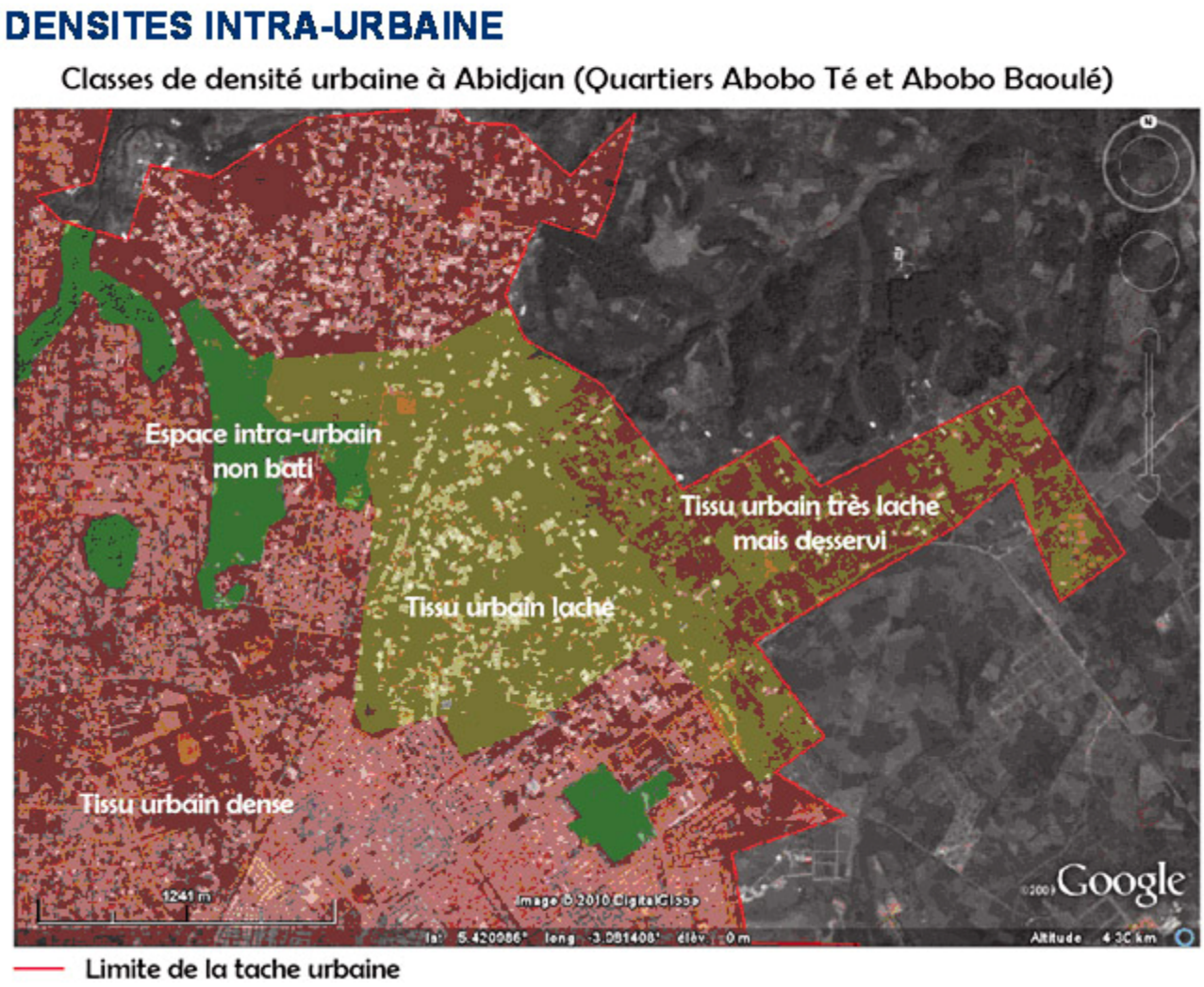
Corridorization of urban sprawl in Cape Coast (Ghana). (source Johanna Baro – EAM)



Discrimination of urban sprawl by image processing
(in yellow), by photo interpretation (in red). Source: Johanna Baro – EAM.



The city of Abidjan (source Johanna Baro – EAM)



Classes of intra urban density in Abidjan (Abobo Té and Abobo Baoulé districts – source, Johanna Baro - EAM).

2. THEMATICS SPECIFIC TO GEODYNAMIC ANALYSIS MAPPING

Four objectives were set for the cartography work:

- ⇨ Define a uniform reference framework based on a typology applicable to the whole of the West African coast, in order to place in context and compare the various local manifestations of coastal erosion.
- ⇨ In the selected typology, take into account criteria of exposure to potential natural risks to human settlements on the edge of the coastal area or likely to be built there in the future.
- ⇨ The diagnostics of the methods of sediment transport from the continent to the coastal area and their contributions to the conditions of equilibrium or disequilibrium in interaction with the coastal drift and sediment transport currents.
- ⇨ Highlighting of elements of reflection on the possible impact on coastal geodynamics resulting from hypotheses about rising sea levels.

The work of cartography was initially presented on a scale of 1:250,000 (which mean, for the study zone, approximately 14 metres of map) and a summary of the work is presented on a scale of 1:500,000.

Aware that a scale of 1:250,000 does not provide the accuracy of LANDSAT satellite image interpretation required on a number of sites to present the context of erosion, the diagnostic study was completed (as it was impossible to express all the information on the map) by means of a systematic "zoom" of the coast at a scale of +/- 1:25,000 (using tools such as Google Earth, among others).

The proposed typology of the coastal systems centres around two complementary readings expressed on the 1/500,000 geodynamic analysis map accompanying this report:

- ⇒ The nature of the shoreline (typology of sea fronts): analysed through the evaluation of 698 segments in 10 geomorphologic classes, whose dynamics and sensitivity to erosion were assessed.
- ⇒ The analysis of a coastal fringe approximately 25 km wide, the sedimentological and lithological characteristics and sensitivity to coastal erosion are evaluated.

The initial typologies devised for the 1:250,000 mapping **have been simplified** for this final 1:500,000 mapping. These original legends were presented with the regional pre-summary report published in March 2010.

NAME	Primary data sources	Treatment	Typology and/or hierarchy	Type of representation
Orientations of sediment deposits resulting from coastal drift (1)	Landsat images, resolution images, bathymetry generated from DEM	Photo interpretation, identification of flows from turbidity plumes, of the shape and orientation of estuary deposits, sand spits and other sediment deposits.	None	Vector
Bathymetry	General Bathymetry Chart of the Oceans – IOC – UNESCO / IHO	Curves generated from the DEM at 30 arc seconds	10 classes	Vector
Hypsometry	Digital Elevation Model SRTM (CGIAR-CSI)[3] at 90 ocean metres – IOC – UNESCO/IHO	Curves generated from the SRTM digital elevation model (CGIAR-CSI)[4] from 90 metres	10 classes	Vector

[3] The quality of this digital field model was confirmed by a CIAT study: **Comparison of SRTM derived DEM vs. Topographic map derived DEM in the region of Dapa.**

(1) The cartographic representation of this thematic shows the directions resulting from the sediment transport identified on the basis of the orientation of the observed deposits. This information has only been shown when sufficient data was available.

2.1. TYPOLOGY OF SEA FRONTS

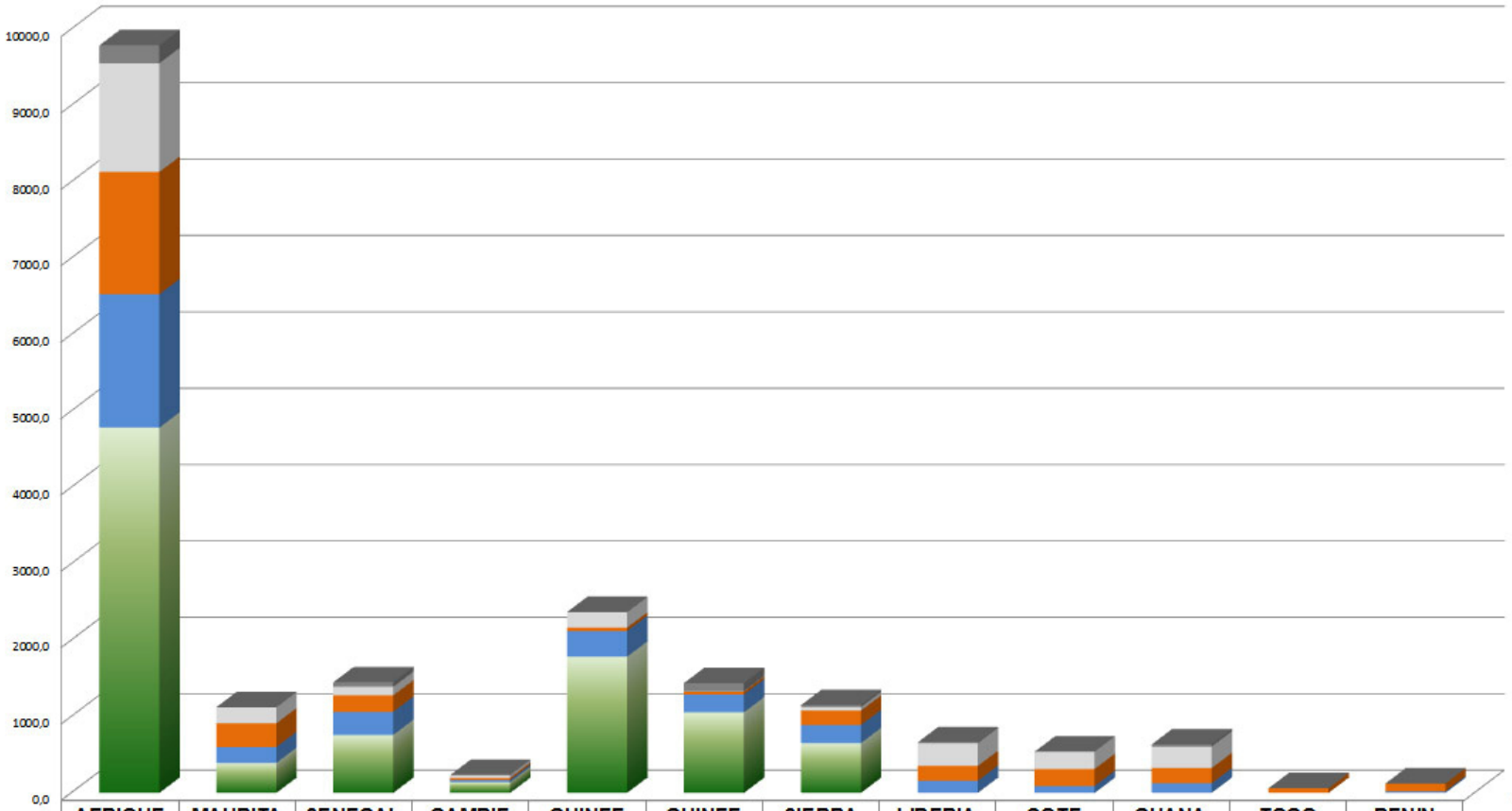
This typology is directly concerned with the nature of the shoreline. The typology adopted for the sea fronts is expressed in the table below:

Description	Code Summary 500 000	Definition and geodynamic coastal context	Exposure to risks of human settlements
1. "Apparent" coast regularly covered by tides (intertidal zone, typically mangrove)		Erosion and sand or mud siltation subject to the interaction of coastal currents and tidal currents serving the mangrove channels and any continental tributaries they may have.	Unsuitable for human settlement except flood protection and agriculture (rice-growing).
	1A	Evolving but permanent and continuous mangrove barrier.	
	1B	Undergoing great change, erosion or accretion, mangroves discontinuous or absent.	
	1C	Narrow mangroves adjacent to other formations and type 4 littoral zone.	
2. Naturally highly unstable sand or mud coast	**2A**	Narrow coastal rims and sand banks adjacent to mangroves. Very active erosion and siltation.	High exposure to storm hazards and erosion (fishing villages and tourist areas) High risk of fluvio-marine flooding, very active topographic change.
	2B	Islets, narrow coastal ridges and sandbanks in islands.	
	2C	Estuary sites with complex fluvio-marine dynamics, spates, low water flows, tidal and currents and coastal drift leading to continuous, dynamic change in the sites concerned.	
3. Sandy coast with straight longitudinal profile adjacent to sandy formations		Coastal drift current and sediment transport always present and in variable intensity, shaping sandy rims and terraces with no rocky obstacles.	High generalised exposure to storm hazards. Risks related to erosion very variable depending on the regions and sediment reserves. High risk of breach-fragmentation of the ridge in 3C or of lido migration. High impact of any development that alters coastal transit.
	3A	Absence of back-lagoons or channels parallel to the shore in proximity to the shoreline, or possible presence more than 2 km away.	
	3B	Narrow coastal rim bordered by discontinuous lagoons and channels back from the shoreline (between 500 m and 2 km from the shoreline).	
	3C	Very narrow coastal rim with continuous close edge of lagoons and channels (< 500m from the shoreline) – Lidos.	
4. Undulating coast with rocky headlands and sandy coves		Dynamics of coastal currents regulated by the headlands and rocky obstacles which act like groynes.	Risk of storm hazards and erosion variable on the scale of the sites. High risk for buildings on the beach and changes in coastal currents in a context where sediment reserves are often limited.
	4A	Coves with wide radius curvature adjacent to sandy terraces and rims.	
	4B	Frequent rocky headlands with sandy coves, in places less exposed to dominant ocean waves.	
5. Rocky coast	**5**	Rocky coast, small sandy beaches in places. Erosion variable depending on the degree of resistance and alteration of rocks.	Risk limited to loose, (subsidence) weathered or fractured rock.

Length of littoral zone by type of coast (scale 1:75,000, spherical distances – 1: length in km, 2: number of segments).
These values are approximate and are only given as an indication[5].

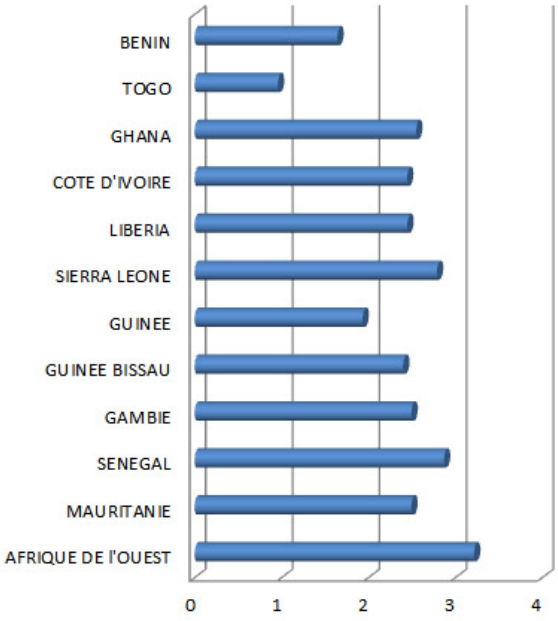
TYPES	WEST AFRICA		MAURITANIA		SENEGAL		GAMBIA		GUINEA BISSAU		GUINEA		SIERRA LEONE		LIBERIA		COTE D'IVOIRE		GHANA		TOGO		BENIN	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1A	2631.0	115	0.0	0	278.7	8	0.0	0	1071.0	58	858.8	30	422.1	19	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
1B	1608.0	55	392.8	9	479.8	14	100.6	3	245.0	9	191.0	14	198.7	6	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
1C	544.0	36	0.0	0	0.0	0	41.3	3	467.2	29	4.7	1	30.8	3	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
2A	479.6	57	0.0	0	67.7	5	10.9	1	189.9	21	148.2	21	63.0	9	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
2B	512.0	61	94.2	8	156.6	15	16.5	2	93.4	11	21.7	5	124.9	19	4.8	1	0.0	0	0.0	0	0.0	0	0.0	0
2C	194.1	68	17.8	1	33.5	2	0.0	0	0.0	0	0.0	0	6.6	1	57.4	37	24.3	8	49.2	16	0.0	0	5.3	3
3A	939.2	37	286.0	10	176.8	3	7.7	2	21.7	4	0.0	0	154.1	4	16.3	2	112.2	2	78.0	7	38.2	1	48.1	3
3B	662.6	65	25.0	4	37.6	6	17.6	3	21.8	5	35.0	5	35.1	6	179.1	21	111.7	6	122.0	6	23.6	1	54.1	2
3C	559.8	67	95.4	6	46.1	6	1.4	1	53.1	7	65.4	7	42.6	6	95.5	16	66.6	8	76.2	8	0.0	0	17.5	2
4A	810.0	60	137.2	8	83.5	7	11.7	1	23.1	4	0.0	0	16.9	1	186.9	20	136.6	6	214.0	13	0.0	0	0.0	0
4B	611.3	55	71.5	9	28.1	3	25.7	4	179.7	13	6.4	2	28.9	4	112.8	11	90.0	4	68.3	5	0.0	0	0.0	0
5	235.7	22	2.5	1	60.3	6	0.0	0	3.0	1	107.5	6	24.2	4	11.2	1	0.0	0	27.0	3	0.0	0	0.0	0
TOTAL KMs	**9787.3**		**1122.3**		**1448.6**		**233.4**		**2368.9**		**1438.7**		**1147.9**		**664.0**		**541.4**		**634.7**		**61.8**		**125.0**	
Diversity (Shannon Index)	3.216		2.494		2.869		2.496		2.400		1.933		2.788		2.448		2.445		2.550		0.959		1.643	

[5] As common usage dictates and as recalled by SHOM (http://www.shom.fr/fr_page/fr_shom/delimitations_maritimes.htm), the length of the shoreline depends directly on the scale it is measured at. The representative of Togo on the UEMOA PRCLEC Regional Scientific Committee nonetheless points out that the length of the coast of Togo is 50 km.



	AFRIQUE DE L'OUEST	MAURITANIE	SENEGAL	GAMBIE	GUINEE BISSAU	GUINEE	SIERRA LEONE	LIBERIA	COTE D'IVOIRE	GHANA	TOGO	BENIN
Littoraux rocheux	235,7	2,5	60,3	0,0	3,0	107,5	24,2	11,2	0,0	27,0	0,0	0,0
Littoraux en caps et anses	1421,3	208,7	111,6	37,4	202,8	6,4	45,8	299,7	226,6	282,3	0,0	0,0
Littoraux rectilignes +/- stables	1601,8	311,0	214,4	25,3	43,5	35,0	189,2	195,4	223,9	200,0	61,8	102,2
Littoraux dynamiques et instables	1745,5	207,4	303,8	28,8	336,4	235,3	237,1	157,7	90,9	125,4	0,0	22,8
Mangroves	4783,0	392,8	758,5	141,9	1783,2	1054,5	651,6	0,0	0,0	0,0	0,0	0,0

Profiles of littoral zones in the West African States (length in kms, spheric distances, scale 1:75,000, approximate values).



Diversity of coastal profiles by type of littoral zone
(Shannon diversity index).

1 MUD OR SANDY COAST REGULARLY COVERED BY THE TIDE

This is an "apparent" littoral zone materialised by a line of mangroves. The "apparent" shore lies under the elevation of the highest seas.

1A APPARENT COAST OF MANGROVES MATERIALISED BY CONTINUOUS BARRIER OF TREES

Definition and geographic location: this is a "fictitious" shore as it is subject to daily flooding and evacuation by the tide (intertidal zone). The border of mangrove trees materialises a fragile balance between:

⇒ a height subject to tidal flows that is acceptable for the maintaining of the aerial roots of the mangrove trees anchored in unconsolidated sandy mud soil rich in organic matter.

⇒ The maintaining of the sediment deposit process favoured by the root network of the mangrove trees, with the maintaining of water circulation to ensure oxygenation of the soil milieu.

The map boundaries of this category were obtained by generating a contour at 0 m from a digital elevation model (SRTM30). However, at the scale of 1:250,000 the shores of many small interior mangrove channels have not been drawn, and still less at 1:500,000. The confrontation between the contours generated from the DEM and the spectral response of the limits of the mangrove areas match almost perfectly at these scales.

The mangroves in Senegal, Guinea Bissau, Guinea Conakry and Sierra Leone are largely concerned by this category. In addition to the mangroves on the sea front, this also covers the apparent shores of the estuaries of mangroves, channels and rias that penetrate deep into the continent, which means a considerable length of coastline in this category.

Coastal geodynamics: the genesis and evolution of this type of coast is governed by a number of factors, which should be apprehended on a local scale. The main factors are summarised as follows:

- The dominant influence of the CDC-ST[6], or their absence.

[6] Coastal drift current and sediment transfer

- The height of the tidal range (typically very high in Guinea and Guinea Bissau).
- The interaction at the level of the estuary between CDC-ST and the flow and flushing effect of the mangrove channels.
- The sediment supply transported towards the ocean from the continent, low towards the rias with small catchment areas or towards low-lying sediment trapping catchment areas, important for certain river outlets, in particular the Corrubal in Guinea Bissau or the Jong in Sierra Leone.
- Change through meander formation in the mangrove channels with continuous destruction and reconstruction of the mangrove shores.
- The impact of recurring drought on the balance of mangrove shores (Sine Saloum, Casamance).
- Lastly, in proximity to the major agglomerations or fish processing sites, the destruction of mangrove ecosystem for firewood.

Human activities on the edge of the coastal area and issues at stake: continuous susceptibility to tidal flooding excludes any type of habitat. To this constraint is added the non consolidation of the mud soil unsuitable for installing breakwaters.

The shore is therefore only attainable by waterway as part of the activities of fishing or gathering utility wood, sticks and firewood from the mangrove trees (in difficult exploitation conditions).

A real boundary of practicability between the land and water activities, access to the shore is developed locally on the sites with the most favourable topography for access to canoes.

Rise in sea level hypotheses: possible decline of the mangrove stand along the coast but adaptation possible depending on the ratio of the speed of sea level rise to siltation.

1B APPARENT COASTLINE WITH DISCONTINUOUS BORDER OF MANGROVES AND/OR COASTAL MUDFLATS (OFTEN FORMER MANGROVES).

Definition and geographic location: Only the most extensive segments (more than 3 km) have been defined. They appear to be associated with gently sloping mudflats at low slope followed by tidal limit, by muddy shallows.

This situation was observed in Guinea Conakry, Guinea Bissau and Sierra Leone, but is relatively rare compared to the percentage occupied by continuous mangroves. This category also encompasses the special case of the mud shores of the Banc d'Arguin in MAURITANIA.

Coastal geodynamics: it is difficult to assess here beyond assumptions/hypotheses to be confirmed to explain in such landscape the two following scenarios which could occur :

⇒ Sites where the mangrove stand is being destroyed by erosion and/or alteration of the milieu, or in some cases even by anthropogenic destruction.

⇒ Sites that are being colonised by the mangroves, as the sediment balance conditions have changed due to sediment trapping by shoals.

Human activities on the edge of the coastal area and issues at stake: same considerations as for category 1A, the reconstitution of a mangrove shore in periurban sectors where the mangrove has disappeared due to wood cutting is not yet on the agenda (as has been done in South-East Asia), except locally in Siné Saloum.

1C APPARENT COASTLINE TYPEFIED BY THIN FRINGE OF MANGROVES ADJACENT TO LOCALLY ROCKY HILL TOPOGRAPHY.

Definition and geographic location: On the ocean front, this type of coastline zone is only rarely present, except in Guinea Bissau in the Bijagos Archipelago and estuaries of the sout. On the other hand, when the shores of the rias that penetrate inland are taken into account, the frequency of this type of coast in combination with type 1B is much higher.

The mangrove stands are on average 50 to 200 metres wide to the inland shore of the highest tides, located at the foot of hills. This contact area may, at a shallow depth, have levels of hardpan at the bottom of the slopes.

Coastal geodynamics: In the case of the Bijagos, it seems that this type of shore is prolonged on the foreshore and sometimes further out to sea by rocky banks that facilitate sandy/muddy sedimentation which is then colonised by the mangroves as soon as the conditions allow it. These shallows play the role of "submerged groynes".

Human activities on the edge of the coastal area and issues at stake: Due to the narrowness of the mangrove barrier to be crossed, these sites are often used as routes for taking canoes between the sea and dwellings located on the nearby hills (frequent case in Guinea Bissau).

Rise in sea level hypotheses: situations vary depending on the sites and the context of current and sediment systems: mangroves reconquering (progradation) by a return of ocean wave heights and oxygenation of silt milieus or continued regression of mangroves due to a tidal range that has become too extreme.

2 COASTAL SANDY OR SANDY/MUDDY ZONES IN LOCALISED SITES WITH VERY HIGH NATURAL INSTABILITY

2A SAND OR SILT LITTORAL ZONES ASSOCIATED WITH MANGROVES AND NOT COVERED BY THE TIDE

Definition and geographic location: this type of coastline is characterised by longitudinal profile generally curve, the curve describing an angle close to 90° in places, at the level of the estuary mouths of major angrove channels.

The littoral zone is adjacent to very low altitude sand deposits, either very recent or current, that in places trace a topography of ridges and channels whose width varies from around a hundred metres to a kilometre, in contact with older sandy terraces or mangrove that is regularly reached by the sea.

This situation is represented particularly in Guinea, Guinea Bissau and the Sherbro islands in Sierra Leone.

Coastal geodynamics: the constitution and balance of these coastal profiles resulting from an interaction between the coastal drift current and the tidal currents (tidal ranges of spring tides often exceed 5 metres in these zones) of the large mangrove channels at the outlets of their wide sea estuaries, or even beyond their direct influence. The resultant force of these two opposing forces is by nature unstable at the level of detail of the sites concerned.

In situations where the littoral zone is more or less a straight line, the influence of the CDC-ST largely predominant, even though this current redistributes sediment from the mangrove channels.

Human activities on the edge of the coastal area and issues at stake: this type of coast rarely possesses soil suitable for agriculture, is hemmed in and in an almost insular situation, with very low drinking water resources, and is not very favourable to permanent human settlement. On the other hand, it offers preferential conditions for fishing activities with camps of fishermen quite often migrant and from other countries.

Rise in sea level hypotheses: Disappearance of very low sand spits and ridges, reconfiguration and reconstitution of spits in the long-term a little further inland with the retreat of the mangroves.

2B COASTLINES OF SANDY ISLETS AND INSULAR SPITS

Definition and geographic location: this category comprises coasts that are predominantly sandy, but very complex individually, including, in places, mudflats and mangroves that have developed typically in an insular situation. This is the case for the Turtle Islands in Sierra Leone, the small islets in the Bijagos archipelago in Guinea Bissau, and the narrow insular sandy spits of Siné Saloum in Senegal.

Coastal geodynamics: the emergence of these islets is typically favoured by the presence of rocky outcrops or hardpan which encourages the trapping and depositing of sediment. As a general rule, these islets are the tips of surrounding shoals that emerge at high tide. In places, they are the relict of larger, estuary spits that are

insularised. Their instability and that of their shores is certainly high and obeys a current system that is probably complex and different from that of the other category 2s.

Human activities on the edge of the coastal area and issues at stake: the surrounding shoals are important for the diversity of marine biological communities and are known to local fishermen. The emerged tips are the site of fishermen's camps.

The Parc National Marin des Poilão (Bijagos Islands) encompasses this type of site, and the Turtle Islands in Sierra Leone should benefit from a similar protection effort.

Rise in sea level hypotheses: Disappearance of certain sandy islets, reduction of surface area and retreat of the coast, reconfiguration of detail.

2C ESTUARY AND COASTAL RIVER LITTORAL ZONES

Definition and geographic location: with the exception of the vast estuaries of the Gambia, Senegal, Corrubal and Konkouré rivers, these estuary sites are bound up with very similar patterns regardless of the extent of the basin/catchment:

⇒ An estuary mouth opened by the waters from the continent and by the tidal flux for the largest rivers.

⇒ Two spits on either side of the mouth, sand rims shaped by the drift current, the sediment transported by which is enriched by river sediment supply. The sand rim and the beach have a straight longitudinal profile facing the ocean and more or less steep curvature at the estuary mouth.

⇒ Behind the sand rims and in parallel to the estuary is a complex of wetlands, salt marshes or freshwater marshes with the sequences of vegetation adapted to the local hydrological and topographic conditions.

In addition to the major rivers (Cavally, Sassandra, Badama and Volta), these estuary zones are particularly present on the coasts of Liberia, Western Côte d'Ivoire and Ghana. They are associated with the geological and topographic conditions of the Precambrian basement (craton) with a high density hydrographic network supplied by abundant precipitations.

The estuaries of the Senegal and the Sine Saloum come with a rather unusual pattern, marked by a long, narrow spit parallel to the shore and an estuary that is undergoing cyclical movement.

Coastal geodynamics: the estuary sites **are constantly evolving** in interaction with:

⇒ The coastal drift current and sediment transport (CDC-ST) which tends to close the estuary outlets by constitution (and often reconstitution) of the coastal rim.

The hydrological regime of the coastal rivers related to the seasons during floods to maintain or reopening of the outlets and low water flow periods during which they tend to be filled up by longshore sediment transport.

⇒ The result of these two contradictory forces exerted perpendicularly eflects the local variability (extent of catchment areas of the coastal rivers, exceptional spate events and the corresponding flows). For many small coastal rivers, the transit of flows to the sea is occasional, through the temporary opening of an outlet or percolation of rainwater (stored in a perilittoral lagoon) through a rim (frequent case for the coasts of Liberia and West Côte d'Ivoire).

⇒ The role of tidal currents for the largest estuaries, which interact with the river flows, particularly during high water periods.

⇒ The occasional role of certain storm surges opening a breach in a fragile coastal rim, thereby favouring a new outlet for the estuary lagoons, which receive the waters originating from the continent.

Note also the impact of changes in coastal geodynamics for the estuary sites of regulated sites (system of flood peaks and sediment transfers) by large dams (Bandama and Volta for example).

THE HIGH, DIFFICULT TO CONTROL NATURAL INSTABILITY OF LITTORAL ZONES CLOSE TO ESTUARIES IS WORTH NOTING.

Human activities along the coastline and issues at stake: Estuary zones are precious sites for biodiversity which is favoured by the salinity gradient and fluvial-marine ecotone:

⇒ Places of exchange, reproduction and migration of the aquatic fauna native to sea, brackish waters and fresh water.

⇒ Highly diversified plant communities and habitats in lagoon areas and peripheries.

The exploitation of these biological resources has long been an incentive to the population to settle permanently or temporarily on these sites which are also favourable for the sheltering of fishing vessels and for access to navigable rivers. Places for exchange, trading, halts for changing transport vehicles and colonial trading posts; the human settlement of estuaries has also been facilitated by the availability of fresh water resources.

The response to the constraints and risks associated with the dynamics of change of these fragile environment has traditionally been resolved by the movement and mobility of “light” human settlements. The same cannot be said for “heavy” infrastructure (harbour, urban, hotel facilities), the sustainability of which is confronted with change forecasts that are unreliable at the level of detail of the sites. (History of Grand Bassam or of the tourist village of Assinie in Côte d’Ivoire). These questions are all the more important as these sites, due to their landscape diversity, the proximity of still water lagoons and sheltered interior beaches, often have a greater tourism potential than the surrounding coastal areas.

Sea level rise assumptions Increased instability of spits, reconfiguration and landward migration of peri-littoral wetlands, acceleration of the dynamics observed.

3 SANDY COAST WITH STRAIGHT LONGITUDINAL PROFILE

In the absence of rocky obstacles, these coasts are continuously shaped by coastal drift currents and the associated sediment transport.

Any alteration of these dynamics by the building of breakwaters in the opposite direction to the current rapidly leads to an accumulation of sediment upstream of the breakwater and downstream erosion, which may affect several kilometres of coast (history of the ports of Nouakchott, Abidjan, Cotonou, Lomé, etc.).

The apparently perfect straightness on a local scale should be tempered by the larger scale where slight undulations on a period of the order of twenty kilometres, or even more, seems to be emerging with sectors that “tend towards erosion” and others that “tend towards accretion” (the west coast of Côte d’Ivoire, for example or Benin – see glossary). These undulatory phenomena with wide periods (time and space) are reflected by a more or less regular displacement of the curvature of the shore in time and space over a period of several decades ("sand ball").

Within the framework of this work, subdivisions were produced, taking account of the presence (proximity to coast and density) of channels and lagoons parallel to the shore.

This criterion is important for identifying the vulnerability of human settlement along the coast, in the current situation faced with marine erosion and under the assumption of a rise in sea level, or of storm surges possibly accompanied by continental spates during periods of high rainfall.

The following should be distinguished:

SANDY COASTS ADJACENT TO DUNE FORMATIONS: this type of coast covers the whole of Mauritania and Senegal down to Dakar, practically uninterrupted. The beach is bordered by a current coastal rim or changes to roughly stable dune formations with no transition. The differentiation of these dune formations is based on:

⇒ The wide diversity of dune landforms related to the history of Aeolian deposits often from several phases in the Quaternary era.

⇒ Their stability and alteration under the action of Aeolian erosion and transport (aridity and density of the corresponding vegetation, wind regime, land-sea and sea-land wind exchanges)

Coastal geodynamics: the CDC-ST is powerful and supported by a prevailing wind regime (Harmattan) North-South to North-East – South-West, directions that are practically parallel to the coastal wind regime. These winds are capable of aeolian sand transfer from the dunes to the coast. However, the sea winds (West-East) can mobilise the sands on the foreshore (which dry rapidly in arid conditions) and dunes behind the beach in almost the opposite direction from the prevailing winds. The winds in the rainy season (even of short duration) also exert an influence in a North-West/ North–Easterly direction, in particular on the dune coast of Senegal where coastal areas have been re-planted with trees to limit the advance of the volatile sands from the coast inland to the continent.

Human activities on the edge of the coastal area and issues at stake: human habitat very rare on the edge of the coast, as fishing communities and fish farmers traditionally settle inland. Note that there are some exceptions that facilitate access to common activities of landing the catches from artisanal fishing, or residential tourist facilities (example of the near surroundings of Nouakchott).

The growing use of four wheel drive vehicles has changed the way the coast is accessed, the beach becoming a more practicable route at low tide than land routes in an unstable dune environment. The beach "boulevard" is therefore connected to the interior road network by tracks that cross the dune rim.

The potential attractiveness for coastal resorts is modest on a comparative scale of international tourism. While sunshine is guaranteed, the wind and the relatively cool water temperatures associated with the Canary current, along with dangerous currents act as constraints. For the moment, tourist frequentation is limited to the urban population of Nouakchott and to a lesser extent from Dakar, driving to the beach for picnics.

The observation of a few buildings "on the water's edge" in the coastal area around Nouakchott shows the risks run by such infrastructure: the fragility of the coastal rim, difficulty controlling aeolian transits, impacts of storm surges.

SANDY COASTAL ZONES ADJACENT TO TERRACES LARGELY DEVELOPED INLAND Inward on a depth of between 2 and 10km. These littoral zones are adjacent to recent sandy terraces, of an average elevation of between 5 and 15 metres, with more transverse topography marked by channels of varying depth, parallel to or curved in relation to the present day shoreline. In the absence of rocky elements, these materials are extremely sensitive to all forms of marine erosion, are continuously remobilised under the action of ocean waves, CDC-ST currents and episodic high swell. This type of coast is particularly developed in an uninterrupted way:

⇨ On the East coast of Cote d'Ivoire from Fresco continuing to Axim in Ghana.

⇨ In Ghana, Togo and Benin, from the Volta delta to the border with Nigeria.

There are other, less extensive portions of coast that present a similar profile, in particular from the Sherbro islands in Sierra Leone to Monrovia.

Coastal geodynamics: Due to their geographic situation, these coastal areas are generally oriented East-West and exposed to ocean waves which are South-West/North-Easterly almost all year round. The CDC-ST is regularly supported by these dynamics with a high potential for marine erosion when this is also aggravated by a deficiency in sediment reserves. The foreshore and the beach offer numerous signs of a situation that is changing greatly and continuously: high berms, crescent shaped beaches, foreshore channels, bars and breaking ocean waves "work" the sandy material constantly.

Human activities on the edge of the coastal area and issues at stake: with the exception of the palm groves and their related subsistence crops in Ghana and Togo/Benin, an ancient tradition, settlement at the edge of these coastlines is a recent practice. Note that the crossing of the bar and the dangers of the sea are not an incentive for small fishing, reserving this activity for more specialised fishing. Human settlement has been developed with the creation of vast palm groves in Côte d'Ivoire accompanied by planned villages, while today vast sectors of coast (hemmed in, it is true, and with soil that is mostly unsuitable for agriculture) are almost devoid of population (southern coast of Sierra Leone, Liberia for example).

The development of major agglomerations close to this type of coast (Abidjan, Lomé and Cotonou), their extension along the road network corridor that is constantly being improved and is easy to install on sandy terrace, the increasing use of four wheel drive vehicles, have been the impetus for a major transformation of certain coastal areas (Abidjan, Lomé-Cotonou) in a few decades. In addition to the residences of rural populations undergoing demographic growth, to which are added social categories or age groups with urban-based incomes, who reside there for reasons of rural comfort and the cost of accommodation which is lower than in urban zones.

However, the most visible transformations are due to the development of second homes for leisure, or for prestige, for certain categories of urban dwellers on a model that tends to move as close as possible to the sea front. Added to this is the installation of coastal road systems in urban zones, and the construction of hotel complexes and tourist facilities that follow the same logic.

In financial terms, the littoral zones concerned accumulate the most costly stakes of the impact of coastal erosion. This point of view does not exclude the socio-economic importance of the disappearance of agricultural land or habitat of relatively modest value.

COASTAL SANDY ZONES ADJACENT TO NARROW TERRACES OF VARYING AGES AND ELEVATIONS:
The characteristics of this type of coast are very similar to the previous type, but the terraces are narrow (0.5 to 1 km wide) by 1 to 5 km in length, with complex topography in transition with the surrounding hills. They are associated with the Precambrian basement of the coasts stretching from Monrovia to Fresco in Cote d'Ivoire and from Axim to Tema in Ghana. Only the most developed have been mapped on the scale of 1:250,000. Type 4 littoral zones, the characteristics of which are detailed below, also present, in the sandy coves, frequent small terraces and coastal rims but more modest in size.

Coastal geodynamics: this is comparable to that described for the previous category, the main difference residing in the local modulations of the CDC by the headlands that frequently limit the extension of these littoral zones.

Human activities on the edge of the coastal area and issues at stake: for historical, cultural and demographic reasons, human settlement on these sites with very similar natural potential is contrasted:

- ⇒ Very high density of palm groves in Ghana with frequent residential facilities for leisure or even tourism.
- ⇒ Very low human presence on the coasts of Côte d'Ivoire and Liberia.

Due to the narrowness of the sandy deposits of the rim, and the topographic complexity of the area behind the beach, the stakes related to erosion are high, in particular on the sites with tourist facilities. Note that this category, for reasons of landscape, often presents a considerable potential for tourism.

This category is mainly represented in Mauritania, where certain depressions (sabkhas) are at an elevation below average sea level, but also in the Gulf of Guinea where the large expanse of lidos separates the channels and lagoons close to the sea shore.

Taking into account the risk exposure of human settlements, three categories have been distinguished depending on the narrowness of the coastal dune rims and the proximity of peri-littoral flooded or flood-prone channels and lagoons.

3A	SANDY COAST WITH STRAIGHT LONGITUDINAL PROFILE LACK OF BACK-LAGOONS, DEPRESSIONS OR CHANNELS NEAR THE SHORE IN PROXIMITY TO THE SHORELINE, OR POSSIBLE PRESENCE MORE THAN 2 KM AWAY.

Rise in sea level hypotheses: the situation gives cause for concern, the coastal trend here should be considered a general trend. The local installations are ineffective, some even counter-productive (walls on the edge of the foreshore exposed to storms) accentuating the reflection of waves and cross-shore transits from the land to the sea. The deepening of the terraces suggests that, when the stakes are limited, human settlements could withdraw inland.

3B	SANDY COAST WITH STRAIGHT LONGITUDINAL PROFILE PRESENCE OF BACK-LAGOONS, DEPRESSIONS OR CHANNELS PARALLEL TO THE SHORE IN PROXIMITY TO THE SHORELINE (500M TO 2 KM).

Rise in sea level hypotheses: same remarks as above, with, however, more limited possibilities of withdrawal.

3C	SANDY COAST WITH STRAIGHT LONGITUDINAL PROFILE PRESENCE OF BACK-LAGOONS, DEPRESSIONS OR CHANNELS PARALLEL TO AND SLIGHTLY INLAND FROM SHORE (LESS THAN 500M).

Rise in sea level hypotheses: Risk of partial disappearance of coastal rims and lidos and radical reconfiguration of certain sites with profound alteration of the coastal landscape. It should be noted that, depending on local events and incoming sediment deposits, some lidos have a natural tendency to migrate, others tend to fragment, connecting the lagoon to the sea.

4	SANDY COAST WITH STRAIGHT LONGITUDINAL PROFILE (STEPPED COAST OR ROCKY HEADLANDS AND COVES)

4A	SANDY COAST WITH UNDULATING LONGITUDINAL PROFILE OF ROCKY HEADLANDS AND COVES

Definition and geographic location: the longitudinal profile and coastal geodynamics are determined by the presence of headlands separating sandy coves with lengths and curvature radiuses with varying degrees of accentuation, that can be analysed in two types:

⇒ Coves 2 to 10 kilometres long with a low curve radius.

⇒ Littoral zones with a higher density of headlands separating the coves of 1 to 3 kilometres, with a clearly marked radius of curvature; this configuration is exposed to ocean waves in the most irregular way, especially when the direction of the ocean waves changes depending on the season (example: Senegalese petite côte).

This type of littoral zone is associated with predominantly sandstone geological formations that are highly weathered. The levels of sandstone that are still relatively unaltered or the inclusions of ferruginous cuirass offers increased resistance to marine erosion on certain sites, allowing the headlands to emerge.

The sandy coves are adjacent to recent deposits in narrow coastal rims, gradual onset terraces, isolated lagoon channels in places, the whole occupying a variable width but most often very narrow (50 to 200 metres), and rapidly relayed by footslopes of hills with typically modest elevation.

The Petite Côte in Senegal, Basse Casamance at the level of Cap Skiring, Caravela island in the Bijagos Archipelago and the coast of Ghana from Sekondi to Tema offer numerous examples of this type of shoreline.

Coastal geodynamics: the headlands and their rocky inclusions, even of short extension, act as hydraulic groynes that alter the path of the CDC-ST currents. The downstream part of the headlands is subjected to a

slightly erosive return current, the upstream part is more favourable to accretion, but in the long term with a compensatory sediment balance.

The headlands' exposure to the ocean waves in certain sections of the littoral zone also plays a role in the local alteration of the CDC-ST paths, depending on their relative orientation, in particular in coastal zones where the direction of the ocean waves is subject to seasonal variations (zone situated to the North of the 9th parallel).

This is also the case of certain metamorphic rock formations in the Precambrian shield that are considerably weathered but with resistant seams of the quartzite type or basic rock (Ghana coast).

Human activities on the edge of the coastal area and issues at stake: the proximity of headlands offering better shelter against ocean waves has long been used for embarking and landing of artisanal fishing and today is modernised in places (Joal, Fadiout). On the coast of Ghana, certain sites have historically been used for landing small vessels. The recent development of seaside tourism, in particular on the petite côte and in Basse Casamance, has profoundly altered human settlement in the littoral zone, which for a long time was restricted to scattered villages centred on fishing activities.

In addition to the hotel facilities aimed at international tourism, the concessions and second homes of the country's residents have multiplied, saturating the available land almost continuously along the edge of the beach, on practically continuous stretches of coast.

The careless location of certain constructions given the inherent geodynamics of this type of coast (and which are perhaps accelerating) leads to increasingly costly impacts.

The extreme fragility of many of the headlands should be stressed (for example Varela in Guinea Bissau) which stand on layers of rock that are often thin and highly altered. In a few cases where the alteration of the rock does not preserve the visible rocky materials, there is a strong temptation to extraction at the level of the headlands, and even preventing this type of "artisanal" practice, the long term consequences of such practices could have heavy impacts.

Rise in sea level hypotheses: the risks seem to be concentrated on the fragile headlands subjected to accelerated erosion by rock falls from the upper part of their slope which are often poorly consolidated.

4B	SANDY COAST, ROCKY IN PLACES, WITH UNDULATING LONGITUDINAL PROFILE WITH HEADLANDS, COVES AND CREEKS

Definition and geographic location: the coast of this type are associated with granite or metamorphic geological formations from the Precambrian shield and are mostly profoundly altered into ferralitic soil and alterites across several tens of meters of thickness. This alteration affects in a much more irregular way, however:

⇒ seams of resistant rock, quartzite, pegmatite, gabbro

⇒ Some of the granite is crumbling into rocky "balls" that have been preserved from weathering.

The substance the most resistant to the contact of marine erosion determines numerous headways, a few sections of rocky coast, blocks of rock on the foreshore or reefs situated out to sea. The total length of this rocky presence on the littoral zone is low (probably less than 10%); the remainder is present in sandy creeks and coves.

While the headlands are directly adjacent to hill topographies, the creeks and sandy coves are bordered by a thin coastal rim relayed by a lagoon channel into which a number of small coastal rivers flow. The transition between channels and hills in the hinterland often comprises a fine layer of older sandy terrace of colluvium apron. A subdivision could be established, based on the highest frequency of small segments of rocky coast and often of rocky reefs.

The most part of the coast of Liberia and the West coast of Côte d'Ivoire is concerned by these types of coast, which are also frequent in Ghana around Cape Three Points.

Coastal geodynamics: due to their geographic situation with a perceptibly East-West orientation, these coasts are exposed to South-South-West/North–North-Easterly ocean waves which keep the same direction for most of the year at this latitude, both in a normal situation and in a storm.

This overview should however be modulated at the level of the actual site, depending on the orientation of the coast whose undulating profile is not strictly East-West and that of the headlands and rock seams which reinforce it in a North-South direction. The local impact of ocean waves, the CDC-ST currents' trajectory in the same predominant West-East direction generate high local variations in coastal geodynamics.

These considerations should be taken into account in assessing the risks relative to marine erosion, and the impact of developments likely to modify coastal geodynamics, which should always be approached on a site by site basis.

Lastly, and despite the contributions of a very dense hydrographic network, there are limited continental sediment reserves and with the narrow continental shelf and the consequent low sediment stock, there is a high risk of beach erosion.

Human activities on the edge of the coastal area and issues at stake: the coasts of Liberia and Côte d'Ivoire long remained forest and were practically uninhabited. Even the advancing agriculture front which has been conquering the forest for several decades has only very partially affected the coast. Apart from delta river mouths, the littoral zone is only inhabited in rare, scattered villages, with little fishing tradition.

Note also that the topography near to the coastal zone of highly dissected hills, to which should be added high rainfall, is not favourable for the building or maintenance of roads and tracks, which is a considerable constraint against improving access.

The creeks and small sandy coves, their hilly surroundings of tropical landscape offer a "dormant" potential for suitable tourism sites, which to date have begun to be developed on the coast of Ghana.

Rise in sea level hypotheses: resumption of degradation of headlands, rock falls.

5 PREDOMINANTLY ROCKY COAST

Definition and geographic location: the long history of the geological and pedological alteration of West Africa has left little rock still resistant to marine erosion along the coastal fringe. The rocky sections of the coast examined as part of this study cover less than 1% of the coastline and within this estimated figure, the portions of coast with rocky cliffs are the exception. Among the principal ones are: the Cape Verde peninsula in Senegal, the rocky breakwater at Cap Verga and Conakry in Guinea, Freetown in Sierra Leone, Roberts Port and Monrovia in Liberia.

Coastal geodynamics: differential coastal erosion has isolated these rock masses which constitute obstacles that profoundly alter the trajectories of the CDC-ST, generating counter-currents and high instability on the beaches located in the surrounding areas. It should be noted that these rocky formations are often deteriorated, fractured and subject to erosion and rock fall.

Human activities on the edge of the coastal area and issues at stake: Historically, a good number of these sites constituted landmarks for coastal navigation and the relatively sheltered natural harbour locations in a geographic context in which protected sites with this aptitude were rare.

With the demands of modern maritime traffic, only the Dakar site has retained this role, and alternative port infrastructure had to be found for the historical sites (insufficient depth for the drafts of modern vessels, in particular).

We should remember the complex current systems in proximity to these sites, and the fragility of the urban beaches close to the major agglomerations (Dakar, Monrovia and Freetown).

Rise in sea level hypotheses: low local impact, except for facilities built without foresight at the foot of cliffs facing the sea.

2.2. TYPOLOGY OF SEDIMENTOLOGICAL AND LITHOLOGICAL UNITS OF THE COASTAL FRINGE

This analysis of lithological units has been conducted in a very summary manner, purely with a view to gaining an overall appreciation of the nature of the existing substrates and sediment reserves. The different units employed for this cartography are summarised below:

ZONES WITH ESSENTIALLY AEOLIAN SEDIMENT TRANSFERS (from Mauritania to the Cape Verde Peninsula)		
Ancient or recent sandy dune formations	**S**	Coastal dune rims and sandy terraces
	SD	More or less flat dune formations.
	SC	"Dior" type sandy soils, ancient Aeolian coverage deposits
Formations associated with low lying zones	**LS**	Temporary, more or less saline lagoons and low-lying land, sabkhras and occasionally flood-prone salt marshes, argilloarenaceous.
	Lsd	Borders of sabkhras and/or saline lagoons
	Al	Alluvial deposits from the Senegal river
	ZH	Other undifferentiated wetlands
ZONES WITH ESSENTIALLY FLUVIAL SEDIMENT TRANSFERS		
Coastal rim and recent sandy terraces	**S**	Sandy littoral rim and sandy terraces with ridges and channels, landform smoothed in places
	Sh	Smoothed terraces that are hydromorphic in the rainy season, sometimes more or less saline.
Ancient terraces	**Sct**	Sandy materials from the ancient terraces and undifferentiated sediment formations.
Profoundly altered sediment formations with inclusions of hardpan and resistant rock	**Ct**	Sandy or argilloarenaceous formations with inclusions of ferruginous hardpan.
	St	Formation of "tertiary sand beds" in Côte d'Ivoire
	Tb	Sand or clay materials from the "terre de barres" formation. Ancient alluvial deposits from the Volta.
	Gr	Sandy materials of varying degrees of altered sandstone (rare)
	K	Clay, sandy, pebbly materials from limestone and marno-limestone to ferruginous cuirasses
Intrusive or metamorphic rock	**P**	Profoundly altered granite and metamorphic rocks. Deposits of harder rocks in places.
	Pr	Solid rocks such as quartzite, gabbro and basalt, resistant to erosion.
Flood zones influenced by tides (intertidal)	**M**	Organic sandy-silts from mangroves and sandy +/- saline materials from islets and "tannes".
Continental wetlands more or less connected to the tides	**ZH**	Undifferentiated wetlands
	Al	Alluvial deposit complexes from the major deltas (Volta), materials of variable granulometry.
	L	Lagoons

2.2.1. AEOLIAN SEDIMENT SUPPLY ZONES

The coastal zone stretching from Nouadhibou to Dakar, with the exception of the mouth of the Senegal river, is characterized by a wide stretch of sandy, predominantly dune coverage. The continent-coastal interface is highly subject to erosion and Aeolian transport under the action of winds from substantially different directions:

⇒ The North-South to North/East– South/West Harmattan which blows continuously during more than six months of the year.

⇒ The West-Easterly sea wind and the occasional South/West/Easterly monsoon winds during the short rainy season which affect the coast to a limited depth of about twenty kilometres that extends in latitude to Guinea Bissau.

The Harmattan is the driving force behind the coastal drift currents (CDC) and sediment transport from continent to coast, but the role of winds in the opposite direction is far from negligible in reconfiguring the dune formations along the edge of the littoral zone and sediment transfers towards the continent. Starting from June in particular a South-North current cell forms opposite the Senegalese Grande Côte.

This global schema should be nuanced however with the increasing importance of sand transfer from the coast to the continent gradually descending towards the South, in particular from the mouth of the Senegal river.

With the exception of the Senegal river and the very occasional coastal wetland outlets, no streams, even temporary, reach the coast.

Note also the existence of the Khayar canyon to the north of the Cape Verde peninsula, whose role in trapping sediment should be taken into account.

S Sc	COASTAL DUNE RIMS AND SANDY TERRACES "DIOR" TYPE SANDY SOILS

Definition and geographic location: Current sandy formations that are very unstable irrespective of potential stabilising vegetation in this climate, these systems form a continuous border along the beaches of the littoral zone. Clearly individualised when narrow, separating the coast from intra continental depressions (cf. Mauritania), it switches in transition to older continental dune deposits of the dior type, which are nonetheless subject to more or less recent aeolian remodelling.

Geodynamics: Changes in the coastal dune ridge can be taken into account to approach the problem of stock-taking between aeolian sediment transfers and those mobilised by the coastal drift currents. The map interpretation suggests the following approximate zoning:

⇒ A zone to the North of the grand sabkhra of Nouakchott where the net results of transfers appears clearly in favour of the wind-borne contribution from the continent in almost the totality of the duration mobilised by the CDC. On the other hand, to the South of this zone, everything suggests that the continental part can scarcely manage, except in places, to maintain the equilibrium of the current rim. This is attested by the thinness of the dune ridge adjacent to the nearby major sabkhras in the central and southern littoral zones of Mauritania, which have a lesser supply of nearby mobilisable sand than the rest of the coast.

⇒ Further South again, after Chott Boul, there is a perceptible tendency of coastal sand to advance inland (this in fact was the reason for the replanting of a ribbon of stabilising trees along the "grande côte" in Senegal).

Assumption hypothesis of seal level rise and/or storm surges: As mentioned above regarding type 3C littoral zones, this hypothesis greatly increases the risks of the dune rim being affected by ocean waves in storm situations, with risks of marine intrusion or flooding from the topographically weak points of the rim.

SD	MORE OR LESS FLAT DUNE FORMATIONS

Definition and geographic location: Without going into the complexity of the forms and history of sandy deposits, the following categories can be identified:

- ⇒ Longitudinal, prominent dunes, mostly present in Mauritania.
- ⇒ Sandy soils of fluviomarine terraces, hydromorphic to a certain extent, in proximity to the mouth of the Senegal river and the Banc d'Arguin
- ⇒ Dune formations, undulated to varying degrees, on the near coastline in Senegal.
- ⇒ Smoothed sandy formations on the Senegalese southern Sahel.
- ⇒ Interrupted "barkhane or sif" dune formations localised in flat sabkhras, rocky outcrops, former alluvial plains. While the volumes of sand are lesser than in the case of the previous formations, Aeolian transits are very active (desert zone to the North of Mauritania, mainly).

Geodynamics: The sediment contributions to the littoral zone of all these formations seems to be significant, mainly to the North of the mouth of the river Senegal.

Hypothesis of rising sea level and/or storm surges: Low impact except for certain formations directly in contact with the shore and on which coastal erosion could accelerate.

LS LSD	FORMATIONS ASSOCIATED WITH LOW-LYING AREAS

Definition and geographic location: In Mauritania, these extend largely to the North of Nouakchott ("grande sabkhra") at an elevation inferior to average sea level in places. South of Nouakchott to the Senegalese border, an almost uninterrupted strip of low-lying land borders the littoral zone situated very close by (Aftout es Saheli). South of the mouth of the Senegal, the relict of a similar network of depressions that has disappeared subsists amidst an extensive sandy milieu (Nyayes zone). In addition to the real, almost permanent lagoons in Diawling Park (unit L), the following can be distinguished:

- ⇒ Sabkhras, low-lying decantation zones, argilloarenaceous to a varying degree, occasionally flooded with high rainfall, with a salt water table near the surface.

- ⇒ The sandy margins of the sabkhras, but at an elevation that remains low, exceptional flooding in places.

Geodynamics: The functional gulleys allowing these low lying areas to be emptied are rare - two or three in proximity to the Chott Boul. It is problematic to identify traces of other fossils under the sand of the littoral rim and the Aeolian sediment contributions.

Hypothesis of rising sea level and/or storm surges: If the sea level rises this could facilitate the re-opening of fossil gulleys and the corresponding sea water intrusions. Similarly, a climate change hypothesis that envisages years with exceptional precipitations could also lead to the reopening of the gulleys which would allow the evacuation of the waters accumulated under these low-lying areas.

2.2.2. FLUVIATILE SEDIMENT SUPPLY ZONES

This zone extends from Dakar to Cotonou. In addition to the remobilisation of fluviomarine sediments by the currents (CDC-ST), the sediment contributions from the continent are transmitted to the littoral zone through a

fluvial or fluvio-marine hydrographic network in the case of mangrove channels and estuaries. These transfers in the nature and volume of sediment depend on a certain number of factors:

⇒ The extent of the river basin, the system of flood peaks, interception in wetlands before sea outlet, the type of sediment coming from the river basin

⇒ The presence of major dams playing a sediment trapping role upstream, but especially regulating the flood peaks which are the main sources of sediment supply.

⇒ The density of the hydrographic network of small coastal rivers that flow into the sea and have fast sediment transport (coast of Liberia, west coast of Côte d'Ivoire) or the presence of a pre-littoral hydrographic network with sediment trapping shallow, low-lying areas (Guinea Bissau, Guinea Conakry, Casamance and Sierra Leone).

Whatever the final destinations of these sediments (coastal redistribution by CDC-ST or deposits on the continental shelf or towards deep sea trenches), it seems that a large part of the present day continental sand reserves are localised in the vast belt of sandy terraces and/or mangroves.

LITTORAL RIM AND RECENT AND ANCIENT SANDY TERRACES

S	COASTAL DUNE RIMS AND SANDY TERRACES

This unit is heterogeneous, and comprises:

⇒ Spits and littoral rims of recent fluvio-marine contribution remobilised in places by Aeolian erosion. Their genesis depends on coastal drift currents, erosion or accretion depending on the sites.

⇒ Terraces attributed to the recent Quaternary era in several siltation episodes, with transverse profile of ridges and channels at an average elevation of 10 to 15 metres and close to sea level for the channels (examples: Sherbro islands, Abidjan terraces and Grand Bassam).

SH	HYDROMORPHIC FLAT TERRACES

This unit concerns low terraces that are relatively flat and flood-prone during high seasonal precipitations, often planted with rice (Guinea Conakry and Sierra Leone), with settlements concentrated on slightly higher sand ridges.

SCT	COASTAL DUNE RIMS AND SANDY TERRACES

This unit corresponds to ancient terraces in transition with peneplains with roughly sandy soils associated with geological sediment formations often with sandstone and profoundly altered (Casamance, Guinea Bissau and Guinea and Sierra Leone). It should also be mentioned that inside the mangrove areas there are numerous islets not reached by the regular tides, of low elevation, sandy to silty and with varying degrees of salinity (tannes). Their contour is traced by the high sea level mark and in light of their small dimensions, many are not identified by a code as part of the 1:250,000 maps.

Geodynamics: In the absence of any rocky obstacles, the most frequent situation, these formations are highly remobilisable by the CDC. Their permeability excludes the development of an active hydrographic network towards the coast; hydrological erosion is restricted at local level to the filling in of the channels. Although they border almost ¾ of the littoral zone, their width is very irregular, varying from 100 metres to 5 km, and so the most easily mobilisable sediment reserves they constitute are liable to large variations from one section of coast to another.

Hypothesis of rising sea level and/or storm surges: at a low elevation, the areas occupied by these highly mobilisable formations are evidently sensitive to the action of marine morphogenic agents (currents, winds, ocean waves and tides), particularly in lido situations, with a thin rim isolating a lagoon from the sea shore.

PROFOUNDLY ALTERED SEDIMENT FORMATIONS WITH INCLUSIONS OF HARDPAN AND RESISTANT ROCK

CT	**PRE-QUATERNARY SEDIMENT FORMATIONS SOFT OR PARTIALLY CONSOLIDATED**
ST	**TERTIARY SAND FORMATIONS IN COTE D'IVOIRE**
TB	**SAND OR CLAY MATERIALS FROM THE "TERRE DE BARRES" FORMATION, ANCIENT ALLUVIAL DEPOSITS FROM THE VOLTA**
K	**SAND, CLAY AND PEBBLE MATERIALS FROM LIMESTONE AND MARL-LIMESTONE WITH FERRUGINOUS HARDPAN**

Definition and geographic location: All these formations dating from the post Cambrian era to the end of the Tertiary have the following in common:

- ⇒ A sedimentary sandstone origin (exceptionally marl-limestone in places in Senegal).
- ⇒ Deep alteration supplies materials with a high sand load and a current or previous hydropedological change implying the genesis of hard ferruginous cuirass layers.
- ⇒ A peneplain topography with a dense network of low-lying ground with plants, which collect the waters and capture a large part of the sediment from slope erosion.

These formations cover a vast pre-littoral belt stretching from the south of Dakar to Monrovia, at times largely separated from the sea front by major sandy terraces and mangrove areas, at times very close to direct contact with the sea in the form of headlands.

Geodynamics: The role of the headlands associated with these formations and mentioned in the characteristics of type 4 littoral zones is the highest contribution to coastal geodynamics. The amplitude of sandy sediment transfer to the coast is difficult to assess, given the considerable interception of the products of hydrological erosion by the mangroves or low-lying areas and the level of remobilisation of present day transport towards the littoral zone.

GRANITE AND/OR METAMORPHIC FORMATIONS OF THE PRECAMBRIAN AND PRIMARY BASEMENT, INTRUSIVE BASALT FORMATIONS

GR	**SANDY MATERIALS FROM SANDSTONE**
P	**GRANITE AND METAMORPHIC ROCK, PROFOUNDLY WEATHERED. SEAMS OF HARDER ROCK IN PLACES.**
PR	**SOLID ROCKS SUCH AS QUARTZITE, GABBRO AND BASALT, RESISTANT TO EROSION.**

Definition and geographic location: There are two major systems in contact with the coast:

⇒ The intrusive granites and metamorphic dispersion trains in Liberia and the west coast of Côte d'Ivoire.

⇒ The complex of granite and various metamorphic rocks, including numerous deposits of greenstone on the coast of Ghana.

All these formations have been and are still subjected to extremely deep weathering leading to ferralitic soils in transition with the alterites in varying degrees of thickness approaching the healthy rock.

Relicts of former evolutions, ferruginous cuirasses still occupy the summit parts of the hilly landform or dissected peneplain, drained by a dense hydrographic network. The eroded materials susceptible to transit towards the coast are of variable granulometry: clay, loam from ferralitic soils, the quartzy gravel of the stone-lines, ferruginous gravel, coarse sandy alterites, quartzy, which are the continental “signature” of many small coarse sandy beaches in the zone concerned.

Note that with forest clearing, surface erosion tends to accelerate, accompanying the normal trend of slope subsidence in forest milieu.

The hardest rocks (gabbro, basalt) enabling the genesis of real rocky coasts of type 5 have been coded PR.

Geodynamics: The differential weathering of certain more or less fractured, solid rocks, or of deposits that isolate numerous small rocky headlands, that have been emptied of all or part of their soil and alterite at the elevation subject to ocean waves. As mentioned for type 4 littoral zones, the angle of the headlands and deposits of hard rock facing the direction of the dominant ocean waves plays a very important role in modulating the coastal drift currents.

The importance of continental sediment supply is probably significant for the major rivers with open estuaries, but the proximity of a deep ocean floor does not enable notable storage that is remobilisable on the coast.

WETLANDS UNDER THE DIRECT INFLUENCE OF THE TIDE

M	**MANGROVES AND MUDFLATS REGULARLY SERVED BY TIDAL FLOWS**

Definition and geographic location: These milieus extend across vast areas in Senegal (Sine Saloum and Casamance), Guinea Bissau, Guinea and Sierra Leone, and to a lesser extent in the Gambia or very locally in the estuary and coastal channel area from Cote d’Ivoire to Benin (cf. undifferentiated wetlands unit). The mouth of the river Senegal and probably the Banc d’Arguin area present conditions of soil comparable to those of the mangroves which grow in less arid zones.

The substrate of the mangrove stands corresponds to fine sediments rich in organic matter with a sandy fraction, which is also fine. The somewhat dense network of channels that guide the tidal flows is constantly evolving, with the formation of meanders and the destruction and reconstruction of mangrove shores.

The zone traced here as mangrove (code M) includes areas of varying size of free water and mudflats devoid of vegetation, as well as numerous sandy islets with saline halos that trace the contour of the near shore reached by the tide.

Geodynamics: It would appear to be useful to distinguish here the interface with the “sea front” littoral zone exposed to ocean waves and the “interior” littoral zone subject only to the "calm" influx of the tide in transition over a strip a few metres wide with emerged islets of mangroves or the continent.

The interface between mangroves and sea coast was broached regarding type B littoral zones; it can be summarised by mentioning the contributions from the mangrove channels (reconfiguration of meanders but especially estuary outlets from the main rivers to the coast by a flushing effect and redistribution by the coastal drift currents). But the tide flowing upriver can be open to certain interior transfers, and in addition to the currents, the trapping role played by the network of mangrove routes should not be neglected.

As a general rule, the tide-continent interface at the level of the interior littoral zone is limited to the intervention of the highest tides liable to remove the saline surface sediments. On the other hand, in the particular case of narrow mangroves framing an interior coast of foothills, this may be subject to the effects of storm swells, even partially attenuated by the thin rim of mangroves. A situation of this type is frequent in the Bijagos Archipelago, where the two types are sometimes only a hundred metres apart.

Hypothesis of rising sea level and/or storm surges: If the sea level were to rise, even by only 1 metre, the overall potential impact on the zone defined here as mangrove could be considerable:

⇒ Acceleration of the natural evolution of the channels that guide the tide and reconfiguration of the hydrological system.

⇒ Associated reconfiguration of the distribution of mangrove stands, the different species of which require specific milieus.

⇒ Reduction in surface area of many small islets and tannes emerged today and reconfiguration of salinity conditions.

Regarding certain traditional human activities in mangroves, the impact could be considerable for rice growing with fields encased by breakwaters to control tides. Suitable land is typically localised in a situation of significant tidal range height. The building of breakwaters in soil and with loose materials, and maintaining them, requires work that cannot be mechanised and is very demanding in terms of qualified labour. Already in difficulty today because of these constraints, this system could be greatly compromised. The other rice growing systems hydrologically connected with the tide could also be greatly disrupted.

For Guinea Bissau, and to a certain extent Guinea, Sierra Leone and Casamance, these issues related to the rise in sea level appear very preoccupying.

WETLANDS

ZH	UNDIFFERENTIATED WETLANDS

This heterogeneous unit comprises:

⇒ Tidal delta and channel complexes

⇒ Wetlands indirectly influenced by marine hydrology

Tidal delta and channel complexes

Definition and geographic location: This category encompasses highly complex systems:

- Topographically: land regularly covered by the tide, land around the edges of this land, spits and alluvial deposits beyond the reach of the tide.
- Hydrologically: lagoons, surface waters and bodies of saline, brackish and fresh water in interaction with the tide and seasonal rains and flood peaks.
- Ecologically, with highly diverse sequences of plant communities adapted to the milieu, biodiversity of land and aquatic flora and fauna.

The fluviomarine deltas on the coasts of Liberia and the west coast of Côte d'Ivoire, central Ghana and on a significant part of the coastal fringe of the left bank of the Volta round to Benin are characteristic of these environments, which can also include mangroves which are not show on the 1:500,000 scale map.

Geodynamics: These zones are liable to play a role in sediment retention, but this role is probably only temporary in delta complexes where the sediment is remobilisable during certain flood peaks depending on the size and rainfall of the river basins.

Hypothesis of rising sea level and/or storm surges: A hypothetical rise in sea level would lead to a reconfiguration of these ecological contexts both globally and in local detail.

Wetlands indirectly influenced by marine hydrology

Definition and geographic location: This category includes wetlands with variable local hydrological conditions which all have in common:

- A low elevation, under 5 metres and often 3 metres above the average tide level.
- Flat geomorphology of low-lying land, pediment and foothills in smoothed sandy terraces or depressions (alluvial grooves, silted channels).
- Frequent flooding in the rainy season, the duration of which varies.
- A fluctuating water table close to the surface influenced by the depth of the brackish waters which are also fluctuating following the conditions of the sites and the season.

In the coastal fringe analysed in this study, this category has mainly been defined on the edge of the "interior" littoral zone in contact with the areas of mangroves and low lying ground or low terraces of continental transition (Senegal, Guinea Bissau, Guinea and Sierra Leone).

In certain climate contexts, the zones affected with recurrent salinity can be identified (Sine Saloum, for example).

From Sierra Leone to Benin, the wetlands are most often associated with ancient alluvial depressions, isolated and partially backfilled lagoon channels.

Geodynamics: This is especially sensitive at the level of sediment transport: a network of low-lying ground, both dense and largely developed inland plays a very important role in retaining the sandy sediment originating from continental erosion.

The low gradient of the hydraulic slope approaching the internal littoral zone leaves little transport energy for a deficient hydrographic network. In Guinea Bissau, numerous sections of low-lying ground situated between the mangrove and the upstream part (the "lalas") are covered with savannah vegetation that captures sand and the deposits retained often lie on former mangrove soils, which gradually subside under the weight of the sand supply.

If we remember that there is no ocean swell accompanying the upriver tidal flow towards the "interior" littoral zone and the modest remobilisation of sediments when it redescends, the conclusion to be drawn is a low sediment contribution from these wetlands towards the marine coastline.

Hypothesis of rising sea level and/or storm surges: The movement from this "interior littoral zone" towards the continent will be perceptible on certain low-lying areas with very gentle slopes, but the most remarkable impact could concern the phreatic rise of brackish waters, in particular the movement of the saline fringe in contact with the "interior" littoral zone and emerged continent. Siné-Saloum would be particularly concerned by this.

AL DELTAIC ALLUVIAL COMPLEXES

Definition and geographic location: These river complexes develop largely in low-lying subsidence areas and/or from the filling up of lagoons. Conventionally their topography comprises bank ridges on the main watercourse and distributaries and lateral zones that are more or less lagoonal in places.

The main channel, and even certain distributaries, are subject to the tide for a varying distance (can be locally important as in the case of the Volta). These complexes have their main outlet on the maritime or major lagoon littoral zones.

The principal delta systems are located in Côte d'Ivoire (Bandama, Comoe), Ghana (Volta), Sierra Leone, with the particularly complex topography of alluvial plains or grooves along the Jong, Sewe and Moa rivers.

Despite the size of their catchment areas, many rivers only have a very small delta output, in the same order of surface magnitude as the many small coastal rivers that flow into the coast from Monrovia to Sassandra. These micro deltas with very complex topography have a frequent presence of small lagoons.

Geodynamics: Delta complexes are platforms for sediment transport, direct by the principal channel, indirect through the erosion of delta deposits. The greater part of this transport is by flood peak and, in the case of rivers whose flow rates are regulated by large dams, only the downstream part of the river basin plays the principal role (flood peaks and sediment that is not trapped upstream by the dam).

The other level of interface to be taken into account concerns the alluvial phreatic sheets which, in proximity to the coast, are in a freshwater system near the surface but at a variable depth are “supported” on water that is saline to varying degrees. The extent and depth of the salt wedge is influenced by multiple local factors (pluviometry, topography, the type of aquifers). It is acknowledged that global flooding by flood peaks is the prime factor in recharging the water table and the absence of such flooding in seasons of modest rainfall causes the water table to salinate (to be confirmed for the left bank of the Volta).

L LAGOONS

Definition and geographic location: The major lagoons are in direct contact with the tide but its influence (tidal range, input of freshwater, salt water,) is subject to high local variations:

- Importance of volumes of freshwater input to the lagoon, contributions from rivers and streams, emptying of phreatic fluvial sheets or slopes and, of course, precipitations on the body of water.
- Extent and volumes of water, bathymetric profile and depth of lagoons.
- Seasonal contributions of fresh water and evaporation.
- Effectiveness and functionality of gulleys enabling communication with the sea.

The shores of the large lagoons are also subject to considerable variations, which range from sandy beach to belts of swampy fixed or floating vegetation.

They are present from the South of Sierra Leone to Benin. The largest lagoon system is in Cote d’Ivoire, and is roughly parallel to the shore. It stretches for more than 250 km almost continuously with 4 gulleys or passes that communicate with the sea, one of which is more or less operational (Grand Bassam). There is also the Cotonou lagoon system in continuity with Nigeria and the Robertsport lagoon which is silting up. In addition to the large lagoons, there are numerous prelittoral lagoons and channels that are narrow but sometimes follow the littoral rim for several dozen kilometres, a large part of which have brackish and/or freshwater vegetation.

Lastly, we mention the large lagoons located inland because their communication with the sea is broken today, like the large lagoon on the edge of Keta in Ghana since the road breakwater practically blocked communication with the ocean (apart from artificial outlets) or the isolated lagoon that has become saline on the left bank of the Volta delta.

Geodynamics: In the absence of any rocky obstacles, the most frequent situation, these formations are highly remobilisable by the CDC. Their permeability excludes the development of an active hydrographic network

towards the coast; hydrological erosion is restricted at local level to the filling in of the channels. Although they border almost ¾ of the littoral zone, their width is very irregular, varying from 100 metres to 5 km, and so the most easily mobilisable sediment reserves they constitute are liable to large variations from one section of coast to another.

Hypothesis of rising sea level and/or storm surges: These systems work as sediment “traps” or at least “filters” for the sediment contributions from the continental river basins. Their tendency to silt up is attested by the large number of hydromorphic alluvial plains at elevations close to that of the lagoons, which has been increasing recently and still is today. (typical example of the Tanoe delta on the approach to the Eby lagoon in Ghana – Cote d’Ivoire).

The final evolution can lead to a major regression (Bandama delta), or even total disappearance of lagoons in the last quaternary episodes (Sewe river plains and connected rivers in Sierra Leone).

In these conditions, it seems obvious that in the West of Cote d’Ivoire and on the coast of Togo, the continental sediment contribution is low and the reserve is limited to remobilisation of coastal sandy terraces by erosion.

3. THEMATICS SPECIFIC TO THE MAPPING OF ISSUES AND HUMAN LAND USE

Name	Primary data sources	Treatment	Typology and/or hierarchy	Type of representation
Railways	Vmap 1 and 0 vector data, topographical base maps on paper, high resolution images.	Merging, verification and correction of primary data from (i) existing, fixed topographical base maps; (ii) high resolution images.	None	Vector
Ports	World Port Index Data	Correction using the interpretation of high resolution images	None	Points
Infrastructures and fishing ports	None	Interpretation of high resolution images	2 levels	Points
Airports	Public data	Digitisation	None	Points
PROTECTED AREAS AND PLACES WITH A PARTICULAR STATUS				
Protected areas	WCPA Database Topographic maps PDALM (Plan Directeur d'Aménagement du Littoral Mauritanien) National diagnostics RAMSAR Database	Corrections, recalibrations, adjustments to contours	None	Polygons
Plantations	Landsat Images High resolution images	Photo interpretation, transfer and digitisation.	None	Polygons
Miscellaneous				
Sites suitable for shrimp farming	Development scheme for shrimp farming in Guinea	Digitisation	None	Points

3.1. TYPOLOGY OF HUMAN LAND USE SYSTEMS LESS THAN 1 KM FROM SHORE

The previously presented analysis of the zoning of human land use densities on a width of around 50 km from the coast has been completed by "targeting" the characteristics of settlements on a narrower fringe directly in contact with the problematic of coastal erosion and the corresponding issues at stake.

The location of settlements and associated infrastructure in risk exposure situations depends on a number of factors:

⇒ In urban zones, the availability of land as close as possible to urban centres leads to the unplanned ("spontaneous") development of settlements on sites where the risks are sometimes very high.

⇒ The adoption of a "global" model of residential life style or tourist practices, which are all the more attractive the closer they are to the seaside, or even on the beach.

⇒ The necessity for fishermen or fishermen-farmers to locate as close as possible to the sea, to be able to leave their canoes near the beach, or on high risk sites that are close to good conditions for making use of the resource.

⇒ The traditions of populations with a predominantly agrarian and forestry culture which, unlike the previous group, build inland from the sea on sites considered "not very attractive".

⇒ Failure to apply or lack of legislation restricting building by the sea, the lack of sufficient awareness of the risks and impacts of the building (housing, enclosure walls and facilities) of residential and tourist accommodation.

The mapping produced shows that, in the current state of affairs, most of the social and economic issues at stake related to coastal erosion are centred on **less than one quarter of the West African littoral zone** and are associated principally with the urbanisation process: urban, residential and tourist consumers of "land near the sea".

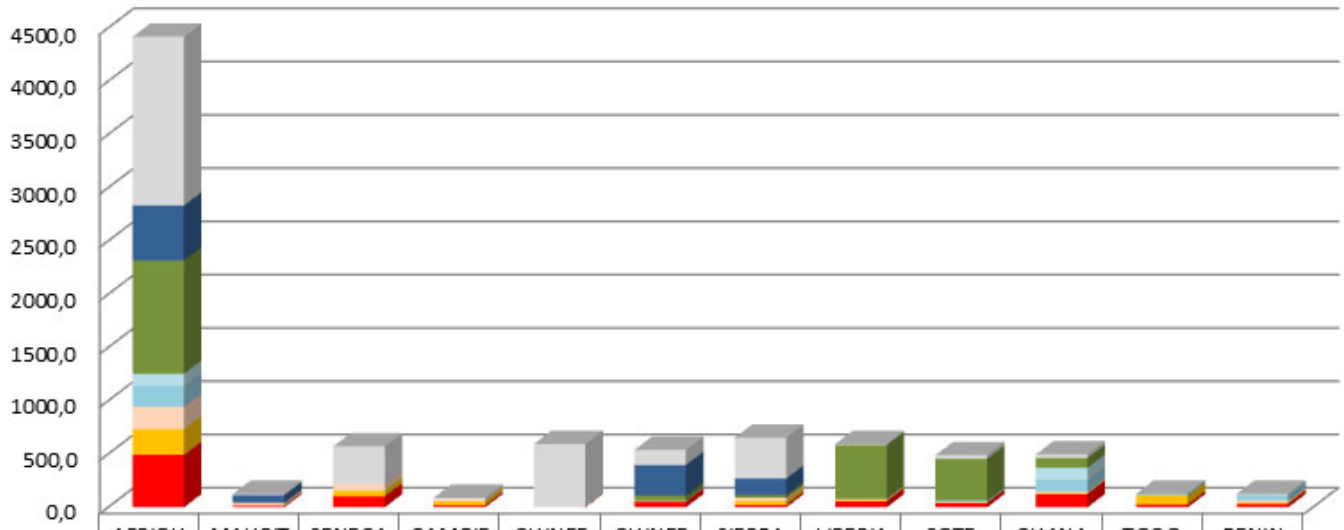
With the expected, desirable rise in living standards, at least for part of the population, the process of land and residence appropriation in these areas in the immediate vicinity of the sea will no doubt continue, as it will elsewhere on the planet.

The table below summarises the framework of this analysis:

Type of habitat	Code	Context	Marine erosion and stakes	
			Social	Economic
A- Urban	A1	Sandy shore	**+** to **++**	**+++**
	A2	+/- rocky shore	**+**	**++**
	A3	Small urban sites in mixed rocky/sandy littoral zones	**+**	**++**
B - Residential tourism, "rurban"	B1	Continuous settlement along the edge of the shore	**++**	**++**
	B2	Discontinuous settlements	**+**	**+ to +++**
C – Rural, agro-coconut groves	C1	Dense, continuous settlements	**+++**	**++**
	C2	Discontinuous settlements	**++**	**+**
	C3	Same as C1 or C2 but in scattered sites with D3	**++**	**+**
D-Rural, coconut groves and various vegetation	D1	Dense coconut groves but settlements distant from the shore	**o**	**o**
	D2	Same as D1 but scattered coconut groves and various vegetation	**o**	**o**
	D3	Uninhabited but change in progress or possible to type D2	**o**	**o**
E – Rural, maritime rice growing	E	Settlements at risk of submersion from sea.	**++**	**++**
F - Small villages and temporary fishing camps	F1	Very unstable, +/- insular sandy sites.	**+ to +++**	**+**
	F2	Rare villages scattered in sandy zones unfit for agriculture	**o**	**o**
G – No settlements	G1	Mangrove, flooded and therefore uninhabitable littoral zone.	**o**	**o**
	G2	Littoral zone in desert region	**o**	**o**

Length of littoral zone by type of human land use in a 12km strip from the shore
(scale 1:75,000, Cartesian distances - 1: length in km, 2: number of segments, approximate values).

TYPES	WEST AFRICA		MAURITANIA		Senegal		Gambia		GUINEA BISSAU		GUINEA		Sierra Leone		Liberia		Cote d'Ivoire		Ghana		Togo		Benin	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
A1	156.8	13	0.0	0	46.4	3	14.9	1	3.2	1	0.0	0	0.0	0	25.6	3	15.4	1	9.8	2	16.7	1	24.8	1
A2	214.7	9	0.0	0	56.2	2	0.0	0	0.0	0	48.3	1	22.3	1	11.8	2	0.0	0	76.1	3	0.0	0	0.0	0
A3	119.6	19	13.8	1	0.0	0	3.0	1	0.0	0	4.5	1	0.0	0	17.7	5	23.4	5	39.2	4	9.8	1	8.2	1
B1	243.1	17	1.6	1	52.0	3	36.2	1	0.0	0	0.0	0	38.1	2	11.6	1	5.5	1	5.5	2	82.3	5	10.4	1
B2	208.2	19	26.3	1	64.0	6	21.9	1	4.4	1	8.7	1	28.2	2	12.0	1	4.8	1	18.8	3	0.0	0	19.0	2
C1	196.7	10	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	14.5	2	107.4	4	20.4	1	54.4	3
C2	115.1	9	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	115.1	9	0.0	0	0.0	0
C3	70.0	3	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	70.0	3	0.0	0	0.0	0
D1	126.4	3	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	126.4	3	0.0	0	0.0	0	0.0	0
D2	308.6	25	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	167.8	17	140.8	8	0.0	0	0.0	0	0.0	0
D3	559.4	41	0.0	0	0.0	0	0.0	0	0.0	0	48.9	4	27.5	2	337.5	29	124.0	4	21.6	2	0.0	0	0.0	0
E	514.0	18	71.7	9.0	0.0	0	0.0	0	0.0	0	286.7	7	155.6	2	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
F1	1447.2	119	12.6	1	216.4	18	14.4	2	588.1	51	141.7	17	383.3	16	10.2	3	35.4	6	34.8	4	0.0	0	10.3	1
F2	137.2	1	0.0	0	137.2	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
G1	3854.2	127	30.9	2	703.2	21	127.6	5	1690.3	52	814.1	27	488.1	19	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
G2	1017.9	10	1017.9	10	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0



	AFRIQUE DE L'OUEST	MAURITANIE	SENEGAL	GAMBIE	GUINEE BISSAU	GUINEE	SIERRA LEONE	LIBERIA	COTE D'IVOIRE	GHANA	TOGO	BENIN
Sites dispersés petits villages et campements	1584,5	12,6	353,6	14,4	588,1	141,7	383,3	10,2	35,4	34,8	0,0	10,3
Habitat en cordon dans les zones rizicoles	514,0	71,7	0,0	0,0	0,0	286,7	155,6	0,0	0,0	0,0	0,0	0,0
Rural en cocoteraies et autres végétations plus éloigné du rivage	1064,4	0,0	0,0	0,0	0,0	48,9	27,5	505,3	391,3	91,5	0,0	0,0
Rural discontinu en cocoteraies pres du rivage	115,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	115,1	0,0	0,0
Rural continu en cocoteraies pres du rivage	196,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	14,5	107,4	20,4	54,4
Touristique résidentiel discontinu	208,2	26,3	64,0	21,9	4,4	8,7	28,2	12,0	4,8	18,8	0,0	19,0
Touristique résidentiel continu	243,1	1,6	52,0	36,2	0,0	0,0	38,1	11,6	5,5	5,5	82,3	10,4
Urbain	491,1	13,8	102,6	17,9	3,2	52,8	22,3	55,1	38,8	125,1	26,5	33,0

Human land use profiles on the littoral zones of the West African countries
(except for uninhabited zones, length in km, Cartesian distances, scale 1:75,000, approximate values).

A. URBAN HABITAT

A1 SANDY SHORE HIGHLY SENSITIVE TO NATURAL MARINE EROSION, PARTICULARLY IN THE CASE OF DEVELOPMENTS THAT ALTER THE COASTAL CURRENT SYSTEM

Social stakes: high risks for certain populations in temporary settlements and on the edge of urban zones, with housing built on the beach or on the edge of cliffs.

Economic stakes: housing, commercial and industrial facilities, equipment of substantial economic value and corresponding losses when destroyed or deteriorated.

Example of location*: Cotonou, Abidjan and Lomé*

A2 SHORE THAT IS ROCKY IN PLACES AND SANDY

Risks related to marine erosion expressed in rock fall from cliffs.

Social and economic stakes: relative to private residences and hotel facilities with a high property value.

Example of location: Accra and Dakar (Pointe des Almadies).

A3 SMALL URBAN SITES WITH SANDY OR ROCKY SHORE AT ESTUARY MOUTHS

Sites with complex current systems, risks analogous to A1 and A2, but with lesser economic stakes, given the often smaller urban extensions and the great local diversity of stakes. It should be noted, however, that there is an increased risk related to possible combinations of exceptional marine surges and continental floods affecting watercourses and/or nearby channels and lagoons.

B. RESIDENTIAL, TOURISM AND "RURBAN" SETTLEMENTS

B1 CONTINUOUS SETTLEMENT ALONG THE EDGE OF THE SHORE

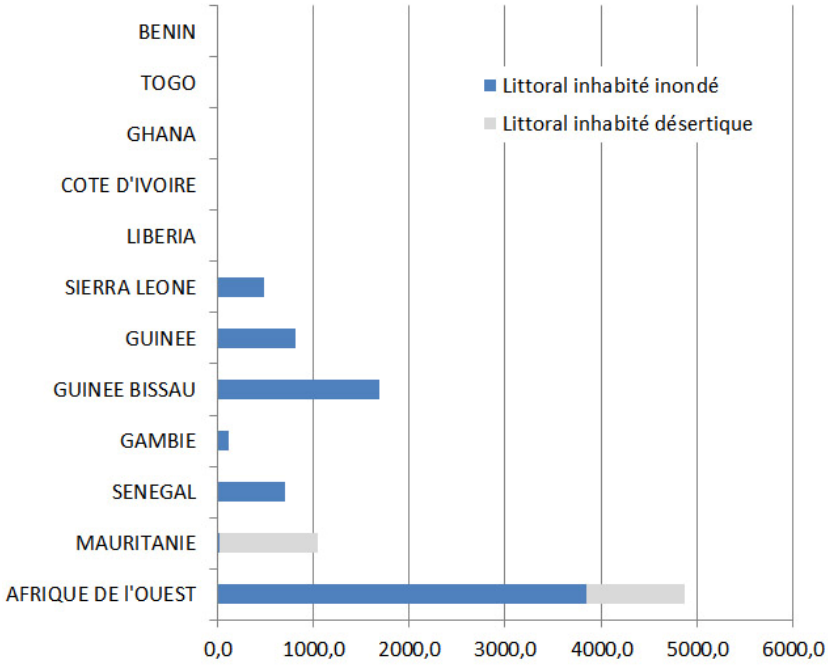
"Rurban" areas with private residences and traditional villages, farming enclaves or natural vegetation present at the extremities of the peri-urban zones of most major agglomerations (Accra, Lomé, Western Cotonou and Eastern Abidjan).

The social stakes are moderate depending on the population densities concerned, but also economic stakes are often very high due to the increasing property value of the residences, hotel facilities and the jobs they provide.

Example of location: *private residences and hotel facilities in continuous conurbation along the whole of the Petite Côte in Senegal (villas and hotels "on the water's edge"), littoral hotel belt in The Gambia*

B1 DISCONTINUOUS SETTLEMENTS

Urban sprawl. In the conquest of construction in littoral zones, this unit is normally evolving towards situation B1 above.



Length of uninhabited littoral zones (1km wide strip from the shore)
in West Africa (Cartesian distances, scale: 1:75,000).

C. RURAL SETTLEMENT IN COCONUT GROVES

Habitat localised on sandy terraces, sometimes between ocean and lagoon, on lidos of varying widths, and associated with coconut groves and crop fields.

Fishing activities extensively practiced, implying accommodation close to the place canoes are stored, therefore on the shore.

Considerable **social stakes** depending on the population densities concerned, with few alternatives, in the event of marine erosion, for a settlement location corresponding to their way of life.

Economic stakes concerning the value of the traditional habitat, but also related to the threatened infrastructure and the productive rural area.

Example of location: *littoral zones of Togo, Benin and the major part of the sandy coasts of Ghana.*

C1 DENSE, CONTINUOUS SETTLEMENTS

Example of location: *Benin, Togo, the Volta delta, Eastern Ghana from Axim to the Côte d'Ivoire border.*

C2 DISCONTINUOUS SETTLEMENTS

Example of location: *the major part of the coast of Ghana which has sandy shores.*

C3 DISCONTINUOUS SETTLEMENTS ON THE LITTORAL FRONT OF HEADLANDS AND COVES

Same as C2, but limited to the scattered, small coves and sandy creeks in Ghana, the remainder being occupied by natural vegetation or shifting cultivation and fallow land.

D. RURAL SETTLEMENT IN COCONUT GROVES AND VARIOUS FORMS OF VEGETATION

This category differs from the previous one by the way the settlements are installed. Bar for exceptions, they are located a certain distance from the shore and are therefore not concerned by marine erosion to any great extent.

Example of location: *coconut groves on the terraces and sandy shores of Côte d'Ivoire, and the scarcely inhabited littoral zone of Liberia*

D1 LARGE, DENSE PLANTATIONS

The Jacqueville terrace in Côte d'Ivoire has a continuous covering of plantations, with scattered villages and settlements always built away from the beach.

D2 LARGE, DENSE PLANTATIONS AND RELICTS OF NATURAL VEGETATION

Same as D1, but the plantations are more dispersed with the relicts of natural or secondary vegetation, enclaves of food crops and fallow land, the presence of small villages often built relatively recently.

D3 HIGHLY DISPERSED SETTLEMENTS IN PLANTATIONS OR NATURAL VEGETATION

This category concerns a vast length of coastline from Sassandra to Monrovia, with, as a constant, practically no settlements whatsoever in the first kilometre from the shore. Human presence on the coast is limited to scattered villages: advance of the pioneering forest clearance front facilitated by the gradual improvement of road access in Côte d'Ivoire, villages always located in estuary sites on the coast of Liberia.

Land use comprises forest relicts that are still preserved and a diversity of natural vegetation associated with the diversity of environments (hills, sandy terraces, lagoons, etc.).

E. RURAL SETTLEMENTS IN MARITIME RICE GROWING

This category is restricted to Guinea Conakry (Kaback, Kakossa and Koba) to the north of Sierra Leone and concerns low sandy terraces, developed rice-growing perimeters or traditional paddy fields. Settlements are located on sandy islets or narrow rims of ridged terraces with the characteristic linear villages.

These sites are more or less exposed to exceptional marine intrusions and, in places, to naturally active marine erosion. The stakes vary greatly on the level of the local sites.

F. SMALL, SCATTERED VILLAGES AND FISHING CAMPS

F1 RARE VILLAGES ON HIGHLY UNSTABLE SANDY SITES THAT ARE MORE OR LESS INSULAR

Sandy, often narrow and insular sites highly exposed to very active marine or fluvial-marine geodynamics (which will be even more active in the future in a hypothesis of a rise in sea level).

Certain sites shelter villages, sometimes quite large (Djiffer and Palmarin in Senegal), others are estuary annexes of less exposed villages (Volta, Bandama and Cavally).

The most frequent case concerns temporary fishing camps, where the main constraint is lack of drinking water.

F2	RARE VILLAGES SCATTERED IN SANDY ZONES UNFIT FOR AGRICULTURE

This category concerns the Grande Côte in Senegal, bordered with active dune massifs that have been more or less stabilised by the replanting of trees. The rare villages on the edge of the shore are located as part of fishing activities and, in certain, specific locations, tourism. They are connected to roads and continental tracks that cross the obstacle of the dunes. They have often been set up with State support, as is the case in Mauritania.

The coastal zone and shore in South Eastern Sierra Leone (Sherbro Island) is "practically deserted" from the point of view of human settlement with very rare small villages and probably a few fishing camps.

G. NO SETTLEMENTS

G1	MANGROVE FLOODED LITTORAL ZONE

Mangrove, flooded and therefore uninhabitable littoral zone. Except for the particular case of the "former" mangroves of Monrovia, this type of milieu is unfit for human settlement, except for buildings on stilts in environments affected by the tide, except for traditional in West Africa (or reclamation, as in Conakry).

The population living on mangrove resources (fishing, salt, and rice growing in places) resides in the tidal plains, on sites that provide easy access to the sea and the mangrove channels.

G2	LITTORAL ZONE IN DESERT REGION

This category has been reserved for the whole of the Mauritanian littoral zone with arid or desert conditions, with no drinking water resources in proximity to the ocean, and occasional very temporary fishing camps.

As for the category F2, we should note the possibility of using the beach as a road, for four-wheel drive vehicles equipped to cross the dunes to reach the road routes.

3.2. TYPOLOGY OF ESTIMATED DENSITIES OF HUMAN LAND USE

The coastal zone was initially and arbitrarily defined as a strip approximately 50 kilometres wide starting from the littoral zone. It encompasses almost all of the major agglomerations on the coastal sea front and their nearby area of influence.

However, we are aware that this area, within its boundaries, only encompasses a part of the employment basin and populations concerned by coastal-related activities (commercialisation of sea produce, tourism and seaside residence, transhumance towards the saline pastures of the arid littoral zones, all sorts of flows associated with harbour infrastructure, etc.).

The objective focussed on zoning the intensity of current human land use, completed, on the basis of this trend, with a prospective of possible future changes.

The criteria selected for this outline are mainly based on satellite imagery indicators and the definition of the different cartography units are essentially qualitative.

A quantitative approach, based on the population densities derived from various sources of survey data, would in fact involve complex work outside the scope of this study, given that the administrative breakdowns of survey data generally differ from the boundaries fixed (arbitrarily) for the coastal zone.

The table of legends that follows summarises the criteria for defining the units mapped:

Cartography units	Intensity of current human land use	Details	Possible future trends
1	Very high > 500 inhabitants	"Rurban", residential, tourism, concentrated rural settlement zones	Increased densification very probable
2	High 200 to 500 per km²	Densely occupied countryside, fallow land disappearing, economy tending towards "rurban"	Variable densification depending on the socio-economic influence of the urban centres in more or less close proximity
3	High to average 50 to 200 per km	Countryside still with arable fallow land or non-arable land	Probable densification depending on the potential of the soil and climate
4	Low to average 20 to 50 per km	Countryside still with considerable savannah fallow land or secondary forests	Variable densification following development of sustainable land use systems
5-S	Low 5 to 10	Sandy zones unfit for farming due to the nature of the soil	Little change
5 F	Low 5 to 20	Former cleared forest land partially developed for farming	Probable densification subject to the settlement of external populations
6 J	Very low 5 to 10	Rocky zones unfit for sustainable farming	Little change
6 F	Very low 5 to 10	Forestry zones being taken over by farming with relicts of more or less extensive forestry formations	Same as 5 F in the absence of an effective policy for the conservation of forest relicts
7	Very low to nil < 5	Weather zones unfit for farming	Little change
P	Low	Large plantations of industrial crops or forestry	Little change if these production systems are conserved
Z	Variable	Conventional rice-growing with controlled natural flooding	Variable changes, in particular depending on impacts of rise in sea level.
AP	Very low	Listed forests and National land parks or marine protected areas.	Variable change depending on control of the land area.

UNIT 1: ZONES WITH A VERY HIGH INTENSITY OF LAND USE (URBAN, PERI-URBAN, "RURBAN" AND TOURISM)

This category comprises:

⇒ **Largely urbanised zones**, "spontaneously" growing peri-urban zones, where housing development is organised along the main road corridors, gradually saturating the areas between these roads: Cotonou-Lomé, Accra – Cape Town-Sekondi-Takoradi, Abidjan, Freetown, Monrovia, Conakry, Bissau, Banjul and Dakar.

⇒ **"Rurban" zones**, particularly along the littoral zone, characterised by the combination of residences near the sea and urban properties, most often motorised, and increasingly residual farming enclaves of "traditional" fishing and farming villages, with some families working in the towns. This type of settlement in coastal coconut groves is often developed on either side of Cotonou, Lomé, most of the agglomerations in Ghana; on the Abidjan – Grand Bassam corridor, South of Freetown, etc.

⇒ **Dense tourism zones**, with their sometimes continuous hotel facilities along the sea front and accompanied by accommodation for the activities and populations associated with the tourist industry. This concerns in particular The Gambia, Casamance (Cap Skiring), Petite Côte in Senegal which is today typified by an almost continuously built-up sea front, hotel areas and second homes. The particular case should be noted of certain coconut groves in the littoral zone that are densely populated by farmer-fishermen under evident urban influence (for example, Axim-Côte d'Ivoire border in Ghana).

Outlook

Whatever the intensity of the future growth of all the coastal agglomerations, this is already visible in the landscapes captured by satellite imagery: visible grids of housing developments, urban sprawl of second homes in rural areas along the sea front, etc.

The behaviour pattern of having a second home by the sea, which is prestigious for urban dwellers, has become a largely global phenomenon, and West Africa does not escape this trend, all the more so since the weather conditions in proximity to the coast are often more attractive than in towns. Consequently, urban pressure on the littoral zone will remain high with dynamics related to the development of infrastructure (access, facilities, drinking water) and the increasing income levels of certain categories of the population.

In addition to the peri-urban and “rurban” littoral zones, certain sectors that are still rural, but with a partially developed tourist potential, could evolve towards a situation comparable to the Petite Côte in Senegal. An analogous situation on the major part of the Ghana coast is to be expected.

UNIT 2: ZONES WITH A HIGH INTENSITY OF LAND USE, PREDOMINANTLY RURAL, BUT IN PLACES IN TRANSITION TOWARDS AN URBAN SYSTEM.

These zones are characterised by widespread farming, encouraged by the availability of agricultural land with no major soil constraints. The amount of fallow land available is decreasing sharply, with dense settlement in villages or hamlets surrounded by plots with hedgerows accompanying orchards in varying expanses of plots. Two situations are to be considered:

⇒ **Countryside evolving towards “rurban” land, in the immediate periphery of the major agglomerations:**

- Areas of groundnut production near Dakar.
- Areas of tertiary sands surrounding Abidjan.
- Belt of densification zones from Takoradi-Capetown, Accra – Tema.
- "Terres de barre" surrounding the Cotonou-Lomé littoral corridor, serviced by a dense network of roads and tracks converging on the agglomerations.

Town-country relations thus have a tendency to diversify, particularly at the level of:

- Flows of staple foods or vegetables towards the town, commercialised or as part of exchanges between families.

- Residences and/or income of certain categories of the population within the family cell: cyclical or occasional migrations towards activities in town, returns to or stays in villages in housing conditions with fewer constraints than in the town.

⇒ **Dense countryside where an essentially farming population is located on flood plains**, who draw their income from flood-prone, uninhabitable paddy fields (mangroves, wet terraces) or the products of the sea. This situation is frequent in Guinea Bissau, Basse Casamance, Guinea Conakry (Koba, Kakossa, Benty, etc.) and in Sierra Leone.

Outlook

With the foreseeable growth of the major agglomerations, the accentuation of the "rurban” lifestyle in rural areas, villages and especially small towns is a highly probable scenario. The same can be said for the diversification of staple food production depending on the potential natural resources (climate, soil, water for irrigation), or the introduction of landless production systems (breeding, vegetables), as is currently the case in emerging countries and MICs.

On the other hand, in countryside on the margins of the urban economy, the growth forecasts based on natural resources remain only modest.

UNIT 3: AVERAGE TO HIGH INTENSITY HUMAN LAND USE

These lands still have a significant amount of surface area that is not cultivated annually, either because it is left fallow but fit for cultivation, or because it is unfit due to the soil or weather conditions. The current situation is quite contrasted, but the outlook for the future is even more so:

⇒ Countryside with a percentage of land unsuitable for agriculture, as intensification concerns arable land only, with a way of life close to that of cartography unit 2. This is the case in Senegal in areas with poor soil, that are nonetheless close to Dakar.

⇒ Countryside that is largely used and structured from a property point of view, but which still has reserves in terms of fallow land for increasingly short periods (Guinea Bissau, Côte d'Ivoire on the periphery of the tertiary sands, cocoa plantations in Ghana).

⇒ Land that has been subject to conditions of insecurity (the Senegal-Bissau border, Sierra Leone and Liberia) where the rural population has been stagnant or has regressed.

Outlook

Except for land that is unfit for cultivation due to the soil or a protection status (listed forests), the tendency towards densification seems logical in the long term.

UNIT 4: AVERAGE INTENSITY HUMAN LAND USE

This type of countryside has a high percentage of potentially arable land, but considerable surface area is still devoted to fallow, savannah and secondary forests. This comprises, essentially:

⇒ **The Southern Sahelian zone**, at the limit of climatic possibilities for obtaining crops due to the rainfall, which is sometimes nil certain years. Outside the perimeters of irrigated land, the resources are mainly pasture; with rural exodus and return following the cycles of resources and the resumption of effective rainfall.

⇒ **Areas that rapidly become savannah after the disappearance of tree vegetation, which often happened a long time ago**. In the area where rainfall is above 2,000 mm (Guinea Bissau, Guinea Conakry and Sierra Leone), the easily leachable soils require long fallow periods in a traditional short cycle agricultural system.

⇒ **Former forest areas in Liberia and South western Côte d'Ivoire**, where agricultural colonisation in plantations and staple crops is not yet complete, with large areas of secondary forest or that have already become savannah.

Outlook

In arid areas, they remain subject to changes in climate and/or to the development, when possible and foreseeable, of irrigation.

The agricultural intensification of areas that have changed into savannah and have high rainfall would require recourse to agroforestry, an agricultural revolution of crops in a short cycle, seeded, under the cover of vegetation, a more intensive development of wet zones in the absence of a rice-growing tradition.

The completion of the agricultural conquest of the post forest areas in Liberia and Côte d'Ivoire remains subject to the settlement of new populations, either from the rest of the country or from other countries in West Africa.

UNIT 5: LOW TO VERY LOW HUMAN LAND USE INTENSITY

Unit 5-S: this comprises the zones that are mainly unfit for sustainable agriculture, either due to the aridity of the climate, or due to the unsuitability of the soil. This is the case, in particular, of the dune areas on the Grande Côte in Senegal, and of the leached sandy terraces in the South of Sierra Leone. The population which is present in small numbers draws most of its income from resources other than agricultural production (transhumance breeding, fishing).

Unit 5-F: this is principally located in Liberia and in the extreme South of Côte d'Ivoire in a situation of incomplete agricultural conquest still centred on the former routes of forestry exploitation tracks, leaving between them areas of forest relicts and secondary vegetation.

Outlook except for new activities, non agricultural or forestry, the settlement of new populations seems unlikely for category 5-S. On the other hand, high potential densification is possible in the hypothesis of the settlement of new populations in zone 5-F.

UNIT 6: VERY LOW HUMAN LAND USE INTENSITY

Unit 6-S: this comprises the rocky landforms that frame coastal Guinea, as the natural environment offers only rare arable sites, with a very long fallow period and extensive pasturing, with no foreseeable intensification in the future.

Unit 6-F: this is reserved for wooded massifs used for forestry or listed forests where agricultural invasion in progress. Satellite imagery shows the number of agricultural clearings and unless there is a return (highly unlikely) to strict protection of the forest, the probable trend in the future is that the landscape will gradually turn into that described for units 5-F then 4.

UNIT 7: VERY LOW TO NIL HUMAN LAND USE INTENSITY

This unit concerns Sahelian or desert uncultivated grazing land, with human land use restricted to breeders camps near water holes or temporary transhumance camps. This category also includes the area of desert where human presence is limited to around a few water holes. This situation is not expected to change much in the future, except occasionally within the framework of activities other than transhumance or nomadic grazing.

MAJOR INDUSTRIAL PLANTATIONS

The boundaries have been drawn on the map for only the largest of these (rubber, oil palms, coconut palms, pineapple, replanting), with permanent human settlement located on the edges of these perimeters. Many small plantations or discontinuous, inhabited plantations have not been taken into account here, in particular the major part of coastal coconut groves, which are often increasingly fragmented the nearer they are to the coast.

Demanding in terms of favourable topographic conditions and real estate resources, a good number of existing plantations have been set up in sites with conditions that are less available today.

To the extent that the socio-economic conditions remain favourable to these systems, the major plantations will probably remain within the perimeters occupied today, even if this means a change of crop. Another possible scenario would be their disappearance by fragmentation through agrarian reform into small farms.

NATURALLY FLOODED PADDY FIELDS

There are considerable surface areas in Guinea Bissau, Guinea Conakry, Sierra Leone and, very locally today, in Casamance in Senegal. Globally, three main systems for mobilising land and water resources should be distinguished:

⇒ Rice-growing on cleared, drained mangroves that are not inhabitable.

⇒ Rice-growing in sandy channels flooded in the rainy season, with settlements concentrated on the sandy rims above water.

⇒ Rice-growing in groundwater and flooding of wet zones and low-lying ground, with the population residing on nearby unwatered hills.

The future of these different types of rice growing, always sensitive to the contingencies of climate, could be called into question if there is even a modest rise in sea level. This concerns rice-growing in mangrove territory, where making and maintaining dykes is labour-intensive. The situation, which is often critical today (see Guinea case studies) would be largely aggravated on vast expanses (often the most fertile) by a rise in sea level of under 50 cm.

PROTECTED AREAS, NATIONAL PARKS, CLASSIFIED FORESTS

Most of these areas have a status that excludes permanent human residence, at least in the central conservation areas, other than for administrative and surveillance staff.

While some activities and frequentations are tolerated or even permitted, agricultural use and accommodation are typically excluded and the intensity of human land use is very low within the boundaries, but often denser around the periphery.