ICZM Plan Suriname - Mangrove Report

Analysis of problems and solutions for the management of mangrove forests along Suriname's 'wild coast'

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Final report

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Executive Summary

This report describes the results of an analysis of problems and potential solutions with regard to the management of mangrove forests along the coast of Suriname. The analysis is based on a literature review, a site visit to Suriname in June 2009, discussions and interviews with experts and resource persons, and three stakeholder workshops in Suriname.

Mangroves in Suriname cover an estimated 100,000 ha, dominated by dense vegetations of *Avicennia germinans* (parwa) along the coastline, with other species dominating along tidal creeks (*Laguncularia racemosa*) and riverbanks (*Rhizophora* spp.). These mangroves provide several major ecological functions and services, including shoreline protection from erosion, sustenance of coastal fisheries and as habitat for millions of migratory shorebirds, breeding waterbirds and other wildlife.

While two-thirds of Suriname's mangroves and other coastal wetlands are protected or managed for wise use, and various environmental laws and regulations are in place, the management of mangrove resources in Suriname is facing a number of major problems, such as habitat destruction & conversion, coastal erosion and sea level rise, hydrological disturbances and various other threats and challenges.

Urgent, high priority problems that require immediate action include the expansion of urban areas into mangroves north of Paramaribo, severe coastal erosion at Weg naar Zee and Coronie, and the lack of awareness on importance of mangroves. Intermediate priority problems that require a response at the medium-term include the limited management capacity (protected areas & MUMA's), coastal erosion in other districts (maintenance of coastal defence structures), and hydrological disturbances that reduce vitality of mangroves (Coronie, Paramaribo-Wanica). Future threats & issues that require a response in the long-term include coastal erosion problems in relation to predicted sea level rise (all coastal districts), future urbanization and industrialization (esp. Parbo-Wanica). Low priority problems that require *ad hoc* solutions & mitigating measures include oil exploration activities and dredging.

In order to address these mangrove management problems, we propose the following potential solutions, as part of an Integrated Coastal Zone Management Plan:

1. **Spatial planning:** It is proposed to <u>establish a set-back line</u> of 3 - 4 km from the coast to delineate a coastal buffer zone. The purpose of the set-back line would be to prevent (further) urban expansion and agricultural development or any other development activity that would compromise the health and integrity of the mangroves, considered critical to buffer/mitigate natural coastal erosion processes. It is further proposed to <u>identify coastal flood hazard zones</u> that take into account future sea level rise predictions. The purpose of a hazard zone is to manage human activities in such a way that their vulnerability is reduced through specific requirements, restrictions or recommendations to reduce the consequences of coastal erosion and flooding. Finally it is recommended to <u>stop urban expansion into the coastal wetlands and mangroves</u> north of Paramaribo and to give appropriate attention for the option to relocate established property and/or land ownership & use to (safer) areas outside the proposed buffer and hazard zones. It is questionable whether a ring dike very near the present coastline will protect this stretch of coast on the long term and will enable the survival of the mangrove forest which is essential to

dampen waves from the ocean and to catch and accummulate/build up the sediments from the ocean in case of sea level rise. It is proposed here to situate the planned ring dike along or south of a set-back line of 3 - 4 km from the coast to delineate a coastal buffer zone. This is according to the Terms of Reference for Study and Design of a Ring-dike, Drainage Channel and a Ring-road in North Paramaribo, which mentions the "determination of the alignment leaving a green belt of about 2.5-4 km along the coast" (Ministry of Public Works, 2005).

2. **Enhance sediment accretion:** It is proposed to artificially facilitate the settling of fine sediments (normally efficient in the presence of mangrove vegetation) in critical coastal areas where mangrove vegetation has been destroyed, resulting in net coastal erosion. This can be achieved through the placement of permeable groins (soft structures) perpendicular to the coast ("salt marsh works") during periods that a mudbank is present in front of these areas. Such permeable groins will reduce turbulence and diminish current velocities (*imitating* the role of mangrove vegetation), creating an artificial low-energy environment in groin fields where sedimentation of suspended material is enhanced. This will facilitate faster accretion of the coast and – as a result – enhance natural (re)colonization of mangroves (parwa).

3. **Mud nourishment:** In critical coastal areas facing net erosion because the mangroves have been destroyed it is proposed to artificially increase the flux of fine sediment towards the coast during periods that there is no mudbank passing in front of them. This may be achieved by mobilizing sediments from the seabed through agitation dredging (mud nourishment).

4. **Restore hydrological connections:** It is proposed to consider the restoration of vital hydrological connections (freshwater flows into the mangrove areas) by perforating specific hydrological barriers (such as "zwamp-kerende dammen", east-west road connection and sea dikes), following hydrological investigations and pilot studies. At some places, a limited number of culverts have already been installed, but further enhancement of the permeability of these dams and dikes should be considered to improve the overall health and functioning of the coastal mangroves and hence strengthen their role in protecting the shoreline against erosion.

5. **Capacity strengthening:** It is proposed to give due attention to capacity strengthening for effective management of MUMA's and nature reserves along the coast, through training of field staff, infrastructural upgrading, improved allocation of financial resources, incentives and regular management evaluation.

6. **Awareness raising:** There is an urgent need to increase the awareness among the general public, media, schools, stakeholders and decision makers on the important ecological functions, values and services of mangrove forests, especially their role in shoreline protection and sustaining coastal fisheries.

7. **Mangrove rehabilitation:** Since no previous experience with mangrove rehabilitation in Suriname exists, it is essential to study carefully the successes and failures from similar efforts elsewhere in the world, before embarking on an expensive rehabilitation programme of any scale in Suriname. Based on lessons learnt from mangrove rehabilitation efforts worldwide and personal experiences, we propose the following 5 critical steps achieve successful mangrove restoration: [1] understand the autecology (individual species ecology) of the mangrove species at the site; [2]

understand the normal hydrological patterns that control mangrove establishment and growth; [3] assess modifications of the original mangrove environment that currently prevent natural recovery; [4] restore appropriate hydrology in order to facilitate natural recruitment of mangrove propagules for plant establishment; [5] only use actual planting of propagules or seedlings after determining (through steps 1 to 4) that natural recruitment will not provide the quantity of successfully established seedlings desired. We recommend salt marsh works in combination with mud nourishment and removal of hydrological barriers (see recommendations 2, 3 and 4 above) as means to facilitate natural recovery of mangroves in degraded areas. Manual planting of *Avicennia germinans* (parwa) is probably not necessary anywhere along the coast given the abundant availability and wide dispersal of propagules of this species. It is further proposed to organize a local mangrove restoration training workshop in collaboration with international experts in this field.

The report concludes with a summary of the outcome of two group discussions on mangrove-related ICZM problems held during stakeholder workshops, as well as a number of recommendations for monitoring and research that will support and improve the management of mangrove resources in Suriname.

1. INTRODUCTION

1.1 Background

The present report describes the results of an assessment of the existing situation, problems and possible solutions with regard to the management of mangrove forests (and other wetlands) along the coast of Suriname. This study formed part of a wider ICZM project (ICZM Plan for Suriname) that consists of several components, including Component I - "ICZM Plan Development and Public Awareness Plan" (sub-project 101) and Component III – "Implementation of a Pilot Plan" (sub-project 102). Both of these components are being carried out by a consortium of Lievense, Deltares and ACE Consultancy for the Ministry of Planning and Development Co-operation of Suriname (PLOS).

This report contributes to the sub-component "physical, biotic and environmental issues" of both sub-projects (101 and 102) and covers aspects of the analysis phase of the ICZM project (description of existing situation and prioritization of problems) as well as the strategy design plan development phase (preliminary identification of possible solutions), with a special focus on the mangroves and coastal wetlands.

The report starts with an introduction to the background, objectives and approach of this study (Chapter 1), then describes the existing situation and problems with regard to mangrove management in Suriname (Chapter 2), followed by an identification of possible solutions (Chapter 3). The report concludes with a preliminary action plan with measures for the short-, medium- and long-term (Chapter 4), and recommendations for monitoring and research (Chapter 5).

1.2 Objectives

The objectives of this mangrove study were:

[1] To perform an assessment of the existing situation with regard to the management of mangroves along the coast of Suriname;

[2] To analyse and prioritize the problems and future scenarios related to the management of mangroves (and other coastal wetlands) in Suriname;

[3] To identify potential solutions for these problems and formulate an action plan with short-term, medium-term and long-term measures for mangrove management in Suriname.

1.3 Approach

The present report is based on a rapid assessment study of available literature, discussions and survey activities during a site visit to Suriname (31 May – 12 June 2009). For the collection and interpretation of information, the following activities were carried out:

- **Interviews**, meetings and discussions with key persons at a range of relevant institutions in Suriname, including Dr. Sieuwnath Naipal (Anton de Kom University - hydrology), Mr. Achmed Sheikkariem (Anton de Kom University - forestry), Mr. Amatali (WLA), Ms. Jolanda Babb (NIMOS), Mr. René Somopawiro (SBB, by phone), Mr. Bryan Drakenstein (LBB), Ms. Wortel (CELOS, by correspondence), Mr. Johan van der Wal (MNO Vervat Suriname NV), Mr. Schalkwijk (GLIS), Ms. Taciana Soerodimedjo (GLIS) and Ms. Minoe Parahoe (WWF);
- attendance of the "**ICZM Workshop** on Legal and Institutional Reforms" (component 2) on 4th June 2009, allowing for interaction with ICZM committee members;
- **field survey** by car of Greater Paramaribo, Wanica and Weg-naar-Zee (4th June 2009);
- **boat survey** of the Commewijne coast, including Suriname-Commewijne estuary, Braamspunt, Diana beach, Wia Wia mudbank in front of the Matapica canal mouth, mangrove forests along the Matapica canal, the Matapica creek and the Commewijne river (6th June 2009);
- **aerial survey** by Cessna 206 on 8th June 2009, covering the coastal areas of Commewijne (up to Matapica canal), Paramaribo-Wanica (incl. Weg naar Zee), Saramacca (incl. Coppename-monding nature reserve and estuary) and Coronie (entire district up to the Nickerie district boundary);
- **field survey** by car of the Saramacca and Coronie coastal areas (including the construction site of the Coronie Sea Dike) (9th June 2009);
- study of available scientific **literature** and technical reports, in particular the final report of the ICZM study by Royal Haskoning / University of Leuven et al. (2006) and numerous previous reports and technical memo's by Teunissen (1978, 1988, 1995, 1997, 2000a, 2000b, 2003, 2004a, 2004b);
- study of **aerial photographs** of 2000 (Lufthansa) and 2005 (GLIS), satellite imagery and maps (incl. vegetation map of Teunissen, 1978 and geological and nautical maps);
- interaction with other project **team members** (Stanley Koole, Marc Willems, Hans Martinus, Tom Bucx, Han Winterwerp, Marcel Marchand, Albert Quist and Pieter Augustinus).

Activities and meetings during the site visit to Suriname were facilitated by ACE Consultancy (esp. Mr. Stanley Koole and Ms. Wilma Wan Tong You) and PLOS (Ms. Lilian Krishnadath). Their help and support is highly appreciated.

In addition to the findings derived from these discussions and activities, the present report also incorporates the results of two group discussions on mangrove-related ICZM issues, which formed part of three ICZM **stakeholder workshops** held in Nickerie and Paramaribo during August 2009.

2. ASSESSMENT OF CURRENT SITUATION

2.1 General description

There is an impressive body of literature and reports on the existing situation of the mangroves, mudflats and other coastal wetlands in Suriname. Rather than repeating or copying this information again in detail, we synthesize the available information here, with due reference to the relevant background documents for further information.

2.1.1 Mangroves in Suriname

The coastal zone of Suriname is characterized by vast intertidal mudflats, narrow sand and shell beaches, and extensive mangrove swamps that are bordered inland by shallow saline and brackish lagoons and swamps. Further inland the marshes become fresh, with patches of swamp forest, and mixed dryland forests on the sandy ridges (Teunissen, 1978). The mangrove forests and adjacent swamps along the coast of Suriname form part of a continuous belt of coastal wetlands that stretch from the mouth of the Amazon River in Brazil to the Orinoco Delta in Venezuela, a region commonly referred to as the 'Guiana's'. The extensive mangroves and mudflats along this coast are some of the most productive on the continent (Spalding et al., 1997).

Mangrove forests in Suriname currently cover a total of about 100,000 hectares (2000 data) (COCATRAM, 2003). They occur along almost the entire length (375 km) of the coastline of Suriname as a fringe with an average width of about 3 km, although this varies substantially (0 - 8 km) depending on the local state of erosion/accretion. Mangroves also occur along the main rivers and tidal creeks, reaching from the estuaries to brackish areas further upstream. Scattered pockets of mangrove vegetation also occur among the brackish swamps behind the mangroves.

There are three main types of mangrove in Suriname:

[1] **Parwa**
This type refers to the fringing mangrove forest bordering the coastline, which consists almost entirely of Black Mangrove (*Avicennia germinans*), locally known as 'parwa'. Black Mangrove (parwa) is also found behind the mangro-zone (Red Mangrove) that fringes the lower (estuarine) reaches of rivers. Seedlings of Black Mangrove establish themselves rapidly on those parts of accreting mudbanks that emerge at about mean high water level up to the high water spring level. Further inland from the coastline and estuarine riversides, Black Mangrove can form substantially tall and dense (mature) mangrove forests up to areas that are inundated only at spring high water;

[2] **Akira**
This type occurs along the muddy banks of tidal creeks and levees, consisting of almost pure stands of White Mangrove (*Laguncularia racemosa*), locally known as 'akira';

[3] **Mangro**
This type of mangrove vegetation mainly occurs on the weak mudbanks along the lower (estuarine) reaches of the rivers in Suriname and is dominated by Red Mangrove (*Rhizophora mangle*), locally known as 'mangro'. This species is less tolerant of salinity and desiccation than the other two species. Riverside mangroves in Suriname may also feature *Laguncularia racemosa*. Further upstream other less salt tolerant mangrove species dominate: *Rhizophora harrisonii* and *Rhizophora racemosa*.

Under the influence of the Guiana Current and waves generated by the NE trade wind, the mudflats along the coast of Suriname are eroding on the eastern side and accreting on the western side resulting in a westward migration of these mudbanks at a rate of about 1 - 3 km per year (Augustinus, 1978). Smaller mudbanks migrate at faster speeds of up to 4 or even 5 km per year. There are at least 7 of these mudbanks (ranging in length from 20 - 70 km) along the coastline of Suriname (Augustinus et al., 1989). The succession of accretion and erosion of the mudbanks, and consequently of the fringing mangroves, has a cyclic character (15-30 years of accretion followed by 15-30 years of erosion, etc., at a given area) and forms part of the natural dynamics of the "wild coast" of Suriname (Augustinus, 1978; Augustinus et al., 1989).

Mangroves along the coast of Suriname undergo alternating periods of accretion (left) and erosion (right).

When the natural drainage system of the mangroves is (temporarily) impeded as a result of siltation and/or consolidation or the formation of a sandbar (chenier), the mangrove vegetation may locally die off, resulting in 'dead zones' ("*parwa-kerkhoven*"). These areas typically turn into shallow lagoon systems where, due to evaporation, hypersaline conditions may develop. Due to siltation these lagoons may become shallower and halophytic (salt marsh) vegetation soon appears in these lagoons, dominated by species such as Sea Purslane (*Sesuvium portulacastrum*) and Salt Wort (*Batis maritima*). When, as a result of coastal erosion, tidal flushing of the area is restored, *Avicennia* and *Laguncularia* may start to regenerate and the salt marsh may gradually become a mangrove swamp once more (Teunissen, 1988; Spalding et al., 1997).

2.1.2 Importance of mangroves in Suriname

The mangrove forests along the coast of Suriname provide a number of major ecological functions and services, including stabilization of the shoreline (thus protecting inland structures, property and agricultural land), sustenance of coastal fisheries, and as a habitat for millions of waterbirds, migratory shorebirds and other wildlife. These functions are briefly elaborated below.

Shoreline protection

It has long been known that mangroves protect and stabilize coastlines. They are more effective than concrete barriers in reducing erosion, trapping sediments, stabilizing shorelines, and dissipating the energy of breaking waves (Pearce, 1996; UNEP/WCMC, 2006). Mangrove-dominated coastal areas tend to exhibit less erosion while exposed and unconsolidated soils of non-vegetated coastal areas and former mangrove areas are more prone to erode (Thampanya, 2006). Wave attenuation by the dense network of trunks, branches and aerial roots of mangrove vegetation can be substantial (Quartel et al., 2007). The structure of mangrove root systems also helps to consolidate the coastal soil; hence the shoreline is more resistant to erosion (Mazda et al. 1997). Furthermore, mangrove roots reduce flow and promote flocculation and sedimentation upon the soil surface, eventually allowing positive accretion (Augustinus, 1995; Furukawa & Wolanski, 1996; Smoak & Patchneelam, 1999). Numerous studies in the aftermath of the 2004 Indian Ocean tsunami showed a clear connection between areas with the highest levels of damage and the absence of coastal forests, strongly supporting the notion that coastal forests (especially mangroves) can provide significant mitigation of tsunamis and storm waves (Dahdouh-Guebas et al., 2005; Forbes and Broadhead, 2008).

Nursery ground for fishes and shrimps

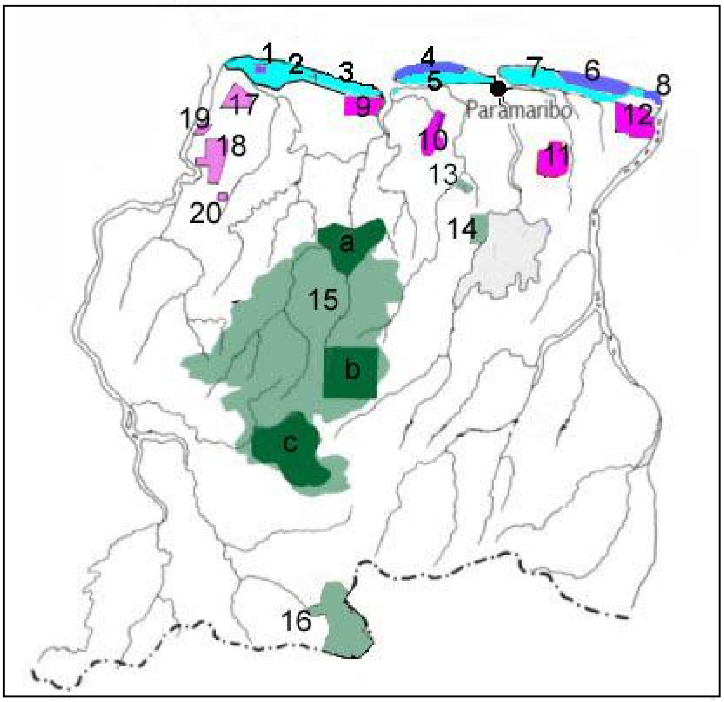
Mangroves contribute substantially to the diversity, productivity and stability of fish communities in tropical coastal waters. Mangrove habitat plays a variety of roles in the lives of fishes and shrimps, including as feeding area, daytime refugia, spawning area and/or nursery ground (Faunce and Serafy 2006; Nagelkerken et al. 2008). This typically includes many species that are of economic importance to fisheries, a sector which contributes 2 - 5% to the GDP of Suriname. Fish and shrimp products also constitute the second most important export product of Suriname (after aluminium), contributing 12.6 % or (47 million USD per year) to the total export earnings of the country (ASP, 2004). Total landings (2007 data) in Suriname are in the order of 20,000 t yr^{-1} (fish) and 10,000 t yr^{-1} (shrimp) (ABS, 2008). Recent studies in Suriname have indicated that 60-80% of all fish sold at coastal fish markets originate from mangrove areas (Finlayson & Moser, 1991) and that up to 90% of all fish and shrimp species in Suriname (incl. those caught offshore) are found in mangrove areas during one or more stages of their life cycle (University of Leuven et al., 2006). A total of 300 different fish species have been recorded from the mangroves of Suriname, as well as 20 species of crabs and 11 species of shrimp (Holthuis, 1959; Teunissen, 2004a).

Up to 80% of all fishes and shrimps sold at fish markets in Suriname originate from mangrove areas

<u>Importance to migratory shorebirds, breeding waterbirds and other wildlife</u>
The coastal area of Suriname is of importance as feeding and/or breeding area for more than 118 species of coastal birds, of which at least 70 species can be classified as waterfowl (De Jong et al., 1984). Suriname is by far the most important wintering area in South America for migratory shorebirds. Every year, several (up to 4) million of these birds arrive from North America to spend the winter months. The coastal mangroves are also important for several hundreds of thousands of larger waterbirds, especially herons and ibises, many of which also breed in the mangroves (Spaans, 2003; Ottema, 2006). This includes the Scarlet Ibis, a unique species with a very restricted distribution area, which breeds in fluctuating numbers ranging from less than 4,000 to as many as 35,000 breeding pairs (Spaans & Baal, 1990; Spaans, 2003; Spaans, pers. comm., 2009). If one divides the Suriname coastline into five sub-areas of equal length, then each of these areas would qualify as a wetland of international importance for waterbirds according to the internationally recognized criteria of the Ramsar Convention. The sand beaches of Suriname (along about 10% of the coastline) are also of critical international importance for spectacularly high numbers of nesting sea turtles (Leatherback, Green and Olive Ridley Turtles).

2.1.3 Management and conservation measures

Several areas along the Suriname coastline have been established as nature reserves (Hertenrits NR, Coppename Monding NR, Wia Wia NR, Galibi NR), multiple use management areas or MUMA's (Bigi Pan, North Coronie, North Saramacca, North Commewijne-Marowijne), Ramsar sites or Wetlands of International Importance (Coppename Monding NR), and Western Hemisphere Shorebird Reserve Network sites (Bigi Pan MUMA and Wia Wia NR). Nearly all of these sites (with exception of Hertenrits NR) include large areas of mangroves. More than two-thirds of the Suriname mangroves and other coastal wetlands are in this way protected or managed.



Protected areas & MUMA's in Suriname
(coastal sites: 1 = Hertenrits NR, 2 = Bigi Pan MUMA, 3 = North Coronie MUMA, 4 = Coppename Monding NR, 5 = North Saramacca MUMA, 6 = Wia Wia NR, 7 = North Commewijne / Marowijne MUMA, 8 = Galibi NR).

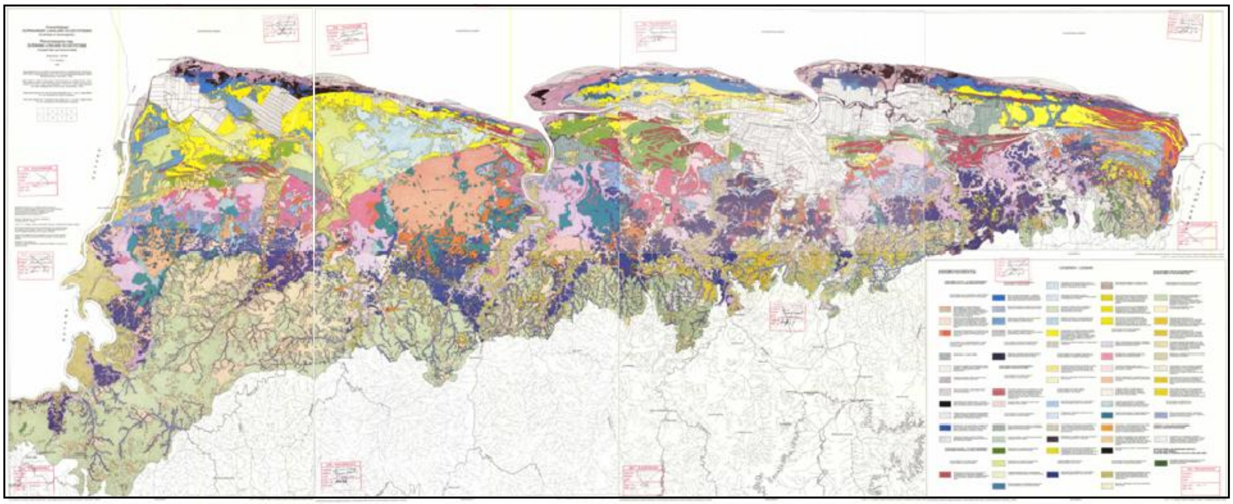
While mangroves in nature reserves are fully protected, the emphasis in multiple use management areas (MUMA's) is on their wise use, thus allowing for non-destructive uses and small-scale extraction of mangrove resources in these areas (McCormick, 1990; Teunissen 1995, 1997, 2000a, 2000b, 2004a; Parahoe et al., 2008). The status of an area as MUMA means that there are special regulations for what is allowed and what not, and any planned developments will be subject to a thorough assessment of potential environmental impacts prior to approval. Most MUMA's have a set-back line ("rode lijn" or 'red line') beyond which no developments, cattle grazing or water discharges are allowed in order to preserve a belt of undisturbed mangroves as protection of the land from the sea.

2.1.4 Legislative and institutional context

<u>National environmental legislation & guidelines</u>
Although Suriname has not yet promulgated an Environmental Act as such, elements of environmental protection and the conservation of biological resources (including mangroves) can be found in other legislation. General environmental rules and regulations for undertakings (including those in mangroves) are provided by the Hindrance Act. The Nature Conservation Act (1954) provides the legal basis for the protection of wildlife and important natural areas on state-owned land and as such applies to all established and proposed nature reserves. MUMA's have been established under the Decree L-2 on the Allocation of State-property Lands. The State Forest Service (LBB) is responsible for the management of nature reserves and MUMA's. The Management Plans of the MUMAs (see McCormick 1990, Teunissen 1997, 2000a, 2000b) recommend special rules and measures in order to prevent destruction of the protective and productive functions of the vulnerable coastal ecosystems, in particular mangroves. The Forestry Act (1990) also applies for the request of permits for

commercial logging, but there have been no such requests in Suriname for logging in mangroves to date. Specific environmental rules and regulations with regard to mining and oil exploration (including when such activities are undertaken inside or near mangroves) are found in the Mining Decree and the Petroleum Act. Although there is no official EIA legislation in place yet in Suriname, the National Institute for Environment and Development (NIMOS) has drafted EIA guidelines which are adopted by the State Oil Company for all its exploration and exploitation activities in the coastal area.

<u>International conventions and agreements</u>
Aware of its international responsibilities regarding coastal management and its resources, the Government of Suriname became a contracting party to several international and regional conventions and treaties, including some that are of relevance to mangroves: Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region or CARTAGENA (since 1983); Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere (since 1985); and the RAMSAR Convention of Wetlands of International Importance (since 1985). The State Forest Service (LBB) is the Management Authority for Wetlands in Suriname, and as such for the implementation of the Ramsar Convention. These international treaties and agreements have not been translated into specific local legislation, but various principles for the wise use of wetlands (Ramsar Convention) have been incorporated into management plans for the MUMA's.



Reconnaissance map of Surinam lowland ecosystems: coastal plain and savanna belt (Teunissen, 1978).

2.1.5 Other coastal wetlands (non-mangrove)

Mangroves constitute the main type of wetlands along the coast of Suriname, and therefore formed the primary focus of this study. There are, however, other brackish and freshwater wetlands in the coastal zone of Suriname. Behind the mangrove belt, a distinct zoning in vegetation can be noticed, related to geomorphology, soil development, ground and surface water hydrology and water quality. In river mouths, the Black Mangrove belt may be fringed by *Spartina brasiliensis*. For further details on the plant communities/ecosystems of the coastal zone, one is referred to the *Reconnaissance Map of Surinam Lowland Ecosystems: Coastal Plain and Savanna Belt* (Teunissen, 1978; see map above).

2.2 Problems

2.2.1 Destruction/conversion of mangrove habitat

The mangroves in Suriname have been reported to cover a total area of about 100,000 ha (COCATRAM, 2003). This area is decreasing is due to conversion of mangrove habitat for the expansion of agriculture (reclaiming abandoned plantations for cattle breeding) and urbanization (expansion of Paramaribo-North and river bank reclamation for housing projects). Other causes include the development of aquaculture (small area at Wanica) and oil exploration (transportation trails and drilling pads all over the coast). Substantial areas of mangroves were impounded and clear-felled much earlier during colonial times to establish near-coastal plantations for agriculture (e.g. at Nickerie, Coronie and Commewijne). More recently, a significant area of mangroves (in the order of 170 ha) was cleared in order to make way for the construction of a sea dike at Coronie (see below). The degradation and loss of mangroves due to these various causes represents a significant loss of valuable habitat, coastal protection and biodiversity.

Loss of mangroves as a result of urbanization is of immediate concern in Paramaribo, where a large part of the remaining mangroves are currently being impounded and cleared to make way for new residential areas. This is a serious threat to the critical role of the mangroves as a “bio shield” in the protection of the city against erosion and floods.

2.2.2 Coastal erosion

Coastal erosion is part of the natural dynamics along Suriname’s “wild” coast, as described briefly above (section 2.1.1) and in greater detail in Augustinus (1978) and Winterwerp (2009). Natural erosion occurs at various stretches along the Suriname coast that are not in a stage of accretion, because they are not fringed by mudbanks. Natural erosion is a temporary process, after which it will be followed by a period of accretion. The sequence of accretion and erosion is related to the westward migration of the mudbanks (at a rate of about 1-3 km per year for larger mudbanks and 4-5 km per year for smaller mudbanks).

Mangroves play a significant and critical role in both stages of erosion and accretion. During periods of accretion, mangroves accelerate the rate of accretion because they slow down currents, attenuate waves and favour deposition of fine sediments by trapping through their dense networks of aerial roots and pneumatophores. During periods of erosion, mangroves reduce the rate of erosion, because they break the waves and slowdown (tidal and wind-driven) currents and in this way buffer the erosive effect of the sea. As the erosion process continues, more and more fine sediment is being eroded from between and under their pneumatophores until the trees are uprooted. Ultimately, the first few rows of mangrove trees facing the sea start to fall over and die. Even dead tree trunks may play a role in reducing the erosion rate of the coastline by breaking waves and reducing the hydrodynamic energy at places where they have been driven ashore (see photo below), although this has not been quantified and requires further study.

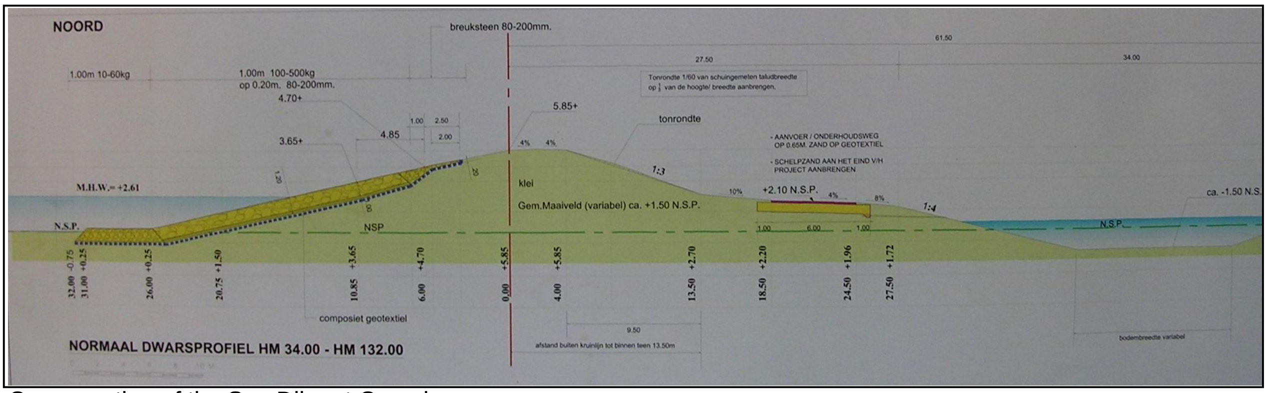
Erosion along mangrove-vegetated parts of the Suriname coast

Analysis of satellite imagery and aerial photography (Augustinus, 1978, 2004; this study) revealed that in periods of accretion, average accretion rates along healthy mangrove-fringed parts of the coast are in the order of several tens of meters per year with localized peaks of up to 200 m, while during periods of erosion (i.e. in the absence of a protective mudbank), erosion rates are in the order of several tens of meters per year with localized peaks of up to 100 m. This implies that during an erosion period of 15-30 years, a maximum of 30 x 100 m = 3 km of coastal area can be eroded away. The alternating sequence of erosion and accretion with a-synchronic rates results in an average **net accretion** of these parts of the coastline in the order of approximately 6-10 m per year over longer timescales (Augustinus 2004 and pers. comm.). In future, this will probably be less as a consequence of sea level rise (Gilman et al., 2008).

When the mangrove vegetation is removed or significantly degraded, the natural dynamics of erosion and accretion is disturbed. The degradation and loss of mangroves results in increased erosion rates during the erosion phase. The degradation and loss of mangroves also results in reduced accretion rates during the accretion phase. These changes in erosion and accretion patterns result in a **net erosion** of these (non-vegetated) parts of the coastline over longer time scales. For the area of Coronie (Ingikondre – Burnside), this was calculated to be in the order of 34 m per year for the period 1914-2007 (Augustinus 2004a and pers. comm.). Another example of an area with such increased erosion along the coast of Suriname can be found at Weg-naar-Zee. The erosion problems along the Suriname coast (accelerated as a result of anthropogenic disturbances) may further increase as a result of predicted sea level rise due to climate change.

At some places along the Suriname coast, coastal defence structures have been built (or are under construction). These range from small-scale ad hoc constructions (waste material, car wrecks, tires etc., such as at Weg naar Zee) to engineered dikes, such as at the Corantijn river mouth and Coronie. At Coronie, previous coastal defence structures have failed to contain the erosion. Currently, a large new sea dike is being constructed here to protect the hinterland (agricultural land and properties). This new sea dike will have a total length of 11.5 km and a width of approximately 100 m (see aerial impression and cross section below).

Aerial view of the sea dike under construction at Coronie



Cross section of the Sea Dike at Coronie

The construction of this € 45 million sea dike started in May 2008 and will take an estimated 6.5 years to completion. The dike will be +5.5m to +5.8m above NSP (equivalent to approx. +3m above mean sea level), and will be covered with armoured rock on the seaside. Various measures have been proposed to minimize the environmental and socio-economic impacts of the dike, including suggestions for its routing (Augustinus 2004a, Teunissen, 2004b).

Experiences with hard coastal defence structures in the neighbouring Republic of Guyana are very discouraging. Such dikes are not only very expensive to maintain (as a result of which maintenance is often neglected), but they also tend to worsen the erosion problems along mud coasts when built in the mangroves close to the waterline, as they hamper the infill of fines from the sea (tidal filling) (Winterwerp et al., 2005; Winterwerp, 2009). At Coronie, this impact comes on top of a significant area of intact mangroves (in the order of 170 ha) that was cleared in order to make way for the construction of the sea dike at this area.

2.2.3 Hydrological disturbance

The discharge of freshwater into the brackish and saline zone along the Ocean is considered essential for the healthy functioning of the mangroves and other coastal wetlands (Clark, 1983, 1992). In coastal freshwater swamps, a number of hydrological barriers has been constructed which prevent the flow of freshwater towards the mangrove zone. In some cases, impounded polders for agriculture (Nickerie, Coronie) and impounded oil fields (Saramacca) have been constructed into areas that used to drain freshwater towards the mangrove zone. Between Coronie and Wageningen, the east-west connection road was constructed right through a freshwater swamp. The road prevented water from the freshwater swamp to flow towards the ocean, resulting in salt water intrusion from the ocean up to the road, causing die-off of large areas of freshwater swamp habitat and blocking the flow of freshwater towards the mangroves. In later years, some culverts have been placed under the road to allow for improved drainage of swamp water during periods of heavy rainfall. In Coronie, an east-west swamp water retaining dam (locally known as “zwampkerende dam”) was constructed to create a reservoir of irrigation water for downstream rice fields. The effects of these hydrological impediments on the functioning and vitality of the coastal mangrove forests in Suriname are currently poorly understood. This urgently requires further study. It is nevertheless possible to draw some general conclusions based on mangrove literature from elsewhere in the world, where this has been studied exhaustively.

Turner & Lewis (1997) reviewed an overwhelming body of scientific literature (including many examples from the Caribbean and tropical USA) describing and documenting the indirect relationship (mostly detrimental to coastal wetland areas) between habitat changes and hydrology. The changes may be somewhat unpredictable in time and space, but it is an undisputable observation that they occur. There are many examples of how rigorously engineered solutions to flooding or transportation problems (e.g. dikes and roads) may result in unintended (sometimes catastrophic) consequences to the natural system. Hydrological alterations or modifications as a result of the construction of levees, dikes, ditches, impoundments, roads, or due to the blocking of (historic) tidal channels, reduced drainage, reduced freshwater fluxes or reduced tidal velocities are known to have resulted in widespread wetland loss, vegetation changes and mangrove die-back in many parts of the world. While massive mangrove die-back due to hydrological changes is sometimes caused by natural events (see for example Erftemeijer and Hamerlynck, 2005), they are most often the result of anthropogenic interference with the natural hydrology.

Reduced vitality and localized mortality of mangroves due to hydrological alterations and barriers will inevitably compromise the important ecological and economic functions of this valuable ecosystem along the coastline of Suriname, especially its critical role in coastal protection.

2.2.4 Other problems

Other existing or potential problems in relation to the management of mangrove forests of Suriname include:

- Oil exploration activities:

Since 1980, Staatsolie developed oil production fields in the coastal area of the Saramacca District (Tambaredjo and Calcutta oil fields). Environmental Impact Assessments have been carried out and environmental management programmes are in place and under implementation. Staatsolie is planning and/or carrying out a series of exploratory drillings and seismic explorations in five prospective areas in the Young Coastal Plain of Suriname (Nickerie, Coronie, Coesewijne, Weg naar Zee area, and Commewijne). The potential impacts of these activities were assessed and evaluated in a series of preliminary environmental assessments (PEIA's) by Noordam & Teunissen (2007-2008). The drilling explorations involve a Caterpillar-mounted drilling rig, a series of mounted pontoons, drilling equipment, a mud treatment system, generators and a hovercraft, that move together through the landscape as a "train" at a speed of about 15 km per day, following a pre-selected route. Noordam & Teunissen (2007-2008) concluded that the exploratory drilling activities are not likely to result in any major significant negative impacts on the environment and also suggested a number of mitigating measures. The impacts on the mangrove vegetation are expected to be localized, small-scale and the mangrove vegetation is expected to recover from the disturbance.

- Dredging (Suriname River)

There are plans for deepening the lower stretches of the Suriname River to allow larger cargo vessels and cruisers to enter Paramaribo and its port facilities. Although implementation of these plans is yet uncertain due to the current (global) economic circumstances, dredging can have significant adverse impacts on mangroves, such a smothering of aerial roots, localized die-off and altered hydrological conditions (including potential effects on tidal amplitude and thus on inundation frequency and duration), with localized adverse effects on mangrove health and survival.

- Lack of awareness

While the ministerial decree for land allocation in the state-owned parts of the estuarine zone ("Richtlijnen voor Gronduitgifte in de Estuariene Zone", 2005) provides a framework for the protection of mangroves in the established MUMA's, a good legislative framework is lacking for the northern parts of Paramaribo and Wanica where all lands are already allocated and different ministries and departments are taking conflictive decisions. There is a general lack of awareness and understanding on the important values and functions of mangroves and of the services they provide to the people and economy of Suriname, especially their role in protecting Paramaribo from flooding and erosion. There is also a lack of awareness with regard to the negative experiences with hard coastal defence structures in neighbouring Guyana. This overall lack of awareness is true for the general public, but especially among decision-makers and politicians, who are in the strongest position to make a difference with regard to their protection and effective management.

- Limited management capacity protected areas / MUMA's

While two-thirds of Suriname's mangroves and other coastal wetlands are protected or are managed for wise use, and various good environmental laws and regulations are in place, this does not necessarily mean that the enforcement and implementation of management plans (incl. of the MUMA's) is efficient and effective. Reorganizations within the ministries of Natural Resources (NH) and Spatial Planning, Land and Forest Management (RGB), changing policies, differing opinions with regard to interpretation of existing policies and legislation, changing priorities in budget allocations, delays in decision-taking, limited institutional capacity especially with regard to local staff on the ground, lack of human & physical resources and financial constraints at the field level, all hamper effective implementation of mangrove conservation and management in Suriname today, especially in the area north of Paramaribo and Wanica.

2.3 Analysis of problems & prioritization

Destruction of mangrove habitat and coastal erosion (which is related to the state of the mangroves) were rated among the top priority problems in most of Suriname's 7 coastal districts in the Multi-Criteria Analysis (MCA). To put the various problems with regard to mangrove management, as identified above, into perspective (analysed by priority, time scale and district), we have arranged them as follows:

Urgent, high priority problems that require immediate action:

- Expansion of urban areas into mangroves north of Paramaribo
- Coastal erosion at Weg naar Zee and Coronie
- Lack of awareness on importance of mangroves

Intermediate priority problems that require a response at the medium-term (1 - 5 years):

- Limited management capacity (nature reserves & MUMA's)
- Coastal erosion in other districts (maintenance of coastal defense structures)
- Hydrological disturbances that reduce vitality of mangroves: rice polders at right bank of Nickerie River, northern SML rice polders, road Wageningen-Burnside, Coronie seaside plantations, Saramacca (northern oil polders), Parbo-Wanica (urbanization and agriculture), Commewijne (aquaculture and cattle farms)

Future threats & issues that require a response in the long-term (5 - 50 years):

- Erosion problems in relation to predicted climate change (sea level rise, increased storm frequencies), incl. adaptation measures (all coastal districts)
- Future urbanization (incl. roads, infrastructure & industries) (esp. Parbo-Wanica)

Low priority problems that require *ad hoc* solutions & mitigating measures:

- Continued oil exploration activities in the mangrove belt
- Dredging

3. IDENTIFICATION OF SOLUTIONS

In response to the various problems and issues related to the management of mangrove forests in Suriname, we have identified a series of potential solutions. These are not presented as ultimate solutions, but as a set of ideas intended to inspire the discussion and as recommendations to responsible ministries and departments for further follow-up action. For each of these potential solutions, we have indicated how they relate to existing policies of the Government of Suriname and international (environmental) treaties, bearing in mind future scenarios of climate change and ongoing urbanization of the region around Paramaribo. Cost aspects, as well as social- and environmental implications are also briefly addressed for each of the proposed solutions.

3.1 Spatial planning (set-back line)

Of significance for coastal defence is the possibility to reduce the risk of coastal erosion, flooding and its consequences in coastal lowlands through spatial planning. By managing the spatial distribution of people and human activities in the coastal regions, and taking potential consequences of climate change into consideration, this risk may be substantially reduced (CPSL, 2005).

Against this background, we propose the following:

- To establish a **set-back line** (equivalent to concepts such as "rode lijn"; "urbanisatie-grens"; "verkavelingsgrens") to delineate coastal buffer zones. The purpose of the set-back line would be to prevent (further) urban expansion and agricultural development or any other development or activity in a coastal strip of mangroves ("greenbelt") that would compromise the integrity and health of the mangroves considered critical to buffer/mitigate natural coastal erosion processes. In this buffer zone, space can also be reserved for future coastal defence measures or retreat of the coastal defence line. The width of the coastal buffer zone may vary between sub-regions of the Suriname coast, depending on local conditions, such as presence/absence of mangrove, presence/absence of build-up (residential) areas and other economic investments. For some coastal areas (e.g. Paramaribo North), the buffer zone may need to have minimum width of about 3 – 4 km, similar to what was proposed by the Ministry of Public Works in the Terms of Reference for the Study and Design of a Ring-dike, Drainage Channel and a Ring-road in North Paramaribo, which mentions the "determination of the alignment leaving a green belt of about 2.5-4 km along the coast" (Ministry of Public Works, 2005). Moreover, this is in line with the results of the Master Plan Study Urban Drainage Greater Paramaribo (2002) and many other recent reports clearly suggesting to keep a sufficient buffer zone (of at least several km's) between a dyke and the coast to assure the continuation of the mangrove ecosystem which is important for the natural coastal protection and the ecology and hydrological environment (NCAP, 2007). For all MUMA's where appropriate, a red-line has already been established, along with clear regulations for wise use. Set-back lines are absent along the remaining parts of the Suriname coast, in particular for the Paramaribo region, where no MUMA could be established as all lands are already allocated. It is crucial that the existence and demarcation of set-back lines is given legal status. Relocation of already established property and/or land ownership &

use within this coastal buffer zone to areas outside this zone should receive appropriate attention, based on the results and recommendations of the Country Study Team Climate Change (STCC) and Netherlands Climate Assistance Programme (NCAP2) studies. It is questionable whether a ring-dike (very) near the present coastline at Paramaribo-North will protect the coast on the long term and will enable the survival of the mangrove forest which is essential to dampen waves from the ocean and to catch and accummulate/build up the sediments from the ocean in case of sea level rise.

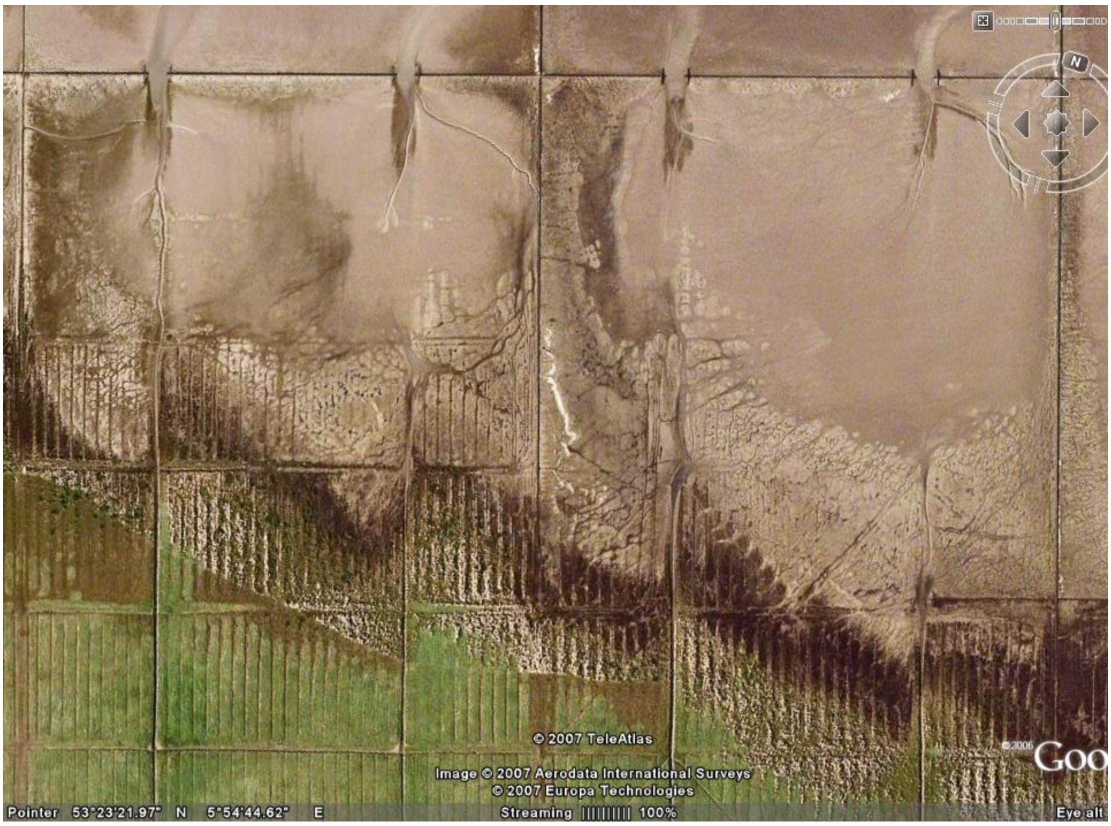
- To identify **coastal flood hazard zones** (taking into account future sea level rise predictions). Coastal flood hazard zones are areas potentially endangered by coastal erosion and flooding. If no natural or man-made coastal defence structures existed, these coastal low-lands would probably become inundated, given current erosion processes and future sea level rise predictions. The demarcation of such zones should also take the potential increase in storm frequency and intensity into consideration. The width of these flood hazard zones may differ between sub-regions of the Suriname coast, depending on local conditions, locally prevailing accretion/erosion rates and socio-economic considerations). The purpose of these zones is to manage human activities (incl. road construction, development of residential & industrial areas, etc.) in such a way, that their vulnerability is reduced through specific requirements, restrictions or recommendations for spatial utilization to reduce the consequences (damages) of flooding & erosion. Also for this hazard zone, relocation of already established property and/or land ownership & use within this zone to safer areas outside this zone should receive appropriate attention.

- To **stop urban expansion** into the mangroves and swamps north of Paramaribo immediately, and to discourage any further plans for the expansion of urban or industrial developments into this region, until a proper set-back line and coastal hazard zone & plan for this region has been agreed and established. This should include appropriate attention for the option to relocate established property and/or land ownership & use to (safer) areas outside the buffer and hazard zones, given the potentially disastrous consequences of anticipated scenarios of sea level rise for people and property in wider Paramaribo.

3.2 Enhance sediment accretion ("salt marsh works")

In critical coastal areas facing net erosion because the mangroves have been destroyed (esp. Coronie and Weg naar Zee), settling of fine sediments (normally efficient in the presence of mangrove vegetation) should be artificially facilitated during periods that mudbanks are passing in front of these areas (also recommended in the report by Winterwerp, 2009). This can be done through the placement of permeable (soft structure) groins perpendicular to the coast, a technique comparable to the so-called "salt marsh works" in the Netherlands (see pictures below). Traditional salt marsh management techniques using permeable groins have been successfully implemented by the Dutch since the beginning of the 20th century. Salt marsh groins in the Netherlands are permeable fences made of brushwood, wedged between parallel rows of wooden poles reaching about 0.3 m above mean high water.

Close-up impression of the “salt marsh works” along the coast of Groningen, The Netherlands



Aerial view (satellite imagery) of the “salt marsh works” along the coast of Groningen, The Netherlands

Salt marsh groins function in that they reduce wave energy (turbulence) and significantly diminish (tidal) current velocities. As a result, an artificial low-energy environment is created in the groin fields where the sedimentation of suspended material is enhanced, and erosion of accumulated sediment is hindered. This facilitates faster accretion of the coast and – as a result – enhanced natural (re-)colonization of mangroves (parwa), recruited through seed dispersal and subsequent establishment of seedlings. Over a matter of several years (or even a decade), this measure will ultimately result in the re-establishment of a buffer of mangrove forest that will mitigate erosion rates during periods that there are no mudbanks in front of these areas. This measure presents a sustainable solution for coastal defence with minimal impacts on the natural system while contributing towards securing the required level of protection and safety.

3.3 Mud nourishment (agitation dredging)

In critical coastal areas facing net erosion because the mangroves have been destroyed (esp. Coronie & Weg naar Zee) the flux of fine sediment towards the coast should be enhanced by artificially increasing the sediment concentration of the coastward transport during periods that there is no mudbank passing in front of these areas (also recommended in the report by Winterwerp, 2009). This may be done by engineering works, mobilizing sediments from the seabed by agitation dredging (mud nourishment). As explained by Winterwerp (2009), these mud nourishment works are not likely to work under conditions of severe erosion, so they should be carried out at the tail of the (passing) mudbank, when erosion would normally start again. We realise that such mud nourishment works have never been carried out before and may be costly (approx. 1€ per m^3), but we strongly recommend that the feasibility of such an option is investigated, possibly in consultation and collaboration with dredging companies. Such an intervention could prove to provide a long-lasting, cost-effective and sustainable solution (especially if accompanied by mangrove restoration) at areas facing serious erosion problems and may be substantially cheaper than the construction of coastal defence structures (such as the sea-dike currently under construction at Coronie).

3.4 Restore hydrological connections (freshwater flows into mangroves)

In the medium-term, it will be important to consider the restoration of vital hydrological connections to enable freshwater flows into the mangrove areas, by perforating specific hydrological barriers, such as the “zwamp-kerende dammen” south of the Coronie rice polders. From these dams, LAHMEYER et al. (1993) recommended to construct separate irrigation and drainage canals (running parallel to the existing irrigation and drainage canals which serve the rice areas) to irrigate dry-crop agriculture on the ridges. These extra canals can also be used to enable freshwater from the Coronie swamp to flow into the mangrove areas in front of the Coronie seadike (under construction). Also to be considered is the construction of more and larger culverts below the East-West connection road between Jenny and Ingikondre in order to improve drainage of the Coronie Swamp towards the mangrove belt. This should only be done after thorough hydrological investigations in these areas. It is probably wise to first implement a few small-scale pilot studies that monitor the effect of localized improved freshwater supply (e.g. following the installation of a culvert) on local mangrove vitality (see recommendations for research in Chapter 4). At some places, this has already been done to some extent, but further enhancement of the permeability of these dams and dikes should be considered to improve the overall health and functioning of the coastal mangroves, and hence strengthen their role in protecting the shoreline against erosion.

3.5 Capacity strengthening

Capacity strengthening for effective management of MUMA's and nature reserves should receive appropriate attention in the medium-term. This may be achieved through training of field staff, upgrading of local field infrastructure & equipment, and improved (and transparent) allocation of financial resources, as well as proper attention for management planning and evaluation. Sufficient incentives may be required to prevent that newly-trained field staff seek better-paid employment in the private sector.

3.6 Awareness raising (on importance of mangroves)

There is an urgent need to increase the awareness among the decision-makers, politicians, stakeholders, general public, media and schools, on the important ecological functions, values and services of mangrove forests. These include their critical role in shoreline protection (preventing coastal erosion and flooding), their role as nursery ground for fishes and crustaceans (supporting fisheries as one of Surinam's most important export industries), and their importance to migratory shorebirds, waterbirds and other wildlife, as elaborated above in section 2.1.2. There is also a need to enhance awareness with regard to the negative experiences (incl. high maintenance costs) with hard coastal defence structures in Guyana.

3.7 Mangrove rehabilitation

Various studies and reports have recommended the rehabilitation of mangroves along the coast of Suriname in areas where the original mangrove vegetation has been degraded or destroyed. It has come to our attention that there are plans to start mangrove restoration works in Suriname. Since no previous experience with mangrove rehabilitation in Suriname exists, it is essential to study carefully the successes and failures from similar efforts elsewhere in the world, before embarking on an (inevitably expensive) rehabilitation programme of any scale in Suriname.

<u>Successes and failures in mangrove restoration elsewhere in the world</u>

In Bangladesh, 120,000 ha of mangroves have been planted since 1966 (Saenger & Siddiqi, 1993, cited in Field, 1998). Nowhere else have mangroves been planted on such a large scale. In this case the mangroves were planted on newly accreted land. Two species of mangrove, *Sonneratia apetala* and *Avicenna officinalis*, dominate the mangrove plantations, usually as monospecific stands. According to Field, the planting of mangroves has been successful in protecting and stabilizing coastal areas and in providing substantial timber production (Field, 1998).

However, Lewis (2005) states that 'in spite of the success in Bangladesh, most attempts to restore mangroves often fail completely, or fail to achieve the state goals' (Lewis, 2005, page 404). Between 1989 and 1995, 9,050 ha of mangroves were planted in West-Bengal, India, with only a 1.5% success rate (Sanyal, 1998 cited in Lewis, 2005).

In the Philippines, during the past 2 decades, more than 44,000 hectares, mostly non-mangrove mudflats, sandflats and seagrass beds, had been planted with mangroves, using almost exclusively the genus *Rhizophora*. In these non-mangrove areas, seedlings experienced high levels of mortality and, in the few that survived (apparently through stubborn, expensive replanting), had displayed dismally stunted growth relative to the corresponding growth performance of individuals thriving at the high intertidal position and natural mangrove sites (Samson & Rollon 2008). Despite heavy funds for massive rehabilitation of mangroves in the Philippines over the last two decades, the long term survival rates are generally low at 10-20% (Primavera & Esteban 2008).

In Thailand, a massive 5-year mangrove replanting programme was launched by the Thai Government during 1991-1996, targeting to replant 40,000 ha. According to Suwannodom et al. (1998) this programme cannot be evaluated as successful, except in a few cases in Southern Thailand where a community-based management approach was followed (Erftemeijer & Lewis, 2000).

An area of about 580 ha of muddy tidal flat on the seaward side of a sea dyke in Ha Tinh province, Vietnam, was planted with mangroves between 1989 and 1993 sponsored by various NGOs, to achieve a sustainable greenbelt for coastal protection against natural surges and erosion. Survival rates were below 40% (Hong, 1994 cited in (Erftemeijer & Lewis, 2000). Despite restoration efforts in the Xan Thui and Tien Ha coastal reserves in northern Vietnam, mangroves have become fragmented and survival rates for replanting efforts are low (Seto & Fragkias 2007).

Samson and Rollon (2008) indicated a large number of reasons for failure of mangrove restoration projects in the Philippines, including ecological, social/institutional and economic factors. Many of these factors also apply to mangrove restoration initiatives in other countries, in particular poor site selection, lack of baseline assessment of the target areas prior to mangrove rehabilitation, absense of clearly defined goals and lack of a proper monitoring and evaluation system.

Mangrove planting on lower intertidal mudflats is to be discouraged or at least reconsidered (Samson & Rollon 2008). Erftemeijer & Lewis (2000) report: '[…] mangrove afforestation on mudflats is not easy, it is often characterized by high mortality rates caused by factors such as barnacle infestation, smothering or burial from excessive sedimentation, wave action and so forth. […] In areas where sedimentation is substantial and mudflats are accreting, such as in the case of Bangladesh and some localized estuaries, success rates are likely to be higher'.

The single most important factor in designing a successful mangrove restoration project, according to Lewis (2005) is determining the normal hydrology (depth, duration and frequency, and of tidal flooding) of existing natural mangrove plant communities (as a reference site) in the area in which one wishes to do restoration.

Key principles for successful mangrove rehabilitation

In order to have a successful mangrove rehabilitation programme in Suriname, we highly recommend the following basic principles, key considerations and practical suggestions, which are based on lessons learnt from many similar attempts worldwide (Lewis, 2001; Primavera & Esteban, 2008) and personal experience (Erftemeijer & Lewis, 2000; Erftemeijer & Bualuang, 2002; Lewis et al., 2002):

Five critical steps are necessary to achieve successful mangrove restoration:

1. **Understand the autecology** (individual species ecology) of the mangrove species at the site; in particular the patterns of reproduction, propagule distribution, and successful seedling establishment.

2. **Understand the normal hydrologic patterns** that control the distribution and successful establishment and growth of targeted mangrove species.

3. **Assess modifications** of the original mangrove environment that currently prevent natural secondary succession (recovery after damage).

4. **Restore appropriate hydrology** and in this way facilitate and encourage natural recruitment of mangrove propagules for plant establishment.

5. Only utilize actual **planting of propagules**, collected seedlings, or cultivated seedlings after determining (through steps 1-4) that natural recruitment will not provide the quantity of successfully established seedlings, rate of stabilization, or rate of growth of saplings established as objectives for the restoration project.

Propagules of *Avicennia germinans* are widely dispersed along the coast of Suriname

Specifically with regard to the situation in Suriname we therefore recommend the following:

- Mangrove rehabilitation should focus on *Avicennia germinans* (parwa), the dominant species along the coast. Attempts to plant *Rhizophora* spp. (mangro) or *Laguncularia racemosa* (akira) along the coast will result in failure, since these species do not naturally occur along the coast proper (see section 2.1.1 of this report);
- Manual planting of *Avicennia germinans* (parwa) along the coast is probably not necessary anywhere, given the abundant availability and wide dispersal of propagules of this species;
- Instead, the rehabilitation effort should concentrate on creating suitable conditions that facilitate / enhance natural recruitment, i.e. by perforating hydrological barriers (improving tidal flushing and freshwater inflows), removing barriers to recruitment (e.g. in 'dead zones' "*parwa-kerkhoven*", dominated by *Batis maritima*) (see also section 3.4);
- The recommended measures to enhance the sediment flux towards the coast (mud nourishment) and enhance sediment accretion rates ("salt marsh works"), as described above in sections 3.1 and 3.2, are likely to create suitable conditions for natural (re)colonization of mangroves (parwa). It may be worthwhile to compare artificially planted sedimentation groin fields with those colonized naturally.
- We highly recommend that a local mangrove restoration training workshop be organized in collaboration with external mangrove restoration experts (e.g. Dr. Robin Lewis III from Florida (see www.mangroverestoration.com), who organizes such workshops annually).

4. RECOMMENDATIONS FOR MONITORING & RESEARCH

In addition to the potential solutions discussed in the previous chapter, we would like to make a number of recommendations for monitoring and research which we believe will be instrumental to improve the management of the mangrove resources in Suriname:

Monitoring

- Mapping of mangroves and analysis of changes in mangrove cover as a result of erosion & accretion and human impacts through interpretation of aerial photography and satellite imagery (plus ground truthing). This should be done at regular intervals; e.g. every 5-10 years nationwide, and every 3-5 years in problem areas (e.g. Weg naar Zee, Coronie, Nickerie);
- Monitoring of natural recolonization of mangroves (esp. parwa) on newly accreting mudbanks along the coast of Suriname;
- Field monitoring of erosion and accretion rates and comparison with analysis of aerial photographs and remote sensing;
- Field monitoring of key hydrological parameters in the mangroves to better understand their temporal / seasonal dynamics (e.g. salinity, inundation frequency, etc.);

Research

- Autecological research of Suriname's mangrove ecosystem (phenology, production, tolerance for salinity, temperature, inundation, etc.);
- Effects of hydrological changes (barriers) on mangrove vitality & survival;
- Factors affecting natural regeneration (incl. temporal and spatial scale issues);
- Mangrove seed production and dispersal (field counts, modelling studies);
- Factors determining successful germination and establishment of mangrove seedlings;
- Effect of mangrove vegetation on hydrodynamics and sediment transport (attenuation of waves and currents, trapping of sediment);
- Erosion effects on mangroves (factors determining resilience, differences between young and mature forest, sparse and dense forest, *Avicennia*- *Laguncularia* and *Rhizophora* forest);
- The contribution of mangrove debris along the coastline on coastal protection/erosion;
- Trials of hydrological restoration and trial planting (experimental) to increase scientific understanding and local capacity in mangrove restoration technology;
- Studies of mangrove restoration areas to monitor how the functional attributes that are generally associated with mangrove forests (ecological functions, shoreline protection, values to society etc.) return over time in the areas that have been restored;
- Use of different coastal areas by migratory shorebirds (mudflats) and waterbirds (breeding) in relation to the health status of mangroves;
- Detailed studies to predict potential scenarios of sea level rise in Suriname and monitoring of actual water levels to validate these predictions;
- Analysis of the (socio)economic value of mangroves in Suriname.

5. RECOMMENDATIONS FROM STAKEHOLDER WORKSHOPS

As integral part of the overall ICZM project for Suriname, three local stakeholder workshops were held in Nickerie and Paramaribo during August 2009. During these workshops, various group discussions were held to discuss the causes and suggest potential solutions for some of the most urgent ICZM problems (deemed of highest priority). Two of such group discussions centered around subjects directly related to mangroves, the outcome of which is summarised below:

Group discussion 1

<u>Problem:</u>
Coastal and riverbank erosion due to destruction of mangroves (coastal zone Suriname)

<u>Causes:</u>

- Unregulated land allocation for housing & construction
- Lack of a clear land policy
- Absence of a (spatial) development plan / zoning scheme
- Inadequate enforcement of laws and regulations (non-compliance)
- Climate change (increased impact from wind & wave energy)
- Shipping & ship wakes (impact on riverbank)
- Extraction of mangrove wood for smoking of fish and riverbank revetment
- Land reclamation in inner curve of river -> erosion in outer curve
- Sand mining in the river
- Infrastructural works too close to the sea (e.g. east-west road connection)

<u>Solutions:</u>

- Good spatial planning for developments along the coast and riverbanks
- Establish strip of mangrove as protection forest ("schermbos"; *sensu* Boswet)
- Implement the management plans for the MUMA's
- Awareness programmes (also for project developers & estate brokers ('verkavelaars))
- Adaptations and enforcement of laws and regulations (incl. penalties)
- Environmental impact assessments for land allocations
- Mangrove rehabilitation
- Implement Climate Action Plan for the coast
- Investigate potential alternatives for mangrove extraction & use
- Speed restrictions for shipping (river) and adaptations to shipping lane
- Protection measures to prevent riverbank erosion
- Regulate sand mining activities (river)
- More & bigger culverts (or bridges) and maintain existing ones (water exchange)
- Political commitment and involvement in daily activities and challenges

Group discussion 2

Problem:
Flooding risk due to destruction of mangroves (Paramaribo-North)

Causes:
- Land allocation projects (initially for ‘agriculture’)
- Lack of spatial planning
- Inadequate awareness with regard to the importance of mangroves
- Shell- and sand mining (‘ritsen’)
- Absence of protection status for mangrove forests
- Dredging of Suriname River (proposed)

Solutions:
- Development plan / zoning scheme, incl. set-back line (‘verkavelingsgrens’)
- Awareness campaigns (importance mangroves + increased flooding risk due to loss of mangroves)
- Mangrove rehabilitation (parwa)
- Expropriation and compensation
- Establish mangroves + swamps north of Paramaribo as (special) protection forest / MUMA / special management area
- Logging ban for mangrove tree species (permit system)
- Stop sand & shell extraction of ritsen
- No further land allocations (north of Paramaribo)
- Stimulate expansion of Paramaribo city to the south (away from Paramaribo-North)
- Implement Climate Action Plan
- Study hydraulic functioning of Suriname River in relation to erosion
- Re-route proposed ringdike along or outside the recommended set-back line

Note: The opinions and proposed solutions described above are those expressed by the stakeholder workshops’ participants and do not necessarily represent the view of the authors of this report or of the organizations that are represented in the ICZM project team

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