



Mapping of Sensitive Coastal Spaces and Environments to Preserve in the west of the Coastal Zone of Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Identification of remarkable areas or spaces of ecological and biological interest in the west of the ivoirien coastal zone in order to propose action strategies for the preservation of these sites, supported by legal guidelines for the protection of these remarkable spaces.

Place and Duration of Study: Western ivoirien coast, November to December 2023.

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Methodology: A participatory and inclusive approach was adopted in order to take into account the views, opinions, concerns and needs of all stakeholders operating in this part of the coastal zone. A cartographic database was created from the 2023 Sentinel 2 satellite image of the Ivorian coastal area. Digital processing of the 10 m spatial resolution image using ARCGIS 10 software made it possible to digitize the land cover layers of this coastal zone.

Results: From Cavally River bordering Liberia-west Tabou border, we have identified 17 coastal sites to be protected, including 4 rivers, 4 biological sites (Voluntary Forest Reserve, Sea turtle nesting sites, Mangrove areas and the new marine protected area planned) and 9 villages. As for the Tabou est-Grand-Béréby coast, there are 23 sites including 8 rivers, 8 biological sites (Marine Protected Area, Voluntary nature reserve, Community forests, Sacred forests, Mangrove areas, Sea turtle nesting sites) and 7 localities threatened by marine flooding.

Conclusion: Coastal sites must be protected by several tools whose protection methods make it possible to adapt to the local context. Thus, on sites, we frequently combine regulatory protection tools, to limit or prohibit certain uses, and contractual tools to finance restoration actions or encourage more sustainable practices, and this, from the implementing decree on sensitive coastal areas and sites to be protected from Law No. 2017-378 of June 2, 2017 relating to the development, protection and integrated management of the littoral.

Keywords: Mapping; sensitive coastal; Ivorian; sentinel 2 satellite image.

ABBREVIATIONS

CIAPOL : Ivorian Anti-Pollution Center
FAO : Food and Agriculture Organization of the United Nations
IUCN : International Union for Conservation of Nature
NGO : Non-Governmental Organization
OECMs : Other Effective Area-based Conservation Measures
PAGIL : Integrated Coastal Development and Management Plan
UNEP : United Nations Environment Programme
WA BiCC : West Africa Biodiversity and Climate Change
WACA-CI : West Africa Coastal Areas-Côte d'Ivoire
WAEMU : West African Economic and Monetary Union
WD : World Database.

1. INTRODUCTION

Protected and conserved areas have long been considered the cornerstones of biodiversity conservation [1] and have an important role to play in achieving many of the Aichi global biodiversity targets and the Sustainable Development Goals [2]. Although data on effectiveness remain incomplete, protected areas can prevent species extinctions and experience lower levels of human pressure than external areas [3,4,5,6]. In 2010, the governments of the world reiterated their commitment to expanding protected and conserved areas by agreeing to conserve 17% of the world's land and inland

water ecosystems, and 10% of its coastal waters and oceans, by 2020. The Protected Planet Report is the first in the series to include data on other effective area-based conservation measures (OECMs) in addition to protected areas. Although Aichi Target 11 refers to 'systems of protected areas and other effective area-based conservation measures', OECMs were not formally defined until 2018 [7]. While protected areas must have conservation as a primary objective, there is no restriction on the management objectives of OECMs, provided those objectives result in effective long-term conservation outcomes for biodiversity [8]. Both protected areas and OECMs can exist under the governance of governments, indigenous peoples, local communities, private actors, or any combination of these. In 2019, the World Database on Other Effective Area-based Conservation Measures (WD-OECM) was established by UNEP-WCMC to compile and report data on OECMs. Coastal ecosystems are negatively affected by anthropogenic habitat degradation [9]. Thus, protection and restoration measures have been proposed to maintain the protective function of coastal ecosystems [10,11,12,13]. To maintain or even increase nature's role in coastal protection requires knowledge about the location of potential beneficiaries in relation to both coastal risk and coastal ecosystems. Regarding sensitive coastal areas to be protected against oil spills, there are Digital database would actually expand Environmental Sensitivity Index and map (ESI map) applications and utilization NOAA. ESI map shows the natural persistence of oil, undisturbed

habitat, and important resources for humans but sensitive to oiling and the expected ease of cleanup according their vulnerability. Main types of information concern Shoreline classification, Biological resources (seabird colonies, sea-grass and kelp-beds, intertidal invertebrates, coral reefs and wildlife and Human-use resources with their seasonality, threatened/endangered status, activity, and relative concentration) and Human-use resources such as water intakes, sand beaches, and archaeological sites, which have added sensitivity and value because of their cultural significance or use by humans [14]. The database provided by Protected Planet Report 2020 on Côte d'Ivoire shows that these are 255 protected areas and other effective area-based conservation measures [15]. This data is not updated because given the numerous environmental challenges facing the country, protected areas have been created on its coastal area, in particular a Marine Protected Area and forest conservation sites. This fits into the adoption of Law No. 2017-378 of June 2, 2017 relating to the development, protection and integrated management of the littoral which prescribes in its article 18 that "protected areas and sensitive or remarkable ecological sites and historic sites are subject to special protection measures defined according to the coastal development directives". An Integrated Coastal Development and Management Plan (PAGIL) has been developed. This plan highlighted the degradation of habitats and the loss of ecosystems in the coastal zone and revealed the urgency of issuing a decree whose purpose will be to list these sensitive spaces and environments to be protected in application of the Article 46 of the aforementioned law. The objective of the study is to contribute to the identification of remarkable areas or spaces of ecological and biological interest in the west coastal zone (zone of high cocoa production) uses GIS and Web data from various sources to design a compiled database, supplemented by field surveys of these spaces and environments of the Ivorian coast. With a view to their preservation and to propose action strategies for the preservation of these sites, supported by legal guidelines for the protection of these remarkable spaces

2. MATERIALS AND METHODS

2.1 Location on the Study Area

A border area with Liberia, the west of the ivorian coastal zone is the country's main cocoa,

coffee and rubber producing area. This area has many of the country's forestry, agricultural and tourism resources. Industry is concentrated in San Pedro (capital of this region and 2nd national port) with 5% of the country's industrial units compared to 90% in Abidjan. These operate mainly in the cocoa industry, flour milling, cement and wood. Fig. 1 presents the administrative location of the study area.

2.2 Data Collection

The documentary research was based on documents and reports made available by institutions and projects that worked on different aspects of coastal vulnerability in Côte d'Ivoire. International institutions such as the West African Economic and Monetary Union (WAEMU), Food and Agriculture Organization of the United Nations (FAO), the World Bank, etc., provided several types of document, including reports, the West Africa Coastal Areas/Detailed Master Plan for regional monitoring of the West African coastline, the Strategy for Adaptation to Climate Change and Risk and Disaster Management, USAID reports, particularly those generated by WABiCC project (West Africa Biodiversity and Climate Change) for the Fresco coastal vulnerability assessment and West Africa coastal erosion and adaptation projects [15], World Bank reports assessing the costs of environmental degradation along the coast, and cost-benefit analyses. At the national level, qualitative and quantitative secondary data were gleaned from assessment reports provided by government agencies such as the National Coastal Environment Management Program, the National Climate Change Program, the Scientific Commission of the Inter-ministerial Committee for the fight against Coastal Erosion, the Ivorian Anti-Pollution Center (CIAPOL) within the Ministry of Environment and Sustainable Development, the West Africa Coastal Areas-Côte d'Ivoire (WACA-CI) project, and the national platform for disaster risk reduction and management. The data collected in each coastal city was carried out using a participatory and inclusive approach in order to take into account the views, opinions, concerns and needs of all stakeholders operating in the coastal zone [16]. Thus, questions relating to the identification, location, characteristics, and attacks of the following coastal areas were addressed.

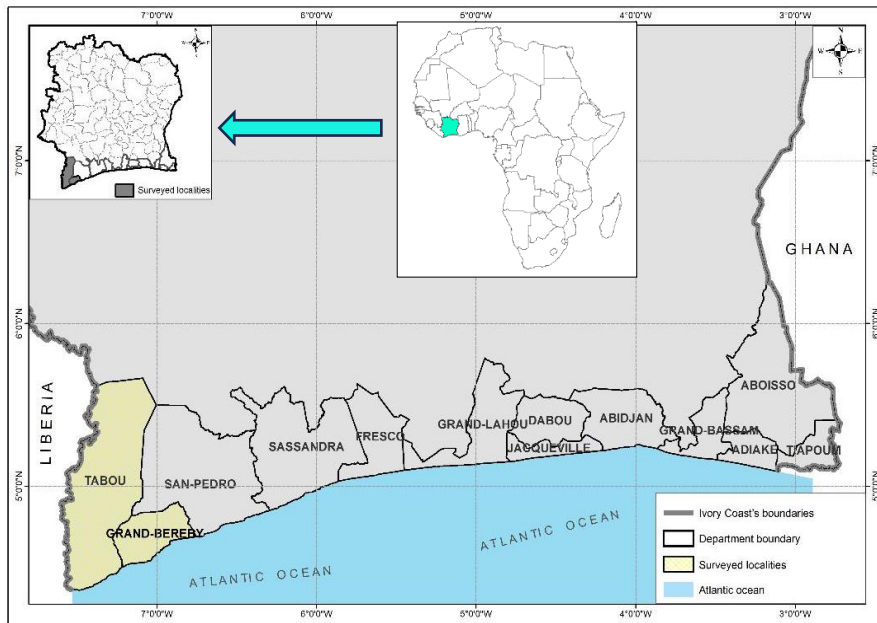


Fig. 1. Location of the study area
(Source: field surveys, 2023)

2.3 Identification of Remarkable Coastal Spaces and Environments to be Preserved

A cartographic database was created from the 2023 Sentinel 2 satellite image of the Ivorian coastal area. Digital processing of the 10 m spatial resolution image using ARCGIS 10 software made it possible to digitize the land cover layers of the coastal zone. The aim was to digitize the different layers of land use, reflecting the remarkable coastal spaces and sites to be

preserved. The information collected in the field made it possible to validate the geographical location and surface areas of these spaces. This inventory will facilitate the strengthening of the legal framework with a view to better supervision of anthropogenic activities within the geographical limits of coastal areas, by maintaining environmental balances and strengthening the fight against coastal risks.

Fig. 2 presents the Flow chart of the study structure.

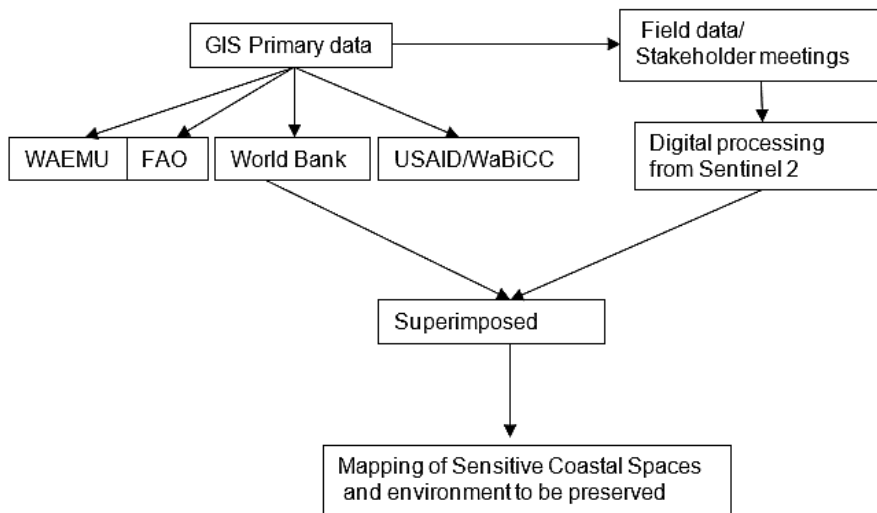


Fig. 2. Flow chart of the study structure

3. RESULTS AND DISCUSSION

3.1 Diagnosis of the Cavally River Estuary-Liberia-West Tabou border

The results show that there are 17 coastal sites to be protected, including 4 on a physical level (Cavally River, Tabou, Hiré and Noublé rivers), 4 on a biological level (Gnanto Voluntary Forest Reserve, Sea turtle nesting sites, Mangrove areas and the new marine protected area planned) and 9 on the socio-economic level (villages of Bliéron, Soublaké, Ouépo, Souké, Bianké, Degné, Yonaké, Gbaouloké, Boké).

3.1.1 On the physical level

The Cavally River, the natural border between Côte d'Ivoire and Liberia, is subject to significant forms of pollution, particularly chemical. This pollution comes mainly from agricultural and industrial activities of oil palms and rubber trees, but also from gold panning activities carried out upstream of the area towards Grabo. Two major rivers exist on this coastal segment. These are the Ponon River and the Tabou River. These respective waterways are home to several protected species, including the dwarf crocodile, the manatee, and the otter. These rivers are subject to pollution from industrial companies located nearby. Effluent discharges into these courses are visible and are marked by silting at the mouth of the Tabou River, a place of exchange and migration of aquatic species.

3.1.2 On the biological level

3.1.2.1 Gnanto voluntary forest reserve

On the border with Liberia, we note the existence of a voluntary forest reserve of 935.84 ha (Gnanto voluntary reserve), belonging to the villages of Gnanto, Prolo and Pymée. This reserve, created with the technical and financial support of GIZ, the NGO Impactum, Mondelez, the San-Pédro Regional Council and IKY (Climate International Initiative), is unfortunately subject to agricultural exploitation. However, the latest studies have shown an agricultural occupation rate of 3%, represented by old rubber plantations. This reflects a real desire of the populations for the conservation of this forest. To date, the transformation of this voluntary reserve

into a nature reserve has not yet been confirmed. The procedures began in 1997.

3.1.2.2 Sea turtle nesting sites

Several marine turtle nesting sites have been spotted on the beaches of Tabou. These are the beaches of the villages of Nandjibo, Boubélé, Dégné, Souké, Yôcôbo, Yonaké and Bianké. Ethnozoological surveys have confirmed that these are green turtles and leatherback turtles, all endangered.

3.1.2.3 Mangrove areas

There is a mangrove located on the Cavally River, in the area of the village of Bliéron. Other mangroves also exist between Soublaké and Bianké. An urban and residual mangrove is located on the Oulô river, in the village of Yôcôbo.

Fig. 3 presents the location of sensitive spaces and environments to be preserved on the Cavally River-Liberia-West Tabou border coastal segment.

3.1.2.4 Project to develop a marine protected area

A marine protected area is planned in this coastal area.

3.1.3 On the human and socio-economic level

The village of Bliéron, located at the mouth of the Cavally River, is threatened with disappearance due to recurring episodes of marine and river submersion that it experiences. These episodes of marine submersion also occur at the mouths of the Oulô river at Yôcôbo (in the dry season) and the Ponon river between the villages of Hipodioké and Douèpo.

3.2 Diagnosis of the Coastal Site Tabou est-Grand-Béréby

In this coastal zone, there are 8 sites on the physical environment (rivers Ponon, Nindja, Oulô, Negwabo, Dodo, Guiré, Némassé and Nero-mer), 8 biological sites (Marine Protected Area, Voluntary nature reserve of the mouth of the Dodo river, 2 Community forests, 2 Sacred forests, Mangrove areas, 2 Sea turtle nesting sites) and 7 localities threatened by marine flooding, for a total of 23 sites and spaces to be protected.

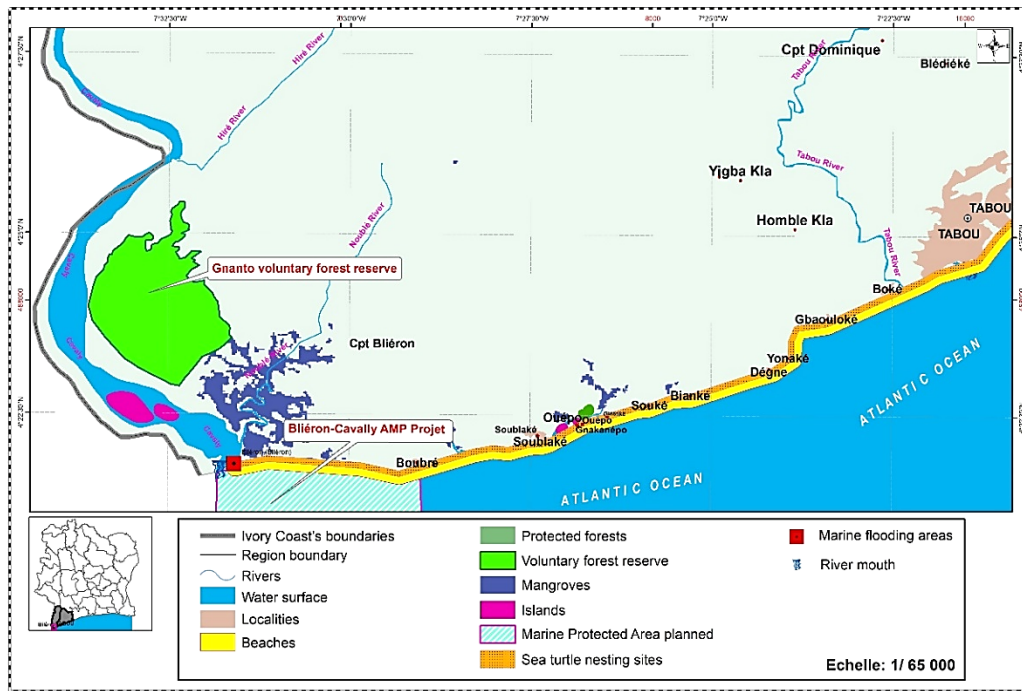


Fig. 3. Sensitive spaces and environments to be preserved on the Cavally River-Liberia-West Tabou border coastal segment
(Source: field surveys, 2023)

3.2.1 On the physical level

Between Tabou est and Grand-Béréby, there is a dense network of watercourses including the Ninja River, border between Tabou and Grand-Béréby and the Dodo River. Between these 2 important rivers, we note the existence of several sacred rivers such as Gawè, Niro, Gnègbagbo, Nananhouo, Niéwé, Gléssogné, Lake Dawa and the Nero River, which deserve to be protected. It is a peninsula which borders the village Nero-mer.

3.2.2 On the biological level

3.2.2.1 Marine protected area

Grand-Béréby benefited from decree no. 2022-448 of July 6, 2022 creating a Marine Protected Area. It is a protected area extending between the Ninja River (Kablaké-Wapo) and the Petit-Djiboué lagoon (Menolé) of the Grand-Béréby sub-prefecture. This Marine Protected Area (272,375 ha) aims to preserve biodiversity, the preservation of the remarkable marine ecosystems of its coverage area and the contribution to the economic and social development of local communities.

3.2.2.2 Voluntary nature reserve of the mouth of the Dodo river

A project to create a voluntary reserve of 3000 ha was initiated between the localities of Mani-Béréby and Teklébo. This reserve is located between the mouths of the Dodo and Gnègbagbo. This project includes elements of environmental management, regulation and public awareness actions and a very positive response has been found to the inclusion of young people in the role of monitors and promoters of the community. The limits of this reserve still remain unknown. However, steps are underway to legally formalize this protected area.

3.2.2.3 Community forests

In this coastal zone, we note the existence of 2 community forests of 13.37 ha and 2.16 ha, located in the village of Toulaké.

3.2.2.4 Sacred forests

In this coastal area, there are two sacred forests, namely the sacred forest of Sekréké, having been the subject of reforestation of 10 ha in Tolou and the sacred forest in Kablaké.

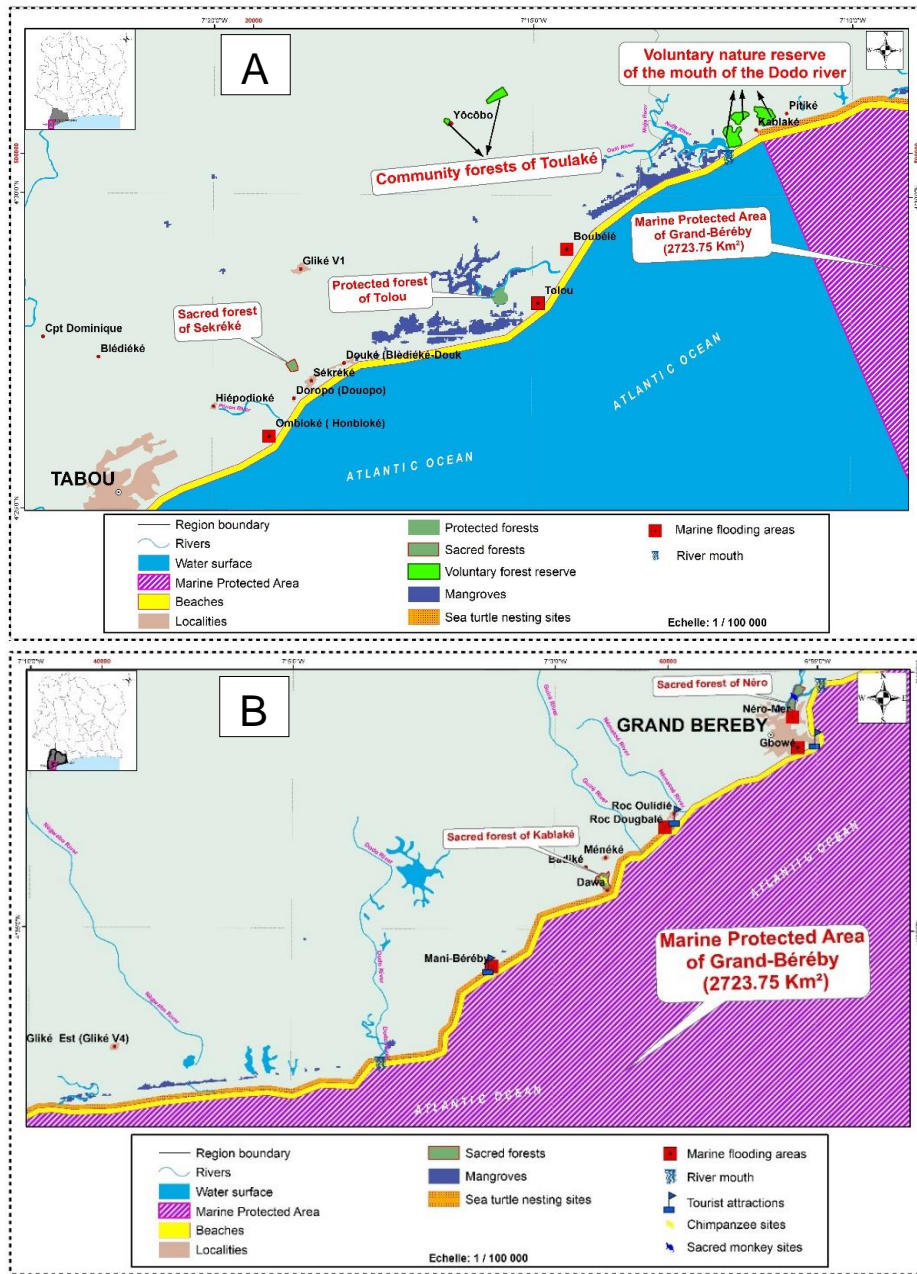


Fig. 4. Sensitive spaces and environments to be preserved on Tabou est coast (A) and Grand-Béréby west (B) coast
(Source: field surveys, 2023)

3.2.2.5 Mangrove areas

A mangrove exists and located in the Nero River and also between Tolou and Boubélé.

3.2.2.6 Sea turtle nesting sites

Two very dense of sea turtle nesting sites are listed in Grand-Béréby, notably in Taboulé and between the villages of Pitiké and Kablaké.

3.2.3 On the human and socio-economic level

The villages of Boubélé, Tolou, Onbloké located along this coastal zone are faced with coastal erosion and episodes of marine flooding. The localities of Rock, Dougbalé, Mani-Béréby, Gbowé and Bébé are also exposed to these same coastal hazards. Furthermore, a peninsula located in the village of Nero-mer deserves particular attention. Indeed, this site located between the Nero River and Lake Gbowé, is

home to small “white-nosed” monkeys now protected by the local population and which thrive in the tropical forest which borders the river. Several beaches which are the subject of tourism can be identified on this coast. These are the beaches of the villages Ombloké, Doupo and Tolou, the most beautiful and most visited beaches. Fig. 4 shows the location of sensitive spaces and environments to be preserved on the Tabou est-Grand-Béréby coastal segment.

3.3 Discussion

The database provided by Protected Planet Report 2020 shows that 275,496 Protected Areas et 660 OECMs for Terrestrial and inland waters protected area & OECM coverage. Concerning Marine protected areas & OECM coverage, there are 18,200 Protected Areas and 196 OECMs, [17]. When we refer to the data on Côte d'Ivoire in this same report, these are 255 protected areas and other effective area-based conservation measures. The results of the study made it possible to inventory 40 sensitive coastal sites and areas to be protected on the west coast of the Ivorian coast, including 17 and 23 respectively between the Cavally River and Tabou and between Tabou and Grand-Béréby. We then understand that the number of sites to be protected on the Ivorian coast is increasing and could be even more important than 255 presented in the Protected Planet Report 2020, because the Ivorian coast includes the Autonomous District of Abidjan, four regions that are San Pedro, Gbôklè, Grand-Ponts and Sud-Comoé, made up of around twenty departments. However, it should be noted that apart from the creation of the Marine Protected Area in Grand-Béréby in 2022, the inventoried sites have remained unprotected. The level of protection of protected areas in the Ivorian coastal zone is therefore low, almost non-existent in most cases. In France, for example, the number of protected areas created remained low during the first half of the 20th century but since the 1970s, this number has increased regularly. The total surface area of protected areas has increased significantly over the last decade, corresponding to the creation of very large marine protected areas following the 2006 law [18]. The preservation of diversity and functional redundancy appears to be a major issue in the context of the management of aquatic ecosystems in order to ensure the long-term stability of systems subject to multiple anthropogenic disturbances [19]. Resources allocated to protecting biodiversity are often

limited, so managers must define priority areas for investments, particularly those in conservation. Species richness and the presence of endemic species are often used to define conservation strategies, but several studies have highlighted the weakness of solely using taxonomic diversity criteria to assess the impact of threats on ecosystem functioning [20,21]. The integration of the functional characteristics of communities can be used in addition to the usual criteria for the definition of a management plan or when defining conservation status in order to prioritize the sites to be protected in the face of environmental disturbances, by focusing on the ecosystem processes. Conservation efforts can be directed towards sensitive communities subject to high intensity threats. Spaces must be protected by several tools whose protection methods make it possible to adapt to the local context. Thus, on certain sites, we frequently combine regulatory protection tools, to limit or prohibit certain uses, and contractual tools to finance restoration actions or encourage more sustainable practices. Land acquisition, which allows sectors to be protected from urbanization, can be particularly associated with contractual management measures favorable to environments and biodiversity. An overlap between maps quantifying the sensitivity and resilience of communities and those reflecting pressures could make it possible to better assess the functional and spatial vulnerability of sensitive coastal sites and spaces and attract the attention of decision-makers for sustainable management of these sites.

4. CONCLUSION

This study made it possible to map the sites, spaces and sensitive environments already protected (Grand-Béréby Marine Protected Area) and those whose preservation deserves to be strengthened on the west coast of the Ivorian coast. The primary data collected did not make it possible to identify sensitive coastal issues in this coastal area. These data had the merit of being updated and supplemented by field observations.

The views and opinions of local and central stakeholders and field visits made it possible to produce an inventory that meets the aspirations of all stakeholders. From Cavally River bordering Liberia-west Tabou border, we have identified 17 coastal sites to be protected, including 4 rivers, 4 biological sites (Voluntary Forest Reserve, Sea turtle nesting sites, Mangrove areas and the new marine protected area planned) and 9 villages.

As for the Tabou est-Grand-Béréby coast, there are 23 sites including 8 rivers, 8 biological sites (Marine Protected Area, Voluntary nature reserve, Community forests, Sacred forests, Mangrove areas, Sea turtle nesting sites) and 7 localities threatened by marine flooding. Coastal sites must be protected by several tools whose protection methods make it possible to adapt to the local context. Thus, on sites, we frequently combine regulatory protection tools, to limit or prohibit certain uses, and contractual tools to finance restoration actions or encourage more sustainable practices, and this, from the implementing decree on sensitive coastal areas and sites to be protected from Law No. 2017-378 of June 2, 2017 relating to the development, protection and integrated management of the littoral.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper

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