©Conservation International Photo by Remesa Lang

NORTH BRAZIL SHELF MANGROVE PROJECT

STATE OF MANGROVES IN SURINAME: A SUMMARY

OVERVIEW OF EXISTING STUDIES

IUCN

CONSERVATION INTERNATIONAL

gef

This document was prepared for Conservation International Suriname as part of the Setting the foundations for zero net loss of the mangroves that underpin human wellbeing in the North Brazil Shelf – Large Marine Ecosystem Project, funded by the Global Environment Facility.

Author: Kayleigh Tjitrodipo – Research Assistant
Contributor: Eunike Alexander – Misiekaba – Technical Manager

TABLE OF CONTENTS

CHAPTER 1

BACKGROUND

The Project *Setting the foundations for zero net loss of the mangroves that underpin human wellbeing in the North Brazil Shelf LME* aims to establish a multi-sectoral consensus and knowledge foundation for the development of an Integrated Coastal Management (ICM) Plan for Mangroves, and to create the multi-disciplinary information base, regional coordination mechanism and multi-sectoral consensus required to implement elements of the CLME+ Strategic Action Plan pertaining to the mangroves that most directly underpin human wellbeing in the North Brazil Shelf LME. To accomplish this, the project will be filling critical knowledge gabs pertaining to mangroves and coastal management.

This report is one of the first outputs of the project, which gives a summary overview on the state of mangroves in Suriname.

INTRODUCTION

Mangroves in Suriname cover an estimated 100.000 ha, which is about 1.6-2% of the world's mangroves (Anthony, 2015).[1] The coast of Suriname has been formed by large-scale mud sedimentation by the Amazon River in Brazil, transported westward through the Orinoco along the coast under the influence of waves and currents.[2] Mangroves are important for the coast of Suriname, because they stabilize the inner mudbank and ensure plant continuity with the older mud shorelines. Progradation takes place, which results in the enlargement of the Young Coastal plain. This active geological role is very important for the coastal zone management initiative in Suriname. Suriname second in terms of the percent of their total population living in the Low-Elevation coastal zones (Dasgupta et al, 2007).

Several major ecological functions and services mangroves in Suriname provide are protection of the shoreline from erosion, provision of spawning zones and nurseries for coastal fisheries, habitat for birds and other wildlife (Anthony, 2015). Mangroves also function as carbon sinks that reduce greenhouse gas emissions, an important consideration in a time of climate change.[3] Not only do they act as filters of pollutants reaching estuarine and coastal waters, they protect coasts exposed to high- energy events such as cyclones and tsunami.[4]

[1] Edward J. Anthony (2015). Assessment of peri-urban coastal protection options in Paramaribo- Wanica, Suriname.
[2] Augustinus, P. G. (2004). The influence of the trade winds on the coastal development of the Guianas at various scale levels: a synthesis. *Marine Geology*, *208*(2-4), 145-151.
[3] Van Lavieren, H., Spalding, M., Alongi, D., Kainuma, M., Clüsener-Godt, M., & Adeel, Z. (2012). Securing the Future of Mangroves, A Policy Brief. *UNU-INWEH, UNESCO-MAB with ISME, ITTO, FAO, UNEP-WCMC and TNC*, 1-53.
[4] Spalding M, McIvor A, Tonneijck FH, Tol S and van Eijk P (2014) Mangroves for coastal defence. Guidelines for coastal managers & policy makers. Published by Wetlands International and The Nature Conservancy. 42 p.

The coastal fringe of mangroves in Suriname is dominated by Black Mangrove (*Avicennia germinans*), sometimes backed by *Rhizophora spp.* Natural mangrove stands in Suriname are typically dense and mature.[5]

Many people living near or within mangroves, have based their livelihoods on these critical ecosystems for thousands of years. Unfortunately, the long-term benefits that mangroves provide, have been overlooked, which have resulted in rapid degradation or significant loss of mangroves cover. The unique roles of mangroves, allow them to be considered under a range of global policy agendas, where coordination must be ensured.

MANGROVE LOSS

The global rate of loss of mangrove areas has been declining over the past two decades; although it remains 3-5 times faster than the overall rate of deforestation, there is considerable variation in the rate of decline among countries (FAO, 2007).[6]

Continued loss of mangrove forests will have serious ecological and socio-economic impacts.[7] These impacts will not only affect dependent communities, but also increase the vulnerability of coastal lands to natural hazards, which in turn will reduce the productivity of fisheries.

Awareness of the importance of the coastal ecosystems is growing, but here is limited expertise in the ecosystem goods and services that mangroves provide and there is a lack of harmonization and implementation of existing laws to protect mangroves in South America.[1]

Possible threats on mangrove forests in South America include:

- Increasing urban and industrial pollution
- Flow of pesticides and micropollutants to coastal zones
- Urban expansion and infrastructure development
- Oil spills
- Planning and construction of dams/dykes or changes in flow regimes and sediment dynamics upstream
- land conversion to agri – and or aquaculture.

The management of mangrove resources in Suriname is facing a number of major problems, such as habitat destruction and conversion, coastal erosion, and sea level rise, hydrological disturbances and various other threats and challenges (Erftemeijer & Teunissen, 2009). Possible effects due to mangrove forest loss and degradation are:

- Reduction of the protective function of the mangrove forest
- The regeneration of potential desired species is reduced
- Damage of wildlife habitat

[5] Erftemeijer, P., & Teunissen, P. (2009). ICZM plan Suriname-mangrove report. *Analysis of problems and solutions for the management of mangrove forests along Suriname's 'wild coast'. Lievense–Deltares report, 35*.
[6] FAO, U. (2007). The world's mangroves 1980–2005. *FAO Forestry Paper*.
[7] Makowski, C., & Finkl, C. W. (Eds.). (2018). Threats to Mangrove Forests: Hazards, Vulnerability, and Management (Vol. 25). Springer.

- The characteristic environment (brackish) is affected
- Overharvesting of resources

Challenges that require immediate intervention, include: 1) expansion of urban areas into mangrove north of Paramaribo; 2) several coastal erosions at Weg naar Zee and Coronie; 3) and the lack of awareness of importance of mangroves.

North of Paramaribo is undergoing mangrove loss at a large scale, because of increasing urbanization. This removal also goes with an increasing call for artificial coastal protection systems such as dykes.

Mangroves management in Suriname is subject to complicated institutional arrangements, has never been of high priority and has not yet fully attracted regular resources either from government or donors. Therefore, it is very important to continue public awareness and to increase the level of community involvement in rehabilitation, protection and monitoring.

In Chapter 2, several cases with regarding to mangrove management problems in Suriname will be explained.

CHAPTER 2 CASE STUDIES

This chapter presents summaries of key case studies and reports regarding mangroves in Suriname.

2.1 ASSESSMENT OF PERI-URBAN COASTAL PROTECTION OPTIONS IN PARAMARIBO, WANICA, SURINAME- EDWARD ANTHONY, 2015

- **Goal and objectives**
  - To inform Surinamese Government and Public on topic and necessity for conservation of the mangrove forests.
  - To give an overview of the coastal system of Suriname; the importance of mangroves for coastal protection; impacts of mangrove removal and costs of coastal protection.
- **Method**:
  - This assessment was based on comprehensive facts, evaluations, and presentations drawn from: personal expertise (2 decades of research on dynamics of the Amazon-Orinoco coast), consultation with relevant agencies, interest group and individuals and field visits to Weg naar Zee and the coast of Coronie.
- **Notes**:
  - The Suriname coast is a 350 km long coast, formed by Young and Old coastal plains. The plains grow via mud from the Amazon, transported westward towards the Orinoco.
  - The inner part of mud banks form new land (progradation) and are welded to coast by mangroves.
  - Most of the population of Suriname, including Paramaribo, are on this coastal plain.
  - The mangroves in Suriname cover 100.000 ha, which is 1.6-2% of the world's mangroves cover.
  - The mudbank migration time from the Cabo Cossipore area to the mouths of the Orinoco varies from 250-900 years, i.e. about 50-250 years along the coast of Suriname. This is important for the understanding of the problems of coastal protection faced by Paramaribo- Wanica.
- **Conclusion**
  - Greater citizen awareness, lead by Mangrove Forum of Suriname (MAFOSUR) is essential, as there is an acute need for data on which to base coastal zone management decisions on this highly dynamic coast.
  - Mangrove conservation will necessitate the implementation and enforcement of setback lines to reduce urbanization.
  - As a solution for coastal protection, artificial systems such as a dyke is not recommended, because of the sea level rise scenario and maintenance of the dykes. Where dykes are emplaced and the foreshore eroded is only feasible at great cost.
  - A dyke may be necessary to provide protection from flooding along the banks of the Suriname River but probably not along the Weg naar Zee shoreline where the mangrove band is still sufficiently wide to buffer marine inundation inland.

- In Suriname, before choosing the dyke option, some possible issues need to be taken into consideration:
  - The causes of shoreline erosion, which depend on the overarching influence of bank and interbank dynamics that are complex in time and space.
  - A cost-benefit analysis that also should consider the viability of the dyke option (including long-term maintenance and Sea Level Rise scenarios).
  - Dykes have an impact on the shoreline environment, especially on the mangrove forests. They may act as barriers that impede mangrove propagule exchange between mature forests behind the dyke and a new mud bank that is waiting to be colonized. They may also impede freshwater supply from inland to pioneer and young mangroves.

2.2 Valuation of Coastal Protection near Paramaribo, Suriname by Lauretta Burke and Helen Ding, February 2016

- **Goal and objectives:**
  - To make a cost benefit analysis of shoreline protection services by mangroves in Suriname.
- **Method**:
  - The analysis approach used involves two stages:
    1. Spatial analysis and quantification of the shoreline protection and flood reduction effect in both physical and economic terms for a year.
    2. To evaluate and compare which shoreline protection scenario results in higher net benefits through a benefit-cost analysis (BCA). The BCA framework is implemented for a 25-year time period.
- **Notes**:
  - Investments in protection and enhancement of mangroves in the Western Zone (Weg naar Zee) and Middle Zone (near the mouth of the Suriname river) make economic sense, while investing in river dyke construction in the Eastern Zone is likely to be the more sensible option for protecting low-lying areas from flooding from the river.
  - Using the Coastal Capital method:
    - Western Zone: mangrove regeneration appears to be more cost-effective solution as it generates a higher net-present value of US$ 290 million for a period of 25 years. (The dyke would cost US$ 104 million)
    - Middle Zone: because of the currently healthy and expanding naturally mangroves, building a dyke would be unnecessary and it would cost US$ 154 million more than an earthen dyke/ mangroves.
    - Eastern Zone: the only option considered to protect the area flooding from the river-side was the construction of a sea wall (river dyke). The costs for this shoreline protection is assessed to be around US$1.2 billion.
    - Different coastal defense options need to be taken into consideration. Such as, hybrid solutions, which provide shoreline protection with increased stability and endurance (in comparison to a dyke construction).

- **Conclusion:**

- In the Western and Middle Zone it would be economically feasible to invest in protection and enhancement of mangrove, while investing in river dyke construction in the Eastern Zone may be the more sensible option for protecting low-lying areas from flooding from the river.
- The total economic benefits of the mangrove protection scenarios are likely to be much higher in reality if the value of other ecosystem goods and services provided by mangroves were included.

2.3 ICZM Plan Suriname – Mangrove Report by Paul Erftemeijer and Pieter Teunissen, September 2009

- **Goal**:
  - To highlight the results of an analysis of problems and potential solutions with regard to mangrove forests management along the coast of Suriname.
- **Method:**
  - This study was based on literature review, a site visit to Suriname, discussion and interviews with experts and resource persons.
  - Also 3 stakeholders' workshops were given in Suriname.
- **Notes:**
  - Two-thirds of Suriname's mangroves are protected or managed for wise use. But Suriname is still threatened by habitat destruction, coastal erosion and sea level rise.
  - Urgent high priority problems that require immediate action are:
    - 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.
  - 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)
  - The limited management capacity (protected areas & MUMA's), coastal erosion in other districts and hydrological disturbances of mangroves are problems that do not need to be forgotten.
- **Conclusion:**
  - Spatial planning: to establish a set-back line of 3-4 km from the coast to delineate a coastal buffer zone. This would be important to prevent further urban expansion and agricultural development, and would help to maintain healthy mangrove forests.
  - Enhance sediment accretion: To artificially facilitate the settling of fine sediments in critical coastal areas where mangrove vegetation has been destroyed, resulting in net coastal erosion. This can be done with Salt Marsh Works, by placing permeable groins that will reduce turbulence and diminish current velocities.

- Mud nourishment: To artificially increase the flux of fine sediments towards the coast during periods that there is no mudbank passing in front of them. This can be achieved through agitation dredging (mud nourishment).
- Restore hydrological connectivity: Restoring fresh water flows into mangroves
- Capacity strengthening: training of field staff, infrastructural upgrading, improved allocation of resources is needed for an effective coastal management.
- Awareness raising of importance of mangroves on the ecological functions, values and services. Especially in shoreline protection and sustaining coastal fisheries.
- Mangrove rehabilitation: it is important to study success and failure in other countries – individual species ecology, assess modifications to original habitat, restore appropriate hydrology, only use actual planting of seedlings to achieve successful mangrove restoration.

2.4 Mangroves, Mudbanks and Seawalls: Political Ecology of Adaptation to Sea Level Rise in Suriname, by Ravic P. Nijbroek, 2012

- **Goal:**
  - This study seeks to understand how global discourses of sea level rise (SLR) and mangrove ecology influence national climate change adaptation policy to reduce coastal vulnerability in Suriname.

- **Method:**
  - A comparative discussion of local knowledge while drawing on scientific methods of data analysis at large scales have been performed in order to answer the research question.
- **Notes:**
  - **The Suriname coast is predominantly shaped by mudbanks and mangroves which together provide protection against coastal erosion and trap sediments resulting in coastal accretion.**
  - Knowledge claims of mangrove ecology and utility in SLR adaptation are contested between scientists, policy makers and community activist groups. Scientific understandings of coastal processes, specifically the relationship between mangroves and mudbanks and resulting erosion, remain inconclusive.
  - Local knowledge has offered alternative explanations for this relationship, but it also has limitations, particularly for large-scale ecological processes.
  - This study argues that global discourses of SLR and mangrove ecology need to be countered for sustainable adaptation to SLR. Equitable adaptation should include local knowledge and understanding of coastal processes while also drawing on scientific methods of data analysis at large scales
- **Conclusion:**
  - This research project assessed **how climate change adaptation to sea level rise(SLR) in Suriname is influenced by discourses of mangroves and SLR, development histories and politics, and existing coastal management practices.**

The need for adaptation is based on Suriname's high exposure and sensitivity to SLR, particularly in the coastal zone where 75% of the urban and rural population lives on land that is 1 to 2 meters above sea level. The two study sites, Weg Naar Zee and Totness in the districts of Wanica and Coronie respectively, have been experiencing erosion which is believed to be at least partly due to ongoing SLR.

- **Globally, discourses of mangrove function should be treated with caution when they are scaled down to local conditions. These discourses claim almost universal protection against coastal erosion and often include images of mangrove species with stilt roots.** Such discourses are repeated locally during mangrove awareness campaigns that usually feature images of red mangroves (mangro) which have stilt roots, but do not occur in significant numbers along the Suriname coast.

- While mangroves are known to provide protection from storm surges and limit coastal erosion (Alongi 2008), they behave quite differently in Suriname. The presence of mudbanks is essential for the growth of mangroves along the Suriname coast. This is because mudbanks provide protection from wave energy so that seedlings can get established and mature trees are not uprooted. Mudbanks also provide large quantities of sediment which are trapped by the mangrove root systems and allow the coast to grow outward and upward. Where mudbanks are not present, the coast usually erodes at a surprisingly fast rate.
- **Scientific explanations of the impact of SLR in Suriname remain inconclusive.** Will mangroves protect the coast from erosion or will they diminish as the sea level rises?
    - McLeod and Salm (2006) have indicated that mangroves will migrate landward with rising sea levels where conditions permit. Parkinson et. al. (1994) analyzed the impacts of SLR on parwa systems in the Caribbean during the early Holocene when SLR was faster than the current predictions for the next century. They found that mangroves would not migrate landward as long as the supply of sediments remains uninterrupted. Evidence shows that both processes, landward migration and sediment accumulation, have taken place in the Caribbean (Alongi 2008) **but it is not clear how parwa trees in Suriname in particular behaved or will behave in the future**. We can assume with high certainty that the supply of sediments will not become a limiting factor in the near future. The Amazon produces several million tons per day (Allison et. al. 2000) of which less than 10% is stored in migrating mudbanks (Augustinus 2004).

- Climate change adaptation is the root cause of sea level rise and mangrove destruction.
- The coastal adaptation costs in Suriname can become quite significant with no end in sight: capital losses are mitigated by the construction of dykes, raising of existing dykes, and investing in maintenance equipment.
- Global annual economic value of mangrove services is $200,000 - $900,000 per hectare

2.5 Mangroves, Mudbanks and seawalls: Whose environmental knowledge counts when adapting to sea level rise in Suriname? Ravic P. Nijbroek, 2014

- **Goal**:
  - To explore global and national discourses on climate change vulnerability, in order to understand how national and local climate change adaptation policies are informed by the scientific knowledge.
  - To explore the perceived risks identified by local actors who develop adaptation strategies based on knowledge gathered over multiple generations and retained through storytelling and other social patterns.
- **Method:**
  - This research is globally based on field research and aerial photographs.
    - Available literature on mangrove ecology and geomorphology of the Suriname coast:
    - The research in Suriname was done from 2009 till 2011.
    - The study area consisted of 3 locations: Paramaribo, Weg naar Zee and Coronie (Totness)
    - These areas were chosen based on coastal erosion, increased flooding and the possible solutions that could bring important sights into the adaptation policy creation process in Suriname.
    - The MAS (Maritiem Autoriteit Suriname) was contacted to assess actual Sea Level Rise
    - 9 government officials from different ministries were interviewed to gain an understanding of environmental perspectives among policy makers.
    - 3 sluice gate managers, 2 fish smokers and 6 additional experts were also interviewed
    - Anecdotal data has also been gathered:
      - local experiences of erosion and environmental change
      - 20 semi-structured interviews at Weg naar Zee
      - 7 semi-structured interviews with people involved with the sea-wall project in Totness. These people are the key-informants, because coastal erosion and the topic had become a sensitive issue to discuss publicly.
- **Notes:**
  - Local power structures determine how knowledge is filtered and reproduced
    - The status quo often persists
  - Politicized narrative of the environmental crisis
    - Deforestation is often blamed on local villagers
    - Discussions of who the ‘mangrove destroyers’ are, little acknowledgement of natural erosion processes
  - Political debates between seawall construction and mangrove rehabilitation
    - “Here we build them because they are politically interesting,” not necessarily because of an economic justification

        - Local people lack necessary skills to find employment with the Dutch engineering companies building seawalls
        - Guyana has a similar but much longer seawall- budget for maintenance is equivalent to 10% of GDP
    - Awareness campaigns use images of the wrong mangrove species
- **Conclusion:**
    - This research project analyzed scientific and local knowledge of coastal biophysical processes, environmental histories, and past political projects to gain an understanding of possible adaptations to future SLR in Suriname. Global discourses of SLR and mangrove function are often presented locally with absolute certainty as matters of truth. However, there are important uncertainties and assumptions that appear to have been overlooked, potentially causing ill-advised adaptations to take place. For example, a focus on IPCC predictions of SLR in the year 2100 means that the immediate and local ways in which rising sea levels are experienced are ignored. Annual or bi-annual high tide water events that cause flooding and salinization of agricultural lands, and rising low tides which prevent drainage of excess water by gravity, should receive more attention from local policy makers. The steady increase of extreme events stress coastal communities by overwhelming and gradually breaking down coping abilities (Pelling 2011).
    - Concern for long term gradual SLR increase is perhaps better suited for areas that experience minimal daily tidal influence, whereas the immediate focus along coastlines like Suriname's, where tides fluctuate about 2.5 meters, should be on
    - high tide events that will gradually increase as sea levels rise. While mangroves are known to provide protection from storm surges and limit coastal erosion (Alongi 2008), they behave differently in Suriname. Presence of mudbanks is essential for the growth of mangroves along the Suriname coast. Where mudbanks are absent, wave energy erodes the coastline and mangroves succumb to physical processes. False narratives of mangrove destruction are produced by government officials and reproduced in public fora. False claims are made that mangrove destruction is not a natural process but due to the actions of unknowing fisherfolk who cause the 'destruction.' Awareness campaigns also target such activities, but incorrectly show images of different mangrove species to support these narratives.
    - A combined local and scientific knowledge is necessary to understand coastal processes and adaptation options to future SLR. In addition, research based on combined knowledge is still needed, and a more situated environmental science would be more inclusive of different environmental explanations and knowledges.
    - There is still much to be learned about sustainable adaptation solutions. It is clear, however, that adaptation interventions should never focus only on future biophysical vulnerability while ignoring pre- existing socioeconomic vulnerabilities (Ribot 2010). Similarly, SLR impacts should not be studied in isolation but in combination with other biophysical and social processes such as changing wind patterns or political election cycles. Given the abundance of mangroves along the coast, the most important adaptation, I believe, is to allow the natural process of sediment accumulation and migration, as well as erosion and

accretion, to take place unhindered where possible. If coastal populations and the government can learn from and adapt to the cyclical and dynamic nature of coastal processes, much time can be gained and scarce resources can be used elsewhere.Existing power structures often influence how global concerns are transformed into law, policy and action. Local farming practices were instead increasing biomass and creating forested landscapes.

- Globally:
  - The benefits that mangroves provide in reducing storm damage in addition to the provision of habitat for marine and estuarine fauna, and resource use value such as production of timber and non-timber products.
  - Coastal erosion is immediately tied to loss of mangrove habitat.
  - Discussions on adaptation to Sea Level Rise often center on seawall construction versus mangrove rehabilitation. Each system provides different opportunities and losses for different communities.
  - The conservation of mangroves remains vague and local communities rely more on past experiences of coastal floods than future predictions, because of the long-term projection and limited local capacity to analyze actual sea level data and develop warning systems.
  - Vulnerable communities are in fact not made more vulnerable through the implementation of poorly informed policies or maladaptation.
- Suriname:
  - The biggest concern in Suriname with regards to mangrove loss is the erosion of the coast from constant wave energy and sea level rise.
  - According to the government officials:
    - Erosion is caused by the destruction of black mangroves (*Avicennia germinans).*
    - At Weg naar Zee the local farmers and fishermen make mostly use of the black mangroves.
    - At Totness only local farmers make use of the mangroves.
    - “Large- scale destruction of mangrove forests” by coastal residents, because of wood for smoking fish and attaching fishing nets.
  - According to the fishers:
    - Fishers confirmed that they use parwa for smoking fish but they do not cut down mangrove trees because it is too wet and does not burn too well.
    - Fishermen prefer alternative hardwood species from the interior forest because they last longer.
    - Parwa is only used as a temporary replacement for construction, because the wood is of poor quality.
    - The number of fishers in Suriname is very small relative to the size of forests of parwa and their growth rate.
  - According to the residents:
    - Weg naar Zee experienced a small land rush during the military regime with settlers squatted on unused land to gain legal tenure.

- In order to possess a property it was a requirement for the locals at Weg naar Zee to put land into production, which resulted in manually digging ditches and removing vegetation.
- In Totness, large scale of mangrove was carried out in the past to create polder plantations.
- The concerns of these polder plantations are:
    - Managing potential saltwater intrusion from high tide events
    - Frequent flow of freshwater from the Coronie Swamp
    - The swamp is seen as hazard and resource, because it causes flooding but also provides much needed fresh water and fish during the dry season.
    - The creation of optimal salinity conditions for mangrove growth of certain species.
    - Species along rivers and creeks reflects this tolerance gradient.

■ Scientific and local knowledge of mangrove ecology:
- Sediments accumulate on the front (west) end of the mudbank and mangroves colonize it when the elevation is high enough with respect to mean high water, where the trees continue to trap sediments (Augustinus & Teunissen, 2008).
- Mudbanks provide primary protection from erosion, while mangroves provide secondary protection, because they alone can not withstand the force of wave energy.
- Mangrove forests without accompanying mudbanks slowly die off resulting in coastal erosion. This is an important deviation of the generic scientific explanation of the primary (as opposed to secondary) role of mangroves in coastal protection.
- Any particular location on the coast may be experiencing land accretion and erosion, in a process that repeats itself about every 30 years (Augustinus, 2004).
- The 30 year periodicity may change if the northeast trade winds also change directions, which could result in modifications to the general shape of mudbanks (Berrenstein, 2010).
- Local communities have additional knowledge of coastal processes.
- A local man (Mr. Feller), one of the key informants of Coronie, explains that locals are aware of two processes that impact mangrove growth: active and passive growth phases.
    - Active growth occurs when the presence of a mudbank protects mangroves
    - Passive growth, however is driven by periods when large quantities of freshwater flow from the Coronie Swamp north and calms the coastal waters and waves.
- Freshwater plays an important factor for the creation of optimal salinity conditions for mangrove growth of certain species.

        - In addition to parwa, two other mangrove species are found abundance in Suriname. The distribution of these species along rivers and creeks reflects this tolerance gradient (Augustinus & Teunissen, 2004).
        - Large scale parwa die-offs have been recorded in areas where very high tide events allowed seawater to flow over elevated mangrove shorelines and created shallow saltwater lagoons.
        - High salinity conditions are created in these lagoons due to evaporation, and in combination with drowning of parwa roots, trees do not survive (Augustinus & Teunissen, 2004).
    - 'Situated environmental science' is a path to more socially inclusive adaptation solutions

2.6 Defining Eco-Morphodynamic Requirements for Rehabilitating Eroding Mangrove-Mud Coasts by J.C. Winterwerp et al.

- **Goal:**
    - To make an analysis of causes of erosion along degraded mangrove- mud coasts and the causes of failure to rehabilitate the coasts.
- **Method:**
    - The study areas in this research include Thailand, Guyana and Suriname. Observations were done in Indonesia, the Philippines and China, because of significant degradation.
    - The study is based on a morphodynamic analysis of the mangrove- mudflat continuum.
- Notes:
    - Degradation is partly caused by the disturbed balance in fine sediment dynamics and changes in mudflat morphology
        - Initial drivers for degradation are decrease in on-shore sediment flux and local increase in wave height near fish/shrimp ponds
    - Positive feedback loop where loss of mangroves reduces wave dissipation, promoting more erosion between the mangroves
        - Part of the reason mangrove rehabilitation along eroding coasts is unsuccessful, is because seedlings are eroded
- **Conclusion:**
    - Besides improved techniques for mangrove rehabilitation and restoration of water conditions, it is also important to restore the fine sediment balance required for mangrove growth.
    - Emerging insights could help to reverse human-induced erosion along degraded mud coasts through mangrove based coastal defense applications.This can prove to

be more cost- effective compared to conventional hard infrastructure solutions, while providing co-benefits derived from the reinstated mangrove services.

- The imbalance between sedimentation and erosion processes is well-illustrated in the alternating accretion and retreat of the mangrove fringed coastline of Suriname.
- In between mudbanks, the coast erodes, otherwise, accretion occurs, with a general net accretion over longer periods.
- Inappropriate spatial planning of coastal land use, and artificial engineering coastal protection works seem to have induced and aggravated the erosion problem along the ocean.

CHAPTER 3 RECENT / ONGOING MANGROVE PROJECTS

In this chapter recent and or ongoing mangrove projects will be described and summarized.

3.1 ENHANCING RESILIENCE OF THE COASTLINE THROUGH REMOVING STRESS, REHABILITATION AND MANGROVE PLANTING,

- **Goal:**
  - To protect and strengthen the coastline through planting of mangrove plants initially on the bare mudbank / mudflat found in the Coronie district at the location Moy and in the following phase in the Wanica district at Weg naar Zee. Realization of this project will demonstrate the technical feasibility of afforestation of the mudbanks / mudflats by *Avicennia germinans L.*
- **Methods:**
  - Preparatory work: The main emphasis during this phase was on data collection of the study area such as topography, hydrology, geomorphology, biology and consultations with the local communities.
  - Production of the plant material. A number of 500,000 mangrove plants were produced in the first phase, sufficient for a 100 ha large area. The mangrove plants were provided by a local organization Phyto-Tech N.V. This organization seems to have the knowledge, know-how and the infrastructure to produce the required amount of plants to this project.
  - Training of the local communities who were actively participate during the planting period. For this purpose, a large-scale awareness program was organized to inform the locals about this projects, its objectives and the techniques to be used during the planting period. The planting and monitoring was done using mud sledges, as used by the local crab hunters.
  - Establishment of the required infrastructure, including, a. o. wave breakers and pipes for irrigation purposes.
  - Planting of mangrove. Many people had to be trained in order to have the plants planted in a short period.
  - Monitoring of the growth process of the plants, the interactions between plants and mudbank dynamics, flora and fauna, and other parameters.
  - The planting and monitoring was done using mud sledges, as used by the local crab hunters.
  - Data exchange.
- **Notes:**
  - The Anton de Kom University of Suriname was responsible for the execution of the project.
  - Together with the other partners, consultants, organizations and local communities the project aim was realized.
  - The planting material was produced by Phyto-Tech N.V., a local organization found in early 2000 and specialized in plant breeding.

- Under guidance of the Anton de Kom University, the planting of the mangroves took place.
- The budget of this project was composed of the costs made for preparatory works, production plants, training of the local communities in planting of mangrove, establishment of the necessary infrastructure, planting of mangrove, awareness rising, and monitoring.
- The project was mainly financed by the Suriname Conservation Foundation (SCF). A small contribution was made by the Ministry of Planning and Development Cooperation and the Anton de Kom University of Suriname.
- The project had a duration of 3 years, starting in 2010 and ending in 2013.

- Two sites were chosen: 1. Weg naar Zee (Wanica district) and 2. Moy (Coronie district). Priority was given to Moy, because of the conditions for planting mangroves.

- **Results:**
  - <u>Expected results from the beginning of the project:</u>
    - Some hundred thousand plants will be grown on a bare mudbank
    - Expertise in mangrove planting is gained
    - More data has been gathered regarding the technology of soft protection of the coast
    - Necessary infrastructure has been tested and adapted
    - Policy makers are informed about the new technology
    - The local communities are equipped with new technology and can proceed further with less support in protecting the coast, while enhancing the resilience of the coast
    - A new contribution is made towards sustainable coastal management of coastal resources
  - <u>Results at the end of the project:</u>
    - It was noticed that the small plants, grown in a nursery, where not resistant to the force of inundating water. But they were also too heavy to remain vertically upright in the upper mud layer. They tend to sink to a depth where oxygen is depleted which implies the death of the mangrove.
    - This project continued until the natural colonization of the new mud bank overtook the experimental site. It could not be determined whether the plantation experiment had any influence on the colonization speed of the natural process.

3.2 Building with Nature Program: Demonstrating ecosystem-based methods as a viable solution to enhance coastal resilience along the Guiana shield coastline of Suriname

- **Goal**:
  - To deliver proof of concept of the utility of employing Building with Nature (BWN) techniques in combination with man-made solutions to restore mangrove ecosystems as a viable and effective alternative form of coastal protection.
  - Conservation International Suriname in cooperation with other partners intends to upgrade the initial pilot to an integral BWN flagship project that eventually functions as a showcase for innovative and sustainable solutions to save deltas in the Guyana Shield.
  - **Building with Nature Concept:**
    - Developing hydraulic infrastructure
    - In harmony with the behaviour of the natural system
    - Letting nature do part of the work
    - In close collaboration with stakeholders and local communities
    - With added value for nature, (local) economy and society
    - Integrated approach to coastal zone protection
- **Methods:**
  - Since April 2015, Weg naar Zee in the Wanica district, has been chosen for the implementation of this project, because of the threatened condition of this area.
  - Sediment Trapping Units (STU) have been constructed to trap mud from the Guyana stream originating from the Amazon river passing by the Suriname coast and hence recreating conditions for mangrove regeneration and subsequently halt erosion:
  - Brushwood are being used to form walls, placed over an enclosed area over a seaward with of about 200 on the mud flat.
  - Wallaba (Eperua falcata) wooden poles are driven into the ground 2m deep, spaced 0.75 m apart in parallel lines 0.5 m apart, filled with brushwood and tightened with plastic wire.
  - These permeable walls can hold sediments coming from the sediment-rich water when entering the enclosed area.
  - To make sure sediment will not easily escape during ebb or gravity currents, it is recommended to reduce the permeability close to the bottom.
  - Project activities for a period of 3 years (2019 - 2021) will be concentrated on protecting the coastline of Weg naar Zee, such as:
    - Upgrading STU's
    - Development and implementation of analysis and monitoring systems to be able to demonstrate proof of concept
    - Conduct of research and analysis
    - Conduct of feasibility studies
    - Involvement/ engagement with the local community for maintenance of the STUs and protection of restored mangroves

        - Awareness building about opportunities of nature- based solutions and public education.
- **Notes:**
    - Suriname has outlined several critical adaptation measures to be implemented in the 2017-2021 National Development Plan, which include the rehabilitation and enhancement of infrastructure to protect the coastal zone, promotion of sustainable land management, and instituting measures towards increasing ecosystem resilience to ensure these naturally adapt to the changing climate.
    - To protect coastal and marine ecosystems, transboundary collaboration and alignment with regional policies and plans are necessary.
- **Results (the first 16 months)**:
    - a sediment deposition of 5-10 cm from June to December 2015
    - a rapid erosion in January 2016 shows an sediment loss of + 1cm relative to the initial level and may indicate extreme conditions
    - the deposition and erosion as mentioned above can be related to the on average much stronger north-eastern winds in the periods December - May, compared to the weaker, more eastern directed winds in the period June-November (NOAA Global Model wind data, averaged over the period 1997-2003; Winterwerp et al. 2005)
    - the net deposition of trapped sediment increased to higher levels, generating mud to the high-high waterline, reached at spring tide.
    - the trapped material becomes more compact because of exposure to the sun (until the next spring tide) and cracks are formed.
    - the compaction and cracks are ideal conditions for mangrove propagules to develop.
    - the success of this STU is also part of the available large sediment supply during this period, which is attributed to the approximation of a mud bank, which is crossing the Suriname river.
    - observations further at the west of the area showed the part that is already eroding away, indicating that the slope in front is too steep.
        - **Conclusions:**
            - It needs to be taken in consideration that the sediment entrapment would not lead to disturbing the sediment balance at the alongshore downstream side of the entrapment unit.
            - Trapping the sediments in a specific area, could result in a shortage of sediment supply behind the unit.
            - The diverted longshore currents may increase in magnitude and may cause increased erosion in front of the unit.
            - A concave profile of the tidal flat will be formed and could hinder the onshore sediment flux beyond the unit.

- **Goal:** To present methods for mangrove rehabilitation at the Weg naar Zee coast, which can be supported by the key stakeholders.

- **Keynotes:**
  - The focus on mangrove rehabilitation in this project is defined as the action of improving the health of the forest (Urbanska, Webb, & Edwards, 1997).
  - Thus the focus will only be on coastal erosion and not on other failure mechanisms.
  - The project has taken place on the coast of the WnZ region. The area has a stretch of 7 km and is the place where most erosion takes place.
- **Method:**
  - This project was divided in two phases: (1) the stakeholder identification & analysis and (2) survey for the design requirements for the variant study and the preliminary designs.
    - (1). Stakeholder Identification & Analysis:
      - Identification of the stakeholders: Interviews with the stakeholders to gather a better understanding of the stakeholders perceptions, interests, goals, resources and their position overall.
        - Analysis phase:
          - To analyze the stakeholders various models such as tables and maps were used.
          - Identification and analysis techniques by Bryson (2004) and the stakeholder mapping theory by Murray- Webster & Simon (2006)
          - All these models are used because of the interesting aspects such as:
            - Stakeholders classification on the basis of their level of replaceability and importance.
            - Stakeholders critically (critical or non-critical) based on their replaceability and dependency.
            - Stakeholders dedication (dedicated or non-dedicated)
            - Stakeholders who share the same interests, perceptions, interests and goals.
            - Which stakeholders would form potential partnerships
            - How to engage stakeholders based on their typology.
    - (2). Survey Design requirements:
      - To gather as much as possible information to know what the locals experiences are and what their wishes are.
      - Surveys were held with Weg naar Zee inhabitants

- To define the survey scope, the number of households to be interviewed, were counted on the basis of a satellite photo on Google Maps.
- 217 surveys were determined that had to be completed in order for the survey to be reliable.
- Statistical data (Baarda & De Goede, 2006) and obtained data from Google Earth and ABS were used.
- They surveys were held 2 days with help from AdeKUS students and a minimum of 217 surveys were held.

- **Results:**
  - (1). Stakeholder Identification & Analysis:
    - Several stakeholders groups' interests for STUs has grown over the past two years (2015-2017).
    - Because of the flood in 2015, the former Minister of Public Works promised that a dike of 8 km would be constructed in the WnZ region. But it became clear that the plans were put on hold due to the lack of finances and other political interests.
    - The 2016 and 2017 annual speeches of the Surinamese president showed that the government is currently more interested in supporting mangroves and STUs as coastal protection measure (Kabinet van de president 2016 & Kabinet van de president 2017).
    - Large capital investments can not easily be made due to the poor economic situation.
    - The stakeholders group; Fishers and Agricultural farmers has more confidence in STUs, their interests is slightly above moderate, and their power remains between low and moderate.
    - The stakeholders 'Place of Pilgrimage' and the 'Inhabitants of the WnZ region' started out as having a very low interest in mangroves coastal management measure, combined with a low power concerning coastal management policy.
    - After 2 years, the interests of the stakeholders as mentioned above has increased, but their power does not change.
    - The stakeholder 'Engineering firms' started out having slightly more interest compared to the other stakeholders. This was also the case for power, which is almost moderate. This increase interest can be explained by the sustainability factor of applying mangroves as coastal management measures.
    - The inhabitants of the WnZ region, Government of Suriname and AdeKUS are important and highly low replaceable.
    - Stakeholders like Fishers and Agriculture farmers, Engineering firms and the Cremation place Weg naar Zee are highly important but also highly replaceable.

- Inhabitants of the WnZ region, Government of Suriname and AdeKUS can be clustered together as dedicated actors. The only difference between these stakeholders lies in their perception, interest and goal.
- Inhabitants of the WnZ region, Government of Suriname and AdeKUS have been deemed as critical actors.
- The stakeholders AdeKUS, the Government of Suriname and the stakeholder group NGO's/ Embassies are strong supporters.
- The inhabitants of the WnZ region are critical actors and can be classified as the 'irritant' type. It is needed to consult and inform them from the beginning of the process in order to engage them so that they do not block the process. This is necessary to do because this group will be affected the most by coastal erosion and its effects.

- (2). Survey Design requirements:
  - 219 responses were received from the surveys, each consisting of 32 questions.
  - Most of the title on land is government lease, followed by rent and at least a small group has full ownership of the land they live on.
  - Given the current coastal management, the Weg naar Zee inhabitants were:
    - 64% very dissatisfied
    - 12% dissatisfied
    - 13% not satisfied/ not dissatisfied
    - 11% satisfied
      - Thus it can be concluded that a minimum of 76% is currently not satisfied with their own safety against flooding in the WnZ region.
      - 58% are not willing to move to a safer place. This means that although they feel unsafe and dissatisfied with their safety against flooding, they are still reluctant to move away from this area, because of the emotional connection with this area.
      - 42 % of the respondents is aware of sea level rise and 58% not.
      - 38% have experienced burden from the flooding in 2015.
      - The majority of respondents (73%) do not know what a STU is, only 13% knew what a STU was and how it works.
      - To protect the inhabitants against sea level rise and the consequences coming with it:
        - 65% respondents want a dike of concrete
        - 38% respondents want a dike in combination with STUs
        - 12% respondents want STUs
      - 76% of the inhabitants are aware that mangrove can be used as coastal management measure.
      - 62% do not know that this can earn money working in a mangrove related sector or with mangroves in general.

- 47% of the locals is willing to follow a training for a job in the mangrove sector.
- The construction of a dike is unachievable, the government has no money available for this issue. It is needed to take action sooner than later, therefore a sustainable and cheaper solution in the current setting, in this case STUs, is an ideal opportunity.

3.4 Other recent / ongoing mangrove projects in Suriname:

Project Title	**Implementing Organization**	**Period**	**Description**	**Status**
Setting up a Mangrove Biodiversity Monitoring System	Foundation for Forest Management and Production Control -SBB	2017-2018	To have an implementation framework for mangrove conservation and management, accurate and up-to-date information on the biodiversity and other characteristics on the mangrove forest is needed.	Implementation phase
Mangrove evolution and adaptation	National Herbarium of Suriname at the Anton de Kom University of Suriname	8 months	Study the parwa mangrove species in Suriname in impacted coastal areas.	Preparation & Development phase
Present mangrove ecosystem composition and health	National Herbarium of Suriname at the Anton de Kom University of Suriname	6 months	Inventory of mangrove ecosystems	Preparation & Development phase

Formulating a National Mangrove Strategy	MaFoSur	6 months	Formulating a sound strategy for sustainable management of the mangrove ecosystems.	Preparation & Development phase
Upgrading the Mangrove Educational Centre Coronie, the 'mangrove' school	Foundation SORTS	2017	Upgrading the MECC, sustainable management and governance structure in place, and validation of information by the Anton de Kom University of Suriname	Implementation phase
Suriname GCCA+ project "Contribution towards the provision of new climate information and institutional governance to help support sustainable productivity and mangrove protection"	Hydraulic Research Division (WLA) of the Ministry of Public Works, Transport and Communication	Ongoing and will end at the end of 2018	Collecting climate data and developing capacity for sustainable water resources management.	Implementation phase
Biodiversity and Economic Valuation of the Bigi Pan (BP) (coastal area) MUMA	Department of Forest management, Centre for Agricultural Research in Suriname (CELOS)	2000-2008 (still relevant)	Specific objectives: - To review the management of the BP MUMA - To map natural features of the study area versus land use types	Closed; Recommendations: - Research & Monitoring have to become integral part of the management of the MUMA. - Data collection

			- To describe the contribution of BP MUMA to the fisheries sector - To assess the role of Mangroves in Bigi Pan MUMA - To identify the perception of the stakeholders regarding BP MUMA - To determine the constraints and opportunities generated by the existence of the Bigi Pan MUMA	has to be placed in a central institute for management and decision making purposes. - Data collection, but moreover monitoring on the fish population in relation with land use and water quality is important to gear the economic activities towards sustainability. - Zoning of the MUMA area is needed.
Mangrove documentaries	Suriname Conservation Foundation (SCF)	On going		Implementation phase
Stichting Develop Art Foundation / Uncovering the Mangrove Services in Suriname	Project Roseternal (promoting Suriname in YouTube films)	Start May 2017	Gathering of information through surveys in relevant coastal districts. With this information, a training program will be set up to train selected	Implementation phase

			groups in the community (especially women and youth) in the use of a camcorder in order to capture video material, pictures and sounds. With these video materials minimal 4 shorts films of minimal 5 minutes about mangrove ecosystem services will be produced in one video documentary per relevant district.	
Office of Sustainable Management of Natural Resources / Promote the sustainable use of ecosystem services of mangrove forests in the Bigi Pan	Projekt Adek Bigi Pan	18 months	Provide key stakeholders active in the Bigi Pan lagoon in district Nickerie, as an input to create a more optimal mangrove management in the future.	Preparation & Development phase
Mangrove rehabilitation project at Nickerie	Project Naipal Bouw kwelders Bigi Pan	8 months	A new approach has been suggested, encompassing the building with nature concept, which include the establishment of sediment trapping units.	Implementation phase
Promoting Integrated and Participatory Ocean Governance in Guyana and	The project is implemented through a partnership between WWF Guianas,	2017 – ongoing (4 years)	The project aims to significantly enhance the governance and protection of marine	Implementation phase

Suriname: the Eastern Gate to the Caribbean	Green Heritage Fund Suriname (GHFS), Guyana's Protected Areas Commission (PAC) and the Nature Conservation Division (NCD) of the Suriname Forest Service ('s Lands Bosbeheer).		and coastal resources of Guyana and Suriname through collaborative processes with all ocean stakeholders, improved knowledge of the coastal and marine environment, enhanced capacity of key stakeholders and informed marine spatial management. It will contribute to substantial progress towards achieving Aichi targets 4, 6, 10, 11 and 14 under the Convention of Biological Diversity (CBD).	

In order to maintain healthy mangrove forests, economic valuations of mangrove ecosystems goods and services need to be assessed. Some of the options are mentioned here below.

- Reduced Impact mangrove forestry practices, which provide high value use of mangroves, ensure long-term benefits to local communities.
- Cohesive management plans for entire countries and ecological units should be integrated into a broader spatial framework of coastal zone management and should involve all stakeholders and sectors.
- An environmental impact assessment must be required when planning to install artificial coastal defenses. The risk such structures may pose to the mangroves and its ecosystem services must be taken into consideration.
- Support of new research and maintenance of long-term data sets on the extent of mangrove resources, their value, and responses to a range of pressures to inform sound policy and management decisions.
- There needs to be a strong link between mangrove ecosystem degradation and persistence of poverty in many rural communities, with regarding to poverty reduction strategies and food security planning. Effective management of mangroves is an achievable and practical way to help ensure food security for many coastal communities.
- Involvement of local communities in mangrove conservation efforts is critical to the success of any management intervention. This can be achieved with rigorous stakeholder identification and analysis, the design collaborative agreements, and the facilitation of equitable participation in policy formulation and management. Local involvement, profit sharing, or payments for ecosystem services can all improve the chances of successful management and long-term viability of interventions. By encouraging local communities to develop alternative livelihoods that are less destructive than (over)harvesting a crucial step to mitigating mangrove deforestation is made.
- To recover lost or establish new mangrove forest, restoration and afforestation are viable options. The lowest cost and highest benefit route is remained while avoiding loss through this option. Mangrove restoration represents the most successful and widely practiced form of ecological restoration in any coastal or marine setting.

In order to achieve successful mangrove restoration critical steps are required [5]:

- Understand the autecology (individual species ecology) of the mangrove species at the site
- Understand the normal hydrologic and sediment patterns
- Assess modifications of the original mangrove environment
- Restore appropriate hydrology
- Only utilize actual planting of propagules
- Incorporating socio-economic aspects and monitoring requirements

To increase the viability of mangroves against threats like sea-level rise, a few enhancing strategies are recommended:

- Apply risk-spreading strategies to address the uncertainties of climate change.
- Identify and protect critical areas that are naturally positioned to survive climate change.
- Manage human stresses on mangroves.
- Establish greenbelts and buffer zones to allow for mangrove migration in response to sea-level rise and to reduce impacts from adjacent land-use practices.
- Restore degraded areas that have demonstrated resistance or resilience to climate change.
- Understand and preserve connectivity between mangroves and sources of freshwater and sediment and between mangroves and their associated habitats like coral reefs and seagrasses.
- Establish baseline data and monitor the response of mangroves to climate change.
- Implement adaptive strategies to compensate for changes in species ranges and environmental conditions.
- Develop alternative livelihoods for mangrove- dependent communities as means to reduce mangrove destruction.
- Build partnerships with a variety of stakeholders to generate the necessary finances and support to respond to the impacts of climate change.

1. Van Lavieren, H., Spalding, M., Alongi, D., Kainuma, M., Clüsener-Godt, M., & Adeel, Z. (2012). Securing the Future of Mangroves, A Policy Brief. UNU-INWEH, UNESCO-MAB with ISME, ITTO, FAO, UNEP-WCMC and TNC, 1-53.
2. Spalding M, McIvor A, Tonneijck FH, Tol S and van Eijk P (2014) Mangroves for coastal defence. Guidelines for coastal managers & policy makers. Published by Wetlands International and The Nature Conservancy. 42 p
3. Edward J. Anthony (2015). Assessment of peri-urban coastal protection options in Paramaribo- Wanica, Suriname.
4. Augustinus, P. G. (2004). The influence of the trade winds on the coastal development of the Guianas at various scale levels: a synthesis. Marine Geology, 208(2-4), 145-151
5. Erftemeijer, P., & Teunissen, P. (2009). ICZM plan Suriname-mangrove report. Analysis of problems and solutions for the management of mangrove forests along Suriname's 'wild coast'. Lievense–Deltares report, 35
6. FAO, U. (2007). The world's mangroves 1980–2005. *FAO Forestry Paper*.
7. Makowski, C., & Finkl, C. W. (Eds.). (2018). Threats to Mangrove Forests: Hazards, Vulnerability, and Management (Vol. 25). Springer
8. Toorman, E. A., Anthony, E., Augustinus, P. G., Gardel, A., Gratiot, N., Homenauth, O., ... & Naipal, S. (2018). Interaction of Mangroves, Coastal Hydrodynamics, and Morphodynamics Along the Coastal Fringes of the Guianas. In Threats to Mangrove Forests (pp. 429-473). Springer, Cham.
9. Nijbroek, R. (2014). Mangroves, mudbanks and seawalls: whose environmental knowledge counts when adapting to sea level rise in Suriname. Journal of Political Ecology, 21(1), 533-550.
10. Naipal, S. (2012). Enhancing resilience of the coastline through removing stress, rehabilitation and mangrove planting. In Meeting on Mangrove ecology, functioning and Management (MMM3) 2-6 July 2012, Galle, Sri Lanka (p. 124).
11. Pellegrini, J. A. C., Soares, M. L. G., Chaves, F. O., Estrada, G. C. D., & Cavalcanti, V. F. (2009). A method for the classification of mangrove forests and sensitivity/vulnerability analysis. Journal of Coastal Research, 443-447.
12. Augustinus, P. G. E. F. (1980). Actual development of the chenier coast of Suriname (South America). Sedimentary Geology, 26(1-3), 91-113.
13. Kauffman, J. B., Bernardino, A. F., Ferreira, T. O., Giovannoni, L. R., Gomes, L. E. D. O., Romero, D. J., ... & Ruiz, F. (2018). Carbon stocks of mangroves and salt marshes of the Amazon region, Brazil. Biology letters, 14(9), 20180208.
14. Luther, D. A., & Greenberg, R. (2009). Mangroves: a global perspective on the evolution and conservation of their terrestrial vertebrates. BioScience, 59(7), 602-612.
15. Vieira, B. P. (2016). Population trends and conservation of the Mangrove Rail. Revista Brasileira de Ornitologia-Brazilian Journal of Ornithology, 23(3), 327-335.
16. Saenger, P. (2002). Mangrove Structure and Classification. In Mangrove Ecology, Silviculture and Conservation (pp. 183-205). Springer, Dordrecht.
17. Mitra, A. (2013). Sensitivity of mangrove ecosystem to changing climate (Vol. 62, pp. 143-157pp). India: Springer.
18. Burke, L. &7 Ding, H. (2016). Valuation of Coastal Protection near Paramaribo, Suriname. Prepared for World Wildlife Fund Guianas.

19. United Nations Development Programme in Suriname (UNDP) (2016). Suriname Global Climate Change Alliance (GCCA+) Contributing towards the provision of new climate information and institutional governance to help support sustainable agriculture productivity and mangrove protection.
20. Çete, C., Haage, S., Hardwarsing, V., Kalloe, S., Ma - Ajong, A. (2018) Mangrove Project Suriname. Prepared for the course CIE4061-09 Multidisciplinary Project. Delft University of Technology, Anton de Kom University of Suriname.