The Living Estuary

A Study of Developing Landscape Spatial Adaptive Strategies to Integrate the Water, Ecosystem and Anthro-Dynamics in the Estuary of Volta Delta, Ghana

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Master Thesis:
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Dr. Ir. Inge Bobbink
Dr. Ir. Marjolein Spaans
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The current state of progression in a delta region around the world can differ significantly from one to the other. In metropolitan delta region in the developed country, from the exploitation for a long time by the urbanization and industrialization and intensive farming, they are facing a deadlock and start to find a new balance between human and nature system. On the other hands, delta region in developing county is facing different challenges. With the limitation in the financial, technological and political sector, people are still living dependently to the natural resources. It is a big challenge and opportunity at the same time, to learn from the over-exploited delta, for the growing delta in developing countries so that it won’t make the same mistakes. The Volta Delta in Ghana, with artisanal fisheries and traditional farmers communities, could be a suitable location to study those challenges.

The Volta Delta Region is facing not only the challenge of severe coastal erosion but also the future challenge of a high rate of population growth, industrialization to exploit the natural resources more and the unavailability of long-term planning of the region.

The estuary area is one of the most dynamic parts of the delta with the combination of the sea and river water dynamics, it has high biodiversity of the mudflat and sandy shore ecosystems, and it is governed by three municipalities whose development strategy need to be integrated. By these challenges, this project aims to show the possibility of future spatial adaptive strategy to integrate the water, ecosystem, and anthropo-dynamics to guide the development in the estuary of Volta Delta.

This project was conducted in three main stages. First, is the investigation, where the landscape is seen as a form of interaction between water, ecosystem and social and economic processes. The design principles with the type of spatial configuration between human settlement and the role of the natural and cultural landscape become the result of this first stage. Scenario building as the second stage of this research exploring the possible extreme condition that may occur in the estuary area in the next 50 years from the influence of combination between several variables. By comparing the dependent variables from each scenario, the design strategies on estuary scale are formulated. These strategies comprise the water management, food production, erosion control, and settlement and mobility sectors. Three sites are selected from this process. All the sites are located in the most affected areas by all the extreme scenarios, and each has distinct landscape spatial configurations in the relation with the types of communities inhabit the sites.

The design implementation stage explores the landscape architectonic design on each site, with three main principles as the common thread. First is the sensitivity in placing the new infrastructure which could either trigger or restrain the...
development itself. On each site, the form of development will give more focus on the balance and re-establishment of the nature system. Second, is the type of intervention that could grow and adapt to certain changes by the natural process or its users. And last, the circular system, where the intervention should keep open for an opportunity of the local economy, as well as the ecological and environmental quality improvement.

The three selected sites were explored with distinct focus of intentions. In site one, the landscape design investigates the possible solution in compromising the erosion both on the sea and riversides. In site two, the effort in recovering the abandoned wetlands as is discussed. The site three that is located at the town fringe, the transition zone that could help to control the expansion of the settlement towards the vulnerable area is presented.

In applying the gradual development, the application of the three sites needs to be considered in stages with long-term basis. The staging of the application part will discuss the priority and timeline of the processes on each site, as well as how the support of the government and stakeholders, and the involvement and participation of the local communities will be integrated into the plan.

After all, keeping balance and integration of the flows that put forward the collective economy improvement is prone to some challenges. For example, the complication to unify the future vision of the government and stakeholders, the possibilities conflict of interest for the broader investment both in the tourism industry and exploitation of natural resources, and even the reluctance of the communities to become part of the new system. Therefore, through the design strategy on the estuary scale, and spatial design configuration on the design principles, as well as the principles in developing the site-specific landscape design that was introduced in this research, is expected to be a guidance or starting point in the negotiation to achieve middle ground between economic and spatial development and nature conservation in a circular balance of its living systems.
INTRODUCTION

Fig 1.3 Map showing the 48 deltas included in a study by Tessler et al., 2015
Source: Meyer et al., 2016
Delta regions represent some of the world’s richest ecosystem (Meyer & Nijhuis (Eds.), 2014). More over, it is a strategic area, not only for food productions from its fertile landscapes, but also for trade and geopolitics positioning, which make it as one of the most valued places for people to live. Each delta has a unique character in which the current state of progression can differ greatly between one delta and the other. However, after humans begin to manipulate the land to form a living environment, the vulnerability factors become inevitable pressure in all delta regions.

Han Meyer (2014) discussed the 4 evolution periods of a delta region. First, the period dominated by land-formation by natural forces. Second, the first human interventions and first urban settlement, where the technology is still on the modest level, with political and financial limitation. Third, is the period where technology and the power of nation states enable structural interventions in the delta system. And the fourth, is the period in looking for new balance between the different subsystems or layers of the delta system.

In metropolitan delta regions, they are facing the transition period between the third and the fourth period, by starting the effort in looking new balance between the nature and human system. Exploitation over years by urbanization, intensive farming, and industrialization causing land subsidence, loss of wetlands, coastal erosion, and salinization. These deteriorating impacts brought awareness to create balance by incorporating natural dynamic processes in the interventions to cope with the vulnerability of the delta. These transitions can be seen for example in The Dutch
Delta, Mississippi River Delta and New York Delta.

On the other hand, some delta regions in developing countries are facing some other challenges. The limitation in political, financial, and technology sectors characterized these deltas being in the second period of the evolution. The Volta Delta in Ghana can be one example illustrating this situation. The population dominated by fishermen and farmers rely their livelihood on natural resources which most of them still managed it traditionally. Despite its vulnerability with the threats of severe coastal erosion, its fertile landscape keeps attracting people to live in. High rate of population growth could lead the Volta Delta in the transition towards urbanization and industrialization evolution. Without the availability of long-term spatial planning, and less awareness in maintaining balance between the nature and built environment, the development could bring the coastal communities into catastrophic situation in the future.

Seeing these phenomena, It is a big challenge to learn from the over-exploited delta by human interventions as in developed country’s delta regions, to formulate sustainable development guidance in developing countries delta region so that the same mistake will not take place. This project aims to show possibilities in formulating the sustainable guidance for development of the Volta Delta’s estuary while at the same time integrating the possible strategy in coping the threats of severe coastal erosion.

Fig 1.5 Growing Delta in Developing Countries
Source : (1,2,3) Google Maps
(4) www.istockphoto.com
(5) www.roaminindonesia.com
(6) www.mekong-delta-tours.com
The main issue on the Volta Delta is the severe coastal erosion which is caused by significant reduction (90%) of sediment supply after the construction of the Akosombo Dam, along with sea level rise and associated change of coastal currents along the West African coastline. The Volta Delta has high severity rate of erosion comparing to the coastal erosion which occurs along the Ghana’s coastline. The erosion has damaged about 5,000 houses in Keta since 1960s and has demolished about 50 houses in Fuvemeh in two years (2014-2016) and displaced about 300 people (Addo, 2017). The coastal erosion brings a lot more problems for the coastal communities. Almost 50% of the inhabitant experiences the flood. Flood also destroyed the agriculture field which was one of the most important livelihoods of the local communities. As the sea level water intrudes more to the land, the salinization of ground water causes loss of soil fertility and the availability of fresh water resources. Salty unfertile farmlands were abandoned, causing unemployment and food insecurity in the region. The mangrove deforestation for firewood makes the coast and the riverbank more vulnerable to flood and erosion. The existing coastal protections were built fragmentary without long-term comprehensive planning and didn’t take into account the potential use of natural processes and ecosystem services in the system.

Despite its vulnerability, the growth of urban development in the Volta Delta can not be totally restrained. It is rather to be controlled in such a way that the delta’s natural systems could still be maintained in the settings. A balance zonation of natural and built environment needs to be established through spatial design that could be developed in short and long terms. The inevitable industrialization of agriculture and aquaculture sectors will be guided with sets of guidelines which could maintain the healthy combination with the natural ecosystems. These negotiation could not be applied merely by imposing new regulations, but also by creating and improving awareness of the local inhabitants to work together in realizing this goal.
COASTAL PROFILES
Development of coastal protection profiles

- Structures construction 2000 - 2003
- Structures construction 2012 - 2013
- Structures construction 2014 - 2016
1. In totopey, the construction of the groynes has not protected the village from the erosion as it stopped on the eastern part of the village.

2. In Kewunor, the erosion threats both on the sea and the river sides. Ada sea defense project has been constructed to protect the area by combination of boulder groynes and sand nourishment along the beach.

3. Severe erosion threats at Fuveme. The community has moved backwards three times to save their properties. In the last monitoring process, accretion on the beach can be found.

4. Boulder revetment has been along the coastline in Dzita and accretion of the beach is evident.

5. No hard protection on the beach of Woe. The fishermen still able to use the beach to dock the boats and fishing nets. A combination layers of coconut trees and intercropping system of vegetable farming, and large-crowned evergreen trees can be found behind the beach.

6. Double layers of boulder groynes has been constructed at the heritage site of Fort Prinzenstein.

7. At Keta east, large but short groynes has been constructed. The accretion with steep coast has been accumulated on the coming direction of the waves. The sloping beach on the other side of the groyne are used for boat dock.

8. At Keta, sea defense project to protect the coastline has been built. A dam is integrated as a main road with a sluice as flood control. The sand bar with coconut trees is situated on the sea side with a lagoon in between the sand bar and the dam.

Fig 1.10 Coastal Profiles along the Volta Delta
Source : Ays Prestasia & Eva Ventura
Coping with the two main challenges needs support from financial, social and political sectors both on national and regional scale. To gain those supports, some measures about the importance of the Volta Delta needs to be understood.

These analysis are intended to show the condition that needs to be anticipated and the strength and potentials which could be improved in the future. The analysis were done by studying the relation between the urban growth pattern in coastal towns in Ghana, infrastructure, land use, and biodiversity on the native ecosystem.
The Volta Delta is located in between the two capital cities of Ghana and Togo, Accra and Lome which are connected by the main infrastructure (trans-country highway). The coastal cities of Ghana grow along the main infrastructures and coastline of the country, which can be seen in the urban growth pattern of Accra, Tema and Ningo-Prampram (see Fig. 3 & 5). In long-term development, the settlements will grow towards the Volta Delta which together with the challenge of climate change and sea level rise could add pressures to the vulnerability of the delta, such as land subsidence, floods, limited fresh water supplies, industrialization, and threats to the existing ecosystems. Thus, to guide this development, a sustainable spatial planning for Volta Delta is needed.

Urban Growth

The Volta Delta is located in between the two capital cities of Ghana and Togo, Accra and Lome which are connected by the main infrastructure (trans-country highway). The coastal cities of Ghana grow along the main infrastructures and coastline of the country, which can be seen in the urban growth pattern of Accra, Tema and Ningo-Prampram (see Fig. 3 & 5). In long-term development, the settlements will grow towards the Volta Delta which together with the challenge of climate change and sea level rise could add pressures to the vulnerability of the delta, such as land subsidence, floods, limited fresh water supplies, industrialization, and threats to the existing ecosystems. Thus, to guide this development, a sustainable spatial planning for Volta Delta is needed.

Fig 1.12 Urban growth trend in Greater Accra Region
Source : UN Habitat

Fig 1.13 Urban area in Greater Accra Region & Lome
Source : Drawn by Author, adapted from Openstreetmap
Vegetable crops are one of the main agriculture commodities in the Volta Delta. It is supported by a combination of good climate, hydrology and its soil structure. The Volta Delta could also act as buffer zone to protect the vast agriculture area north of the Delta from the sea dynamics pressures, such as flood, storm, and erosion (see fig. 7). Beside farming, abundant river and marine resources make the fishing activities on the sea, river and lagoons bring significant contribution for the local economy. (Brinks, 2017)
The Fig.1.19 & Fig 1.20 show the rich biodiversity; a combination between sandy shore ecosystem, vast wetlands, grassland and forest; together with its serene ambience, unique culture, appearance of rare animals; such as the marine turtles; and potential for various water sport activities could potentially be developed to support the tourism sector. Eco-tourism that involve the local communities in its running system will benefit them as new type of livelihood.
This graduation project will focus on the estuary area of the Volta Delta. The area include the Volta river mouth, the landscape and coastal communities in the radius of 5 km from the river mouth. This distance is used based on the range of tidal influence towards the river.

The estuary is the most dynamic area of the delta which has big influence on the coastal development of the eastern coast of Volta Delta. The social and political dynamics take place as the estuary are governed by three different local administrations, who still develop fragmentarily of their lands and communities. The huge potential on the ecology and economy sectors enhance the complexity of the systems.

The Living Estuary term is meant to study on how these three dynamics can be integrated to formulate a sustainable development strategy. A place which could give good balance between human & nature ecosystem, at the meeting point of the river and the sea.
This graduation project aims to develop landscape architectonic design principles for future adaptive strategies by integrating the water dynamics, ecosystem dynamics and anthropo-dynamics in order to enhance the spatial and living quality in the estuary of Volta Delta, Ghana.

In order to achieve the research objective, some research questions were composed as follow:

1. How are the current systems of the delta dynamics, ecosystem dynamics and anthropo-dynamics in the Volta Delta Estuary?
   - How did the estuary develop before and after the construction of Akosombo dam? (focusing on the natural dynamics and processes)
   - What type of ecosystems comprise the Volta Delta estuary, and how can they be utilized as coastal protection?
   - What are the main economic activities of the local communities, and how do they influence the land use and spatial pattern in the estuary of Volta Delta?

2. What design principles could be derived from the interrelation between the delta dynamics, ecosystem dynamics, and the anthropo-dynamics of the Volta Delta’s estuary?

3. How to develop future scenarios for the Volta Delta estuary?
   - Which variables should be taken into account in developing the scenarios?
   - What strategies need to be applied in each scenario?
01.06
Project Relevance

The outcome of this project is intended to show possibilities to guide the development and trigger discussion between the stakeholders to realize sustainable solution for the Volta Delta in facing challenges from population and economic growth, and the threat of sea level rise and deteriorate ecosystems.

In the relation to larger context, this graduation project is intended to research the possibilities of developing landscape design, to optimize the ecosystem services as means to balance the delta dynamics, and to improve the living quality of the local communities in a developing country’s delta region. The complexity of social and economic challenges in applying the design strategy will also be studied in order to propose a future sustainable solution.

Landscape architecture design could play a role to enhance the living quality of the local communities by improving the balance between human and nature systems.

01.07
Reading Itenerary

• What are the most plausible future scenarios for Volta Delta estuary?

4. How to develop design strategies in the most affected areas by applying the design principles of the integration between the delta dynamics, ecosystem dynamics and anthropo-dynamics?

5. What spatial and systemic detail designs could be applied on the affected areas?

6. Could the strategy create a framework which can be applied in other delta regions?

Chapter 1 consists of the context of the social and economic challenges on delta regions in developing countries, the significance of the Volta Delta, the problem field of the project, the research objectives, research questions, and relevance in the scientific and social lenses.

Chapter 2 consist of the theoretical framework, research framework and methodology, and the timeline in finishing the project.

Chapter 3 consist of the investigation of the delta dynamics, ecosystem dynamics and anthropo-dynamics in the estuary of Volta Delta, and the synthesized design principles as form of intergration between the three dynamics in a spatial configuration.

Chapter 4 consist of the three extreme scenarios, comparison of the dependent variables, design strategy on estuary scale, and selected location to be developed further in the implementation stage.

Chapter 5 consist of the implementation of the principles and strategies into site specific landscape designs. This chapter also present the detail designs, staging timeline of the projects and form of involvement of the stakeholders and local communities in the application processes.

Chapter 6 consist of the conclusion of the research, evaluation and reflection of the project.
METHODOLOGY

Fig 2.1 The groyne at Keta East sea defence project
Source: Author
02.01
Theoretical Framework

Landscape as Processes:
Integration of the Three Dynamics

“It is in estuaries and delta where the richness of the land meets the abundance of the sea, creating an environment of high diversity, dynamism and productivity” (Diop et. al. Eds. 2016). In the estuary of Volta Delta, the water dynamics on the meeting point between the river and the sea, the combination of ecosystem dynamics which comprises the banks and the shores, and the socio-economic aspects of the anthropo-dynamics could lead to the perspective of landscape as processes. The landscape on the estuary could be seen as a holistic and dynamic system of systems, an expression of dynamic interaction between ecological, social and economic processes (Nijhuis, 2013).

In addressing the landscape as processes, it is important to understand the interaction between natural and human systems to facilitate the aesthetic, functional, social and ecological relationship between them. As a growing delta in a developing country, the landscape processes also aims at guiding development in the spatial, ecological, social, and economic sectors in the estuary of Volta Delta. An open-ended strategy will be studied as in staging to achieve a sustainable development in the future.

Adaptive Design Strategy:
Gradual Development of the Nature and the Society

Adaptability of a system could be referred to the definition of resilience by Holling (1973) as the ability of a system to absorb change and disturbance without changing its basic structure and function or shifting into a qualitative different state. It could also include the ability to self-organize of change in the social-ecological systems (e.g., Holling 1996, 2001; Levin et al. 1998; Carpenter et al. 2001; Folke 2006; Wu & Wu, 2013).

In a vulnerable nature and society like the Volta Delta's estuary, the design intervention and development strategy should provide opportunity in time and space for nature and society to gradually adjust in the changing situation. A mutual supportive relationship between nature and society need to be established, and the interventions should also involve the active participation of the local inhabitant and stakeholders to increase the resiliency towards certain change of the systems in the future. To realize these intentions, principles of building with nature and ecosystem services can be used as bases to formulate the design and development strategies for the estuary of Volta Delta.

Building with Nature

Building with Nature approach looks for integrated and flexible solution by making use of natural processes in such a way that meets the need for infrastructure while creating the opportunities that benefits both the economy and ecology sectors (De Vriend & Van Koningsveld, 2012).

Building with Nature approach helps to explore ways to deal with uncertainties and multi-stakeholder decision-making processes. In the development of design principles, the location-specific design rules and environmental norms are needed to fit the solution with the local environment. The societal factors needs to be taken into account to make sure the application of the concept could be adopted by the local communities.

Strategies in using the Building with Nature approach:
Multifunction Infrastructure
Utilize natural processes and provide opportunities for nature as part of infrastructure development processes, as well as align the interest of the stakeholders.

Adaptable Solutions
Promotes the consideration of more gradual developing solution to allow society to respond and adapt to the changing circumstances.

Active Stakeholder Involvement
“Building with nature also means building with society” (De Vriend & Van Koningsveld, 2012). Provide valuable insights by enhancing the stakeholder involvement into local systems to increase the possibbility of acceptance of the offered solutions.

Governance Processes
The project have to comply with existing legislation and procedures. To understand how the system works and the important players is important to help to identify and connect to relevant arenas and actors.

Dealing with Uncertainties
The Building with Nature approach also aims to explore and evaluate the options to deal with the uncertainty in the future.

Ecosystem Services
This concept shows a healthy relationship between natural environments and human well-being and the how benefits and value for society could be gained by the connection between spatial structures and ecological processes. (Andersson, 2006; Termorshuizen and Opdam, 2009, in Lierop, 2011).
This project aims to optimize the potential of the ecosystems to cope with the challenges in the estuary, both to work together with the water dynamic in making favorable condition for living environment and to improve its economical value for the local communities. In this case, the use of ecosystem services needs to be limited to sustainable levels in order to ensure that natural systems keep functioning to provide these services (De Groot, 2006).

Another reason to use the principle of ecosystem services principles is to provide insight that maintaining ecosystem by natural processes is often cheaper than to substitute the loss of an ecosystem service by heavy infrastructure and technological solution (TEEB, 2009 in Lierop, 2011), where in the estuary of Volta Delta case will help the financial limitation problem to develop this region.

The ecosystem services principles can be divided in four groups (TEEB, 2010 in Lierop, 2011). The Provision services which include the food production and fresh water provision, The Regulating services which include the erosion and flood control, The Cultural services which include the educational, recreational and other cultural benefits, and The Supporting service which include the nutrient cycles.

Conclusion:
Towards Sustainable Development

The adaptive design strategies for sustainable development of the Volta Delta's estuary can be achieved by applying the three theories elaborated above. The three dimensions of sustainable development; economic development, social development, and environmental protection (Munier 2005, Koglin, 2009, Shen et al, 2011) are included in the combination of the three theories as will be applied in this project (see diagram.x).

The perspective of landscape as processes will be applied in this project on the Investigation Stage; where the estuary will be analyzed in the 3 main dynamics aspect, the Water Dynamics, the Ecosystem Dynamics, and the Anthro-Po-Dynamics; as well as on the synthesis of the design principles as the result of the Investigation stage.

In this project, the Building with Nature approach will be used in the Scenario Building Stage which could will result the Design Strategies in the regional and local scale. The exploration of the scenarios is a form of dealing with uncertainty. Independent, dependent and constant variables will be tested in plausible scenario to formulate the most feasible scenario as proposal for sustainable development planning in the Estuary of Volta Delta. Multifunction Infrastructure and Adaptable Solution will guide the formulation of design strategies. Active Stakeholder Involvement and Governance Processes strategies will be implemented in this project by the workshops and discussion with the local stakeholders and the other experts from various disciplines together as this project is part of The Volta Delta Project by DIMI (Deltas, Infrastructures, and Mobility Initiative) and Delta Alliance.

The Ecosystem Services principles will be applied as an assessment on the Implementation Stage. To optimize the role of native ecosystems for the human well-being in spatial and ecological processes, the detail designs need to provide the provision, regulating, cultural, and supporting services.

[Diagram: Theoretical Framework]

Figure 2.2 Theoretical Framework
Source: Author
Figure 2.3 Research Framework
Source: Author
Research Framework, Approach and Methods

There are three main sections in this thesis project's methodology (see diagram, p.26). First part is the Investigation. In this part, the analysis about the relation between the natural and human processes in the Volta Delta's estuary will be investigated. The analysis will be based on the perspective of the Landscape as Processes. The second part is the Scenario Building. A plausible scenario, design strategy, and selected location as the most affected areas will be the results on this section. The third part is the Implementation of Design Principles, in which the design strategies will be elaborated into several detail designs.

I. INVESTIGATION

Approach:
- Layer Approach
In the perspective of landscape as processes, to address the interrelation between the natural and human systems, the estuary will be analyzed in three main layers, the water dynamics, ecosystem dynamics, and anthropo-dynamics.
- Cross-reference Mapping
The information was gathered in four ways. Literature study from various engineering fields, the map readings, site visit, and the discussion with the experts from various disciplines. The information is processed to create conclusion maps of the processes, sections and diagrams showing the spatial development regarding the three dynamics in the estuary.

Methods:
Water Dynamics
In this section, the water system on the larger scale is investigated to see the area of influence in relation to the delta and the estuary in particular. The dynamic forces which come from the river, the sea, and the atmospheric force, and how these forces influenced the spatial development through time will be discussed.

Ecosystems Dynamics
In the Ecosystem Dynamics part, first the type of the ecosystems in the estuary will be analyzed including the component and the cycle of each ecosystems. The goal from the analysis is to understand the healthy habitat requirement and the interrelation of different ecosystem in the estuary and to see how the ecosystem services concept can be explored. On the next step, the spatial principle on using the ecosystem as natural defense from the erosion and flood risk will be discussed.

Anthropo-Dynamics
In the Anthropo-Dynamics part, how the social and economic activities influence the landscape will be discussed. The main economic activities greatly dependent on the natural resources. It makes the type of the activities, the mobility and how it could change the landscape in the future need to be analyzed. On the second part, the influence of the economic and social structure of the local communities to the land use and spatial pattern will be investigated. On the third part, the elevation of land in the estuary area will be analyzed together with the other spatial criteria from typology of local communities settlement, to map the possible location for the community's migrations from which are living in the most vulnerable area.

Design Experiments
On the Investigation part, the design experiment will be conducted in searching the interrelation between Water Dynamics, Ecosystem Dynamics and the Anthropo-Dynamics to formulate the design principles. Some case studies will be used as input for the design and practical principles. The principles will be categorized based on the role and relation between human settlement, the natural and cultural landscape. These principles will be applied later on the design strategies in some selected areas in the Volta Delta estuary.
II. SCENARIO BUILDING

Approach:
Scenario building is used as research approach to study the spatial change on the estuary scale in the next 50 years in the influence of variables in the extreme ratio of combination between them. This study is used as a tool to formulate design briefs by understanding the elements which will be significantly influenced by the spatial development in the future.

Methods:
In this stage, the combination between constant, independent, and dependent variables which could influence the future condition on the estuary will be discussed. The constant variable is the sea level rise’s rate of 3mm/year and average erosion rate of 4 m/year. The independent variables include population growth, economic growth and nature conservation. Three scenarios will be developed with 3 independent variables, with dominance of positive growth of one independent variable and negative growth or stagnancy of the other two independent variables. Four dependent variables will be used as comparable elements between three scenarios. The dependent scenarios include the water management, food production, sea level rise and erosion control, and settlement type and mobility. Comparison between the dependent variables from all scenarios will be used to develop the consensus model and design strategies for sustainable development proposal for the estuary area. The three scenarios will be overlaid to find the balance on the variables to accommodate the negotiation between various actors or stakeholders and determining the most affected areas. Some locations in the affected areas with various spatial characters and combination of different communities will be selected to be developed further on the next stage of this research. The layers of water systems, elevation, infrastructure, current settlements, will be studied to develop the scenario on the spatial perspectives.

Design Experiment
On this stage, the design experiments are conducted by combining the determined variables to study the influence of these variables in the spatial dimension. The comparison of the three extreme scenarios could be used to the further experiment to formulate the feasible designs and strategies.

III. IMPLEMENTATION

In this stage, the design strategies which are determined as the result from the scenario building stage, will be elaborated into spatial and systemic detail designs on the selected areas in the estuary. The design principles from the result of the analysis and case study on the Investigation stage will be tested and adapted.

Methods:
Design Experiment
On this stage, the design experiment will be conducted in the process of applying the combination of design principles to suit the specific condition on each selected area. The principles of Ecosystem Services will be used as an assessment to realizing the sustainable development goal and optimize the ecosystem role in the nature and human systems.
02.03 Time Planning

**Investigation**
- Site selection
- Initial site analysis & problem statement
- Research question & sub-research question
- Initial theoretical framework
- Initial research methodology

**Scenario Building**
- Elaborated site analysis
- Design Experiments to formulate Design Principles
- Methodology (Theoretical Framework, Research Framework and Methods)
- Developing Scenarios
- Initial Conceptual Design
- Draft Report 1 (Problem Statement, Site Analysis, Theoretical Framework, Methodology, Initial Scenario Building)

**Design Principle Implementation**
- Developing scenarios, determining the most affected area
- Experimental Models
- Estuary scale design strategy
- Elaborated design and development strategy for some selected areas
- Draft Report 2 (Completion from Draft Report 1 with initial description of the design)
- Draft Design (Local scale) – elaboration with plans, sections and perspective drawings
- Draft Report 3

**Reflection**
- Complete detail illustration of the designs
- Reflection: Design value (ecological, social, economic)
- Physical Model
- Report

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03

LANDSCAPE AS PROCESSES

(left)

Figure 3.1 Coastal area at Ada Foah

Source: Author
The Formation and Major Influences

Based on delta classification by Galloway (1975), the lobe-shaped of Volta Delta can be included between the (river) sediment and wave domination (see Figure 3.3). It have only a single channel to bring the sediment from the upstream to the delta, which makes the tidal influence is only a minor importance on shaping the Volta Delta. The sediment domination is the result of historic abundance of riverine sediment input into the system during the Holocene (Roest, 2018). It can be seen on the seaward protrusion from the bed-rock geological composition. The Volta Delta later become a wave-dominated delta as the distribution power of the waves striking the delta shoreline is stronger than the carrying power of the river.

The wave domination formation which characterized by a strong long-shore current become clear with the smooth coastline contour and well-developed beaches and dunes. A sand spit (an elongate and narrow accumulation of sediment that is attached to land at one end) develops and protects the extensive wetlands that cover the delta plain (see Figure 3.4). It is possible that the delta could shrink and eventually disappear if the wave climate become strong enough to carry all the river sediment away (Bosboom & Stive, 2010). The main elements of the Volta Delta consist of a single channel and estuary, two main coastal lagoons (Songor and Keta Lagoon), extensive wetlands and large sand spit formed from the river mouth towards the east (see Figure 3.2).
The formation of the delta depends on the interaction between the river flow and sediment supply, and the distribution of the river sediment by waves and tidal current. The relative influence of these three major factors affecting the morphological structure of the delta.

Fig 3.3 Delta classification by Galloway (1975)
Source: Drawn by author, adapted from Bosboom & Stive, 2010

Fig 3.4 Formation of wave-dominated delta
Three deltas with comparable shape and formation.
Source: Drawn by Author, adapted from Bosboom & Stive, 2010

Volta Delta, Ghana
The Living Estuary

Fig 3.5 The Volta Delta boundaries.
Source: Drawn by Author, adapted from DECCMA, 2017.
The Boundaries and Vulnerability Rates

The Volta Delta is defined based on 5m-contour line above sea-level and administrative districts (see Figure 3.5). The 5m-contour line focuses attention on the impact of coastal processes and hazards linked to sea-level rise and climate change. The administrative boundaries cover nine coastal districts; South Tongu, Ada East, North Tong, Keta Municipal, Ada West, Ketu South, Central Tongu, Ketu North, and Ningo Prampram. The delta covers an area of 4553 sq.km, with total population of 856.050 (Ghana Housing and Population Census, 2010) with fishing, agriculture and salt production as the main source of livelihood (DECCMA, 2017) (see Figure 3.6).

The vulnerability assessment by DECCMA (2017) indicated that the risk levels vary mainly between medium and high risk from multiple hazards namely coastal erosion, flooding, drought and salinization. This indication is corresponds with the vulnerability assessment of the sea level rise modeling. This modeling showing the rates for one meter (predicted global mean sea level rise), two meter (the upper limit of global mean prediction), and for five meters (a long term scenario involving catastrophic condition) (UN-Habitat, 2018) (see Figure 3.7).

Figure 3.6 District Boundaries, Population Density, and Livelihood Types.
Source: Drawn by Author, data adapted from Ghana Statistical Service (2014) & http://www.citypopulation.info/
Fig 3.7 Vulnerability area by multi hazards and sea-level rise.

Source: Drawn by Author, adapted from DECCMA, 2017 & UN-Habitat, 2018.
Landscape Typologies

In the Volta Delta, the cultural landscape as agriculture field dominates the landscape type with 44.6% of the total area. It is followed by the natural landscape of savannah grassland (19.8%), wetlands (11.6%), and lagoon (8%). The settlement area covers 6%, and the rest of configuration is covered by forest, sand dunes and muddy areas (DECCMA, 2017 and Addo, 2017).

03.01.03
Landscape Typologies

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Fig 3.8 Landscape type configuration
Source: Drawn by Author
Sedimentation and erosion are natural processes in a delta, it couldn’t be fully controlled. It is about making choices which area needs to be protected and which area needs to let the erosion happened. Understanding the dynamics processes could help in formulating the adaptive design strategies which allows future changes by the dynamics processes.

Analysis:
1. **Water Systems**
   River and coastal system on the larger scale
2. **Water Dynamics Forces**
   The dynamics influences by the sea, river, and the precipitation.
3. **Land Lost and Formation**
   Spatial development by erosion and sedimentation
Volta River and Volta River Basin

The Volta River Basin is a transnational catchment area shared by six riparian countries. The watershed area includes 40.2% in Ghana, 42% in Burkina Faso, 6.35% in Togo, 4.8% in Mali, 3.6% in Benin, and 3.2% in Côte d’Ivoire (see Figure 3.9). The major tributaries of the Volta River Basin are the Black Volta, White Volta, and Oti River. In Ghana, three dams were constructed on the Volta River for hydroelectric power plant and irrigation purposes, the Akosombo dam, Kpong dam, and Bui dam (see Figure 3.10). These three dams have greatly reduced sediment discharge downstream from about 71 million m$^3$/year to about 7 million m$^3$/year (90% reduction) (Addo, 2017).

Before the operation of Akosombo dam, the river discharge varied from the peak season in September and October to the low season in December to May, with the various capacity from 6500 m$^3$/s to 1000 m$^3$/s. After the dam was completed in 1964, the discharge of the Volta River is heavily regulated on average 1150 m$^3$/s (Andreini et al., 2000 in Roest, 2018). The current discharge is therefore slightly higher than the low-discharge flow and much less than the peak discharge flow before the dam.

Fig. 3.9 Volta River Basin
Source: Drawn by Author
Based of investigation of various operation scenarios by Logah et al. (2017), it can be concluded that severe impact by flooding to the inhabited areas will happen if the river discharge exceeds 2300m³/s. Regulated river discharge create relatively constant salt intrusion which reaches 10-15km upstream from the river mouth (Andreini et al., 2000 in Roest, 2018). The salt water intrusion is highly depends on the sea tides, river discharge, and the morphology of the river mouth.
Coastal Development

Evolution phases of the Volta Delta mouth, barrier system and longshore drift cell structure.

(a) Volta River brought sediment downstream. A single longshore drift cell assuring transport of sand from the mouth of the Volta to the Bight of Benin outer barrier. The westward shift of the location of river channel and mouth could be noted on this stage.

(b) The construction of Akosombo dam and the Volta lake. The cell destabilisation associated with the increasing distinct spit, resulting in a drift divide in the area of Keta. The reduction of sediment supply triggers the severe erosion of the Keta-Kedzi barrier sector to assure drift requirements towards Togo.

(c) Continuation of weak through-drift in the Keta–Kedzi sector, where the shoreline was developed in the early 2000s by the Keta sea-defense project.

(Anthony, et al. 2016)
Waves & Littoral Drift Direction
Sediment transport by the wave force can be considered as the most dominant factor along the Ghanaian coast. The wave climate of the Ghanaian coast is dominated by swell from South to South-West directions. These long waves cause a littoral drift along the coast towards the East. This is supported by the evident of the offset eastern spit, the shape of the offshore bar, the diversion of the estuary westwards and the widening of the beach from west to east.

Wind
The Volta delta coast are very steep and narrow with a slope of approximately 1:3, and the lower 1:10 to 1:15 which are unfavourable for the moderate wind climate driven sediment transport (Roest, 2018).

Tides
In the Volta delta, the tides are identified as semi-diurnal, with a mean range of around 1 m, and mean spring tidal range is about 1.95 m (Anthony et al., 2016). The tidal range hardly decay in the estuary up till 5km upstream (Bolle et al., 2015). The tidal flow in the river is influenced by the morphology of the river mouth.
Fig. 3.12 Estuary Dynamics
Source: Drawn by Author
Land Lost and Formation

The combination of alongshore drift and tidal in- and outflow, and the altered flood pattern in the Lower Volta influencing the formation of the sand spit on the river mouth (Roest, 2018; Adjei-Boateng et al., 2012; Obiri Korang et al., 2013). Before the construction of Ada sea-defence structure, a large spit were formed from the west side of the river mouth. The closing of the river mouth makes imbalance in the native ecosystem. It triggers the growth of aquatic weeds which disturb the ecological system and the fishing activities (shrimp and clams industry), and the vector snails which increase the rate of infectious disease on the local communities (Nyekodzi, 2015). Dredging activities carried out by the Volta River Authority (VRA) in 1990 and 2009 were done to break open the spit. It allows the intrusion of seawater into the estuary. When the spit breaks, the loose part of the spit is transported towards the eastern coastline by wave interactions (Roest, 2018). (see Figure 3.13).

The Ada sea defence project (west side of the river mouth), consist of groynes fields in combination with beach nourishments, is built between 2012 and 2016. The groynes block the alongshore sediment transport and the nourishment is functioned as a barrier to protect against wave overwash (Bolle et al., 2015; Bollen et al., 2011 in Roest, 2018). These constructions prevent the western spit to grow back but also plausible in creating flooding disaster on the east side of the river mouth, for example the flooding in Fuveme in 2016 (Roest, 2018).

Fig. 3.13 Estuary Development
Source : Drawn by Author, adapted from GoogleEarthEngine
CONCLUSION

From the analysis of the water dynamics in the Volta delta and the estuary scale, some initial conclusions could be derived:

**Give room for erosion**

The erosion process in the estuary can not be fully restrained. The west side of the river mouth has been protected by the Ada sea-defence project with groynes and sand nourishment which makes the erosion on this side has been prevented. While some adjustment to integrate this system with the natural elements, the east side of the river mouth needs to be prepared for erosion and floods as the result of this hard structures. Some communities need to be relocated to the safer places, and some soft intervention such as sand nourishment need to be applied on the east to prevent severe erosion affect the wider communities.

**Increase water outflow from the dam during rainy season**

The adjustment on the capacity of water outflow during rainy season from the dam is needed. This adjustment will be followed by better distribution of the river water downstream by reopening the abandoned creeks. It could help to prevent floods on the inhabited areas and at the same time aids the native ecosystems.

**Integration with the nature systems**

The construction of hard structures for coastal defence need allocation of huge amount of financial support. It could prevent the cycle of the nature ecosystems, and if it is planned fragmentarily, it will only cause bad impact on the neighboring coast. Combination between hard and soft structure with integration with the nature ecosystem could be the more sustainable approach in dealing with the delta dynamics. For this reason, it is important to understand how the nature ecosystem works to create certain equilibrium in the estuary.
A coast is never a single line to border the land and the sea. It is a natural ecosystem which have high adaptability for the dynamic of the delta. Over exploitation by urbanization, the role of native ecosystems are often neglected. This analysis aims to study the native ecosystem as valuable elements which can be integrated to design a sustainable livelihood while at the same time maintain its ecological value.

Analysis:
1. Mudflat ecosystem
   Component, spatial settings & utilization as coastal erosion
2. Sandy shore ecosystem
   Component, spatial settings & utilization as coastal erosion
Fig. 3.2.2.1 shows the soil types comprise the Volta Delta. Unconsolidated sand, clay and gravels dominate the soil type in the estuary area. These soil types are prone to the erosion if there is no additional measure to protect the coastal area. In the figure (3) also shows that the same zone consist of strand and mangrove area, where the two main ecosystems (sandy shore & mudflat ecosystems) can be utilized to protect the coastal zone from the erosion.
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MUDFLAT ECOSYSTEM

Fig. 3.2.2.2 shows the main vegetation comprise the mudflat ecosystem. Three types of mangroves can be found in the estuary of Volta Delta. The red mangroves (*Rhizophora racemosa*) grows closest to the river or the creeks. The black mangroves (*Avicennia marina*) grows on the swampy area, and the white mangroves (*Laguncularia racemosa*) grows on the slightly higher area in the wetlands. In Ada Ramsar Site (west of the river) there is no *L.racemosa* can be found, while in Keta Ramsar Site, the three type of mangrove species comprise the vast area of wetlands in South Tongu. Mangroves grow on the clay soil with high water level which will be periodically flooded during the rainy season.

Healthy mangroves are a precondition of all aspects of coastal protection. Sufficient sediment and fresh water supply and connections with other ecosystem could benefit in recovering the mangrove ecosystem. Conversely, pollution, subsidence (due to deep groundwater extraction or oxidation upon conversion) and unsustainable use threaten the mangrove existence (Spalding et.al., 2014). The first 100 m mangrove forest can reduce the wave height of 13-66%, while 500 m wide of the forest will reduce 50-99% of the wave height. (Tonneijck et al., 2015).

The lost of mangroves can change the pattern of sediment movement. The rapid breakdown of organic matter makes the soil contain oxygen causing land subsidence.

Restoration of mangroves by enhancing the sediment supplies or applying permeable barrier to reduce erosion may help the re-establishment in the location where mangrove has been lost (Spalding et.al., 2014).
**Rhizophora racemosa**  
**Red Mangrove**

*SIZE.* It can reach 30–50m in height, although commonly will grow 5–8 m.

*HABITAT.* The intertidal wetland zone, with variable rainfall and elevation of 0–6 m elevation between mean sea level and highest tides.

*SOIL.* Fine clay, black mud sediments with relatively high loads of organic carbon. Sites with aerobic sediments consisting of fine sands to coarse stones and rocks, and coral ramparts.

*SALINITY.* The plants survive well in fresh water and grow best in saline soils. The optimal salinity range is 8–26 ppt (parts per thousand), compared with approximately 34–36 ppt for seawater.

(Source : Allen & Duke 2006)

**Avicennia marina**  
**Black Mangrove**

*SIZE.* It can reach 3-15 m high.

*HABITAT.* It grows well on a sand and mud beaches and shores that exposed to air at low tide and under water at high tide.

*SOIL.* It tolerates heat (but require moisture), poorly drained water, neutral to alkaline soils.

*SALINITY.* It could grow in the exposure to both aerial and soil salinity, and fresh water.

(Source : Arnold, 2013)

**Laguncularia racemosa**  
**White Mangrove**

*SIZE.* It can reach 12–18 metres high

*HABITAT.* It typically grows more inland than the other type of mangroves. It grows in coastal areas of bays, lagoons, and tidal creeks.

*SOIL.* L.racemosa could grow in anoxic soils (without oxygen). Although the roots submerged in anoxic soil, the lenticels structures supply the oxygen for the plant to compensate this condition.

*SALINITY.* It has as high as 105 ppt rates of salinity tolerance depending on soil conditions. This high tolerance is due to the ability to excretes excess salt through pores or salt glands on the surface of the leaves.

(Source : Sweat, 2009)
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SANDY SHORE ECOSYSTEM

The coastal green belts zone should not only prevent coastal erosion and other natural hazards, but also take into account the benefit it can give for the socio-economic of the local communities as well as the sustainability in the ecological sectors.

Several purposes that can be served by the coastal green buffer as follow:
- hold and trap sediment to stabilize the shoreline and develop land for areas such as intertidal mudflats with mangroves and sandy coast.
- reduce the force of storm surges and waves
- potential resources for food, materials and livelihood for the local communities
- benefit biodiversity and preserve habitat for wildlife conservation and ecotourism development

In order to provide those services, water-edge vegetation that can be found locally need to take account the width of the buffer zones that depends on the slope of the region.

Fig. 3.2.4 Main vegetation in sandy shore ecosystem
Source: Drawn by Author
Fig. 3.2.2.5 Coconut trees and Spatial configuration
Source: Drawn by Author

- **ATMOSPHERE**: Creating a scenic beach view, supporting tourism purposes.
- **WIND BREAK**: A row or two of coconut trees can reduce wind speed through the area. Protect the houses, crops, and top soil. Reduce wind erosion.
- **SHADING**: Used by locals and tourists alike to help escape from the hot sun.
- **BOAT MOORING**: Often used to supply a friction lock to prevent the net and boat from being pulled back out.
- **ROOT SYSTEM**: Is comprised of hundreds to thousands of thick fibrous roots. It holds soils in place and slows erosion. The decomposing dead trees add top soil and increase the water holding capacity of the soil.
- **BUFFER ZONE**: Min 100m-wide.
The Living Estuary

Wetland is a rich habitat for huge amount of organism. Fig. 3.2.2.6 shows the birds species that can be found in Volta Delta wetland as researched by Piersma & Ntiamoa-Baidu (1995). The diagram also shows the interconnection of the organism that live both in the mudflat and sandyshore ecosystem. Three type of endanger species of marine turtle, namely the green, leatherback, and olive ridley marine turtle seasonally nest and breed on the Volta Delta beaches, especially those close to the estuary area. The diagram also intends to show the living cycle of the ecosystems and how a combination of healthy ecosystems could establish the natural system to help the coastal protection.

Native Animals and Its Living Cycle

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CONCLUSION

Re-establish Buffer Zone

To give space for the water dynamic, the boundary between the waterline and the area where people can begin to build the settlement should not become a single line, but rather it requires a buffer zone with a healthy span range. This zone needs to be re-established by providing the required condition for the native ecosystem to grow, for example by bringing back directed periodic floods to aid natural distribution of the mangroves, and involving the communities to replanting the zone with certain species that can hold the soil from the challenge of coastal erosion. In addition, the role of the native ecosystem should not only protect human from possible hazards, but also bring new opportunity as source of livelihood and ecological sustainability.

Conserve the turtle breeding beach

Type of interventions should consider the preservation of required condition and space to keep a healthy ecosystem cycle. On the coastline, hard structures as protection against erosion should not prevent the marine turtle to land on the beach. Eggs produced by turtles do not fully hatch. Hatching eggs can provide nutrients for infertile sand. This allows vegetation such as ground cover to grow and nutrition supply for coconut trees which will then form a new system that can withstand longer sand erosion eroded on the coastline area.
In Volta Delta, the livelihood of the local communities are still highly dependent to the natural resources. It makes the economic and social activities are strongly related to it. It is needed to understand on how the development of living spaces and economic activities could adapt to the dynamic processes of the delta.

Analysis:
1. **Main economic activities**
   Fisheries & aquaculture, agriculture and mangrove harvesting
2. **Land use and spatial configuration**
Main Economic Activities

Artisanal Fisheries

Vegetable Farming

Mangrove Harvesting

Fig 3.2.3.2 Main Economic Activities
Source: Author
1. FISHING

Artisanal fisheries, small-scale fisheries generally using traditional fishing techniques and small boats, is one of the main livelihood of the coastal communities in Volta Delta.

From the interview with the Wildlife Division officer for Keta Ramsar Site, information about the cycle of fishing activities is gathered. The peak productive fishing season is between August to October. The second productive season is between April to June, while the least productive season is between November to March. It is related to the annual climate in Ghana where the rainy season fall within March and November with the peaks are in May/June and October. The peak of fishing season also related to the season where the Marine Turtles can be found on the estuary beach within September to January (see Fig. 3.2.3.3).

![Fig. 3.2.3.3 Fishing activity seasonal cycle](source)

![Fig. 3.2.3.4 Economy cycle in the fishing communities](source)
In their economic system, the fishermen will sell the fish to the women to be processed with smoking technique. The selling revenues from fresh fish will be deducted for fuel and maintenance cost first before it can be divided evenly for each fisherman who went in the same boat. The smoking activity can be done independently by single family or in communal smoking place. Mangrove woods are commonly used to give certain flavor to the smoked fish. The smoked fish will be collected and sold collectively to the larger market or individually as food vendor in the local market which mainly done by the women (see Fig. 3.2.3.4).

Settlement Configuration.
Fishing communities always live close to the coastline and riverbanks. In the communities that have both the sea and river sides, the settlement is built closer to the river side. Most of the fishing boats are placed along the riverbanks to keep it safe from the waves. The fishermen prefer to locate the boats close to the houses to look after it easily. On the communities that only has sea side, the boats are located on the sloping beach.

Coconut trees grow around the settlement. Some of the communities has layers of coconut trees on the seaside, but some other settlements are exposed. The houses are built close to each other with woven coconut/palm leaves separate them to give privacy for each house. Communal space can be found at the shaded area in between the houses, as well as at the inner court of the public facilities such as school or the assembly buildings. (see Fig. 3.2.3.5)
The main crops in the coastal region are vegetables includes tomato, cabbage, shallot, spring onion, carrot, okra, pepper, and maize. The sources of fresh water supply are obtained by extracting the ground water by deep well with traditional system by using rope and bucket and spread the water manually, bore pump with pipe and sprinkler, and pump the water from the creeks.

The information about the irrigation system was gathered from the interview with a farmer in Ada Foah and Woe. In Ada Foah, the bore pump needs to dig 30-50 m deep to get the fresh water. There is no water storage used in this system. The bore pump is run with generator every time it needs to water the crops. While in a smaller farming in Woe, water supply from water distribution pipe is stored in a water tank which then be...
distributed to the sprinklers. A larger adjacent farming area still using traditional deep well which needs to reach until 15 m deep to get the fresh water (see Fig. 3.2.3.7).

In the farming with irrigation system, the farmers can harvest the crops three times a year in March, July, and December. A month after the harvest period is the planting period where the soil is cultivated, and new seeds are planted. The vegetable crops needs three months to be harvested (see Fig. 3.2.3.6).

Intercropping system between maize and vegetable crops can be found in the observed area in Woe, located on the east side of the estuary. The distribution of the harvested crops are by either collective when the truck pick to the farm land, or individual distribution with informal stall along the main street. There is no crop processing industry found in the observed area.

The main challenge in the agriculture sector is the salt intrusion which avert the growth of the crops, which is caused by the coastal erosion and perpetual extraction of ground water. In this case, distribution and storage of water supply from the river and the rain could help to overcome this problem.

Settlement Configuration
Most of the farming communities settled on the higher area with sandy soil. The houses use more permanent structures such as concrete column, bricks, and metal roof. Close to the river, the village is surrounded by grove of trees while the farms are located on the outer side close to the water (see Fig. 3.2.3.10).
3. MANGROVE HARVESTING

The shift of the livelihood

Before 1960
High low rate of water from the Volta River into the farmland ensure the crop production and fishing activities in the estuary area.

1960 – 1980
The significant reduction of water flow to the farmlands as a result of dam regulation in the 1960s collapsing the agriculture sector with a huge decline in major crops yield and loss of livelihoods in the majority population in the estuary area. This condition make some communities shifting their livelihood to harvest the mangroves to be sold for fuel wood, construction materials and charcoal (Aheto et al., 2016). During this period of time, the activity of harvesting the natural grown mangrove was followed by small scale mangrove planting by individual farmers.

1980 – 1990
Large scale mangrove plantings were done in in 1980s and 1990s by several communities who formed the Mangrove Planter’s Association. The first large scale harvesting after 10-15 years growth of the trees in 2011.

1992-2010
By the economic needs, less awareness of the importance of protective and ecological functions of the mangrove forest resulting the unbalance between the rate of planting to the degradation and exploitation of it. The mangrove extents subsequently declined by 16.9% to 39.46 km² in this two decades period as a result of community harvesting activities (Aheto et al., 2016). And if it is continued, it can increase the vulnerability of the land in the estuary and the delta as a whole.

To overcome these issues, there are some strategies which could be done.
(1) Water management to re-establish the agriculture sector as main source of livelihood.
(2) To control the harvesting activities by creating zoning between the protection and production function of the mangrove forest.
(3) To introduce the substitution of species for fuel wood.
Fig. 3.2.3.13 Distribution of Mangrove Forest
Source: Drawn by Author, adapted from Aheto et al., 2016
The Communities and the Market

The main mangrove market is located in Anyanui, situated on the west branch of Volta river. The market is facilitated with a dock for passenger boats to transport people and goods from the market to Ada Foah. The main mangrove species sold for firewood is the Red Mangrove. This species can grow rapidly close to the water and has more woods from its roots which makes it more profitable in the market. People buy the firewood in daily basis, with one small pack of woods for one family/day for daily cooking or smoking the fish. Larger batch buyers will distribute the woods to the village markets along the coast towards Keta.

The communities who harvest the mangroves live on the wetlands close to the riverbanks, or on the dry area in the middle of the wetlands. The settlement are arranged in clustered configuration and surrounded by trees (see Fig. 3.2.3.16). Beside harvesting the mangrove, the communities also fish on the river, make charcoal from the woods, and plant cassava for domestic use.
MANGROVE RESTORATION PROGRAM

Mangrove restoration program was held by Wildlife Division of Forestry Commission in Ada with the funding from various NGOs, as an effort to replant the mangroves in the wetlands area and to plant *Acacia mangium* as substitute species for firewood. This program involves the local communities of Obane and Kwalakpoyom in the planting process and preserves the mangroves from harvesting.

This program was preceded by re-opening the natural creeks of Luhue and Futue creeks from the aquatic weeds and reeds, and digging the soil to give more space for the water. By this re-opened creeks, the communities get better access to the water to be used for agriculture purposes.

The *Acacia mangium* was selected to be planted because it can grow rapidly with quite amount of branches and could stand in brackish environment. The woodlot can be harvested alternately in different lots in 4-5 years. The other plant variant that can be planted as woodlot includes *Albizia sp.*, *Eucalyptus sp.*, and *Leucaena sp.*

From this program we can learn that in involving the local communities in the ecosystem recovery program, we need to give immediate and gradual benefit for them. In this case, better access of fresh water for agriculture can give advantage for them after the creeks is cleared, while long-term benefit can be attained from the woodlot planting.
The tourism industry has considerable potential to be improved as it is part of the development plan from the Ministry of Tourism, Culture and Creative Art of Ghana (MOTCCA) to expand the existing tourism destination from the core triangle of Accra-Kumasi-Cape Coast to the new corridors, including the secondary tourist ‘spurs’ towards Ada Foah (see Fig. 3.2.3.25). However, this industry has not absorb employment significantly for the local communities. Tourism facilities are all managed by private individuals owned by Ghanaian from bigger city such as Accra, or foreign owner. In current condition, ecotourism is only beneficiary economical to boat owners who carry tourist around the island. This has not been aligned with the purpose of ecotourism itself where its function should provide “better linkages, reduce leakages of benefits out of the locality, create local employment and foster sustainable development of the locality” (Brinks, 2017).

In relation with the flood and erosion, there was no known flood experiences by the tourist facilities, and sand bags were used to control erosion on the river side.
Ada Foah is the center of tourism industry of the Dangme East District. With the river and the sea, water sport like sailing, boat cruise, canoeing and fishing become the popular activities to be experienced in Ada Foah.

Tourist could reach the facilities by private and public vehicle from the main junction at Kassee. Boats can be rented from the boat harbor to cruise around the islands in the river, or crossing the river to the western side. Public transport such as ferry also commonly used to cross the river, although it is not currently unavailable. For daily activities, there is passenger boats departing from a smaller dock close to the market which will stop in some point between Ada and Anyanui.

The tourism package offer 1-3 days tour include relaxing at the beach, marine turtle watching, water sport, visiting crocodile island, checking out the basket weaving industry, and palm wine distillers, and visiting the Songor lagoon Ramsar Site for bird watching.

Tourism facilities mainly located along the riverbank as many people from Accra usually use the place to spend their weekends. On the estuary islands, private residents were also built as holiday home. Each tourism accommodation on the riverbank has its own boat dock with rental jet boat as part of the tourism package. The accommodation commonly has one orientation to the river. It is surrounded by trees or wall to keep the privacy (see Fig. 3.2.3.27).

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Fig. 3.2.3.26 Tourism Facilities along the riverbank
Source: Author

Fig. 3.2.3.27 Spatial configuration of the tourism accommodation in two different locations.
Source: Author
CONCLUSION

Spatial Configuration

Three types of relationship of settlement configurations towards the natural water system can be seen in these following diagrams:

- **Fishing Communities**
  - Settlement are built closer to the river side
  - Settlement are surrounded by trees, but are still exposed on the sea side.
  - Settlement are built parallel to the coastline

- **Farming Communities**
  - Settlement are built closer to the river side
  - Settlement and farming field are separated by grove of trees
  - The farming field are located on the outer side of the village, closer to the water.

- **Tourism Accommodation**
  - The accommodation are built on the edge of an island or along the riverbank
  - The accommodation is surrounded by trees or wall to provide privacy
  - Each accommodation has its own boat dock
  - The accommodation on the riverbank are built on the edge without any distance as bufferzone towards the river.

Accessibility

To increase the economic potential of local communities, connectivity and accessibility needs to be improved. Both land and water access can enhance the distribution of agricultural and fishery products. Potential improvements can also trigger varieties of derivative business from agriculture and fishery sectors such as food processing or construction material from the clam shells.

Zone differentiation for protection and production function

The livelihood activities that still have high dependency to the natural resources need to have zonal arrangements to ensure that the utilization will not threat the protection zones. For the exploitation of the wood materials, this effort could also be aided by the introduction of substitution species with faster regeneration time without loss of the functions it replaces.
03.03
INTERRELATION OF THE THREE DYNAMICS
as design principles

The interrelation of the three dynamics for design principles, can be concluded in the types of relation between human settlement, cultural and natural landscape.

I divided the role of cultural and natural landscape in this area into 3 roles which also related one to the other (see Fig. 3.3.2). 1) To breath, is the role for the land part which gives space for erosion and sedimentation. 2) To protect, is the role for the landscape which could hold the land in place. And 3) To produce, is the role for the cultivated area for agriculture and aquaculture. The outer circle on the diagram shows the degree of human intervention on each role of natural and cultural landscapes, where the dark red color shows the human intervention.

The first interrelation will discuss integrated systems of agriculture and aquaculture with the vegetation as protection landscape. For example, the silvo-fisheries which shows how a sustainable systems of shrimp farming nearby the mangrove forest and how the settlement could be built in this settings.

The second interrelation will discuss how to add economic and ecological value even the place where the erosion and sedimentation occurs. For example, aquaculture on the riverbanks, and how the buffer zone should be maintained on the shore and riverbanks.

The third interrelation will discuss how to use the natural processes to develop the natural protection elements. For example, the use of sand engine and the technique of growing mangrove by flowing more fresh water or trapping the sediment with permeable structures.

On each interrelation, systemic and principle sections are developed as design principles. The conclusion from the reference study is also used as input in developing the design principles (see Appendix 1, p. 181). In the next stage of this research, these design principles will be tested on the selected locations on the estuary area.
**Principle 1**

The design principle 1 shows the combination of recovered mangrove ecosystem as buffer zone along the main creeks, and integrated mangrove-shrimp farming system. The dug soil to create the ponds can be used to stabilize the land close to the settlement area (see Fig. 3.3.3). The allocation of the silvo-aquaculture farm is also based on the consideration of the accessibility to the farmer’s house, river-based and road transportation system, as well as the existing land elevation (Tran, 2005 in Bosma et al., 2014).

In the estuary area, people have started to convert the wetlands into fish or shrimp ponds. A foreign investment has made a large-scale intensive aquaculture near the coast of Ada Foah. Without a guidance system that integrates the aquaculture to the nature system, the expansion of this industry might be uncontrolled and cause environmental degradation that impact the local community.

As some cases in the Southeast Asian countries, over time the transformation of mangrove forest into shrimp ponds has had negative environmental impacts (Primavera, 1991) and has increased inequality, especially locally (Adger, 1999 in Bosma et al., 2014). So that, the silvo-aquaculture is expected to be a win-win solution for the re-establishment of the mangrove forest and offering livelihood for poor communities (Sukardjo, 1989; Primavera, 2000; Oswin & Ali-Hussain, 2001 in Bosma et al., 2014), as well as a form of anticipation of floods and sea level rise in the vulnerable area.
Bosma et al., (2014) describe the types of mixed mangrove-shrimp production system as follows:

1. Integrated system
The mangroves are planted on platforms, and the shrimps are raised in between the rows, with regular exchange of the water for the shrimp management and other aquatic organism.

2. Associated system
The mangroves are planted on one centralized platform, and the water could cover wider area.

3. Separate system
The shrimp pond and the mangrove plantation and clearly separated by dikes, which is also used as biofilter of the effluent of the farm.

(see Fig. 3.3.4).

The yields of the farm could varies greatly depends on several factors such as pond management, recruitment of wild shrimp, stocking density of the shrimp, leaf litter decomposition, tree cover, water exchange, and predators (Bosma et al., 2014).

The mixed mangrove-shrimp production system has been developed in Southeast Asian countries such as Vietnam and Indonesia since 1978 (Bosma et al., 2014). The ratio between the mangrove forest to the open water culture area is maintained between 8:2 to 6:4 (Fitzgerald, 2000; Tarunamulia et al., 2015). Although according to Johnston et al. (2000) shrimp harvest peaked under the cover of 45%, while the estimated highest production of the timber is in the 55% coverage.

The separate system can improve the connectivity of the mangrove plantation to the nature system and create options for intensification. However, this system is only recommended if the practice if intensive aquaculture is intended. Otherwise, it is better to stay with the more sustainable integrated system (Bosma et al., 2014).

In the integrated system, the platform to plant the mangroves needs to have connection to the floods by the tidal influence. It can help to speed up leaf litter decomposition, improve nutrient exchange and the growth of the mangroves, as well as to maintain its contribution to its biodiversity functions (Bosma et al., 2014). In filter ponds, water can be stored during spring tides, and create possibility for the farmer to raise Tilapia or Siganus to improve water quality, and seabass or snapper to prevent disease agents to enter the main pond. (Tendencia et al., 2006; 2013, in Bosma et al., 2014).
Design principle 2 shows the relation of agroforestry principle and settlement in between two creeks. The agroforestry is “land use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence” (www.fao.org). The principle of agroforestry used in this setting is the agrosilvopastoral system which is a combination of three elements, namely trees, animals, and crops that involve animals as well as scattered trees on croplands used for grazing after harvest period (www.fao.org).
In spatial configuration proposed for the estuary situation, the agrosilvopastoral system can be divided into several combination based on the type of agroforestry system by USDA. It includes alley cropping, riparian forest buffer, and silvo-pasture system. While in the agriculture field, the trees also functioned as windbreak to protect people and livestock, benefit the soil and water conservation.

In the setting between two creeks, distance on both sides of the water stream needs to be kept free from construction of any permanent structure to accommodate the seasonal water height from the river. The riparian forest buffer with mangroves trees will be part of this zone. The alley cropping and silvo-pasture will be located with reasonable distance to access the water from the creeks. The irrigation system needs to be provided, with retention basin to supply the water even during the dry season. The water basin will only be viable on the clayish soil with shaded area to reduce the intensity of the sun penetration and reduce the evaporation of the stored water. The settlement can be built on the higher ground that could still easily access the agroforestry field (see Fig.3.3.5).

The trees that will be planted in alley cropping system are the substitution species for mangroves as firewood, such as Acacia mangium, Albizia sp., Eucalyptus sp., and Leucaena sp. The trees are arranged in the distance and position that will not shades and hamper the growth of the crops. The planted trees have various kind of utilization based on the age of the harvesting periods. For example, Acacia trees will be ready for harvest as fuel wood after 4-5 years, 6-7 years for pulpwood and rotation of 15-20 years as sawn timber (Orwa et al., 2009). While eucalyptus trees needs 3-4 years for fire woods, 8-15 years as pulpwood and charcoal, and 15-30 years as sawn timber.
Principle 3

In the Volta Delta area, reported by citifmonline.com, that in 2014, Volta region is the highest producer of rice in the country. With two rainfall pattern, fertile land and Volta river that flowing through this region, the water supply is abundant to the farms. However, the cultivation of rice farming in the coastal areas has not been widely implemented.

In certain areas in Asian countries, such as West Bengal and Kerala in India, and Java in Indonesia, tidal swamps in coastal area have been converted as rice fields (Kutty, 1987). This rice field is cultivated seasonally during the rainy season when the coastal inundated areas become less saline. Long-stemmed and salinity resistant varieties paddy are used. The brackish water
The involvement of the farmers in the water use and management practices of this culture is considered crucial (Koide et al., 2015). Regarding the African aquaculture situation, Miller (2006) mentioned that the opportunity of aquaculture lies in extensive application of integrated aquaculture with cost-effective and locally available inputs over large areas, rather than maximized production in intensive practices.

Fig. 3.3.10 shows the rotating system of the rice-fish culture. During the rainy season, the fish will be raised in the refuge pond. After the harvest period, the rice area will be flooded and so that the fish will have larger area to grow. In the case of higher salinity during the dry season, species of shrimp can also be raised in the pond.
Principle 4

Fish supplies about 60-70% of the protein in a typical coastal Ghanaian diet (Rao et al., 2012). Beside the large scale aquaculture in the Volta Lake, small and medium scale aquaculture has been growing along the Volta River. Pen and cage fish culture are two types of small to medium scale aquaculture that can be found along the river. Pen and cage can be constructed with wood, bamboo, etc. as frameworks on which the nets or other fencing materials are stretched to form an enclosure. In pen culture, the river bed serves as the bottom of the pen, while the cage culture needs sufficient space between its bottom and the river bed (www.mofa.gov.gh).

In applying the integrated spatial configuration, certain distance as riparian buffer zone needs to be established before any settlement or hard edges on the riverbank can be constructed (see Fig. 3.3.11). Based on the Standard for Riparian Buffer Zones by Ministry of Water Resources, Works and Housings of Ghana, Along the Major perennial river/stream, 10-60 meters buffer width needs to be established, while at the wetlands, it is 30-meters around the perimeter as defined from the high water elevation (MWH, 2011).
In this principle, the natural processes is utilized to develop the protection elements. The first principle is using the sand engine principle where large amount of sand is located on certain point along the coastline to be distributed gradually by the waves and nourish the adjacent coastline from the erosion. The second principle is the methods to growing the mangroves. The first method includes the strategy to bring back the periodic floods from the river. The flood will inundate the wetlands and distribute the seeds of the existing mangrove to the larger area of the wetlands, that will slowly settle and grow. The second method is to capture the sediment brought by the waves by using permeable structure made of brush woods to slow down the waves and settle the sediment. As the sediment grow and the soil stabilized, the planting of the mangroves can be started. The existing permeable structures can be taken off and reinstalled it further towards the water (see Fig. 3.3.13 and 3.3.14).
Design Hypothesis

As conclusion of the analysis, hypothesis also tested in the estuary scale, to see the consequences of changing certain system. These experiment will also be developed as part of the adaptive design strategy for the estuary scale.

Bring and distribute more fresh water

The construction of the dams on the upstream of the volta river reduce the supply of fresh water to the delta. This condition increase the salinity of the water by the intrusion on the sea water which collapsing the agriculture field. By regulating the dam to bring more fresh water, and distributing towards some new channel and reservoir could increase possibilities for better condition in the agriculture sector. The periodic floods also helps the distribution of mangrove seedlings. The channel which could be connected to the lagoons could help to reduce the salinity of the water and bring more fish. The soil which dug to connect the channel can be put to higher up and add fertile soil in the agriculture area.

Keep the river mouth open

By seeing the development of the sand bar on the estuary, it is likely that the accretion on the west side of the estuary will be created again in the future. It is because the less outflow from the river by the regulation from the dam. This offshore bar reduce the flow from the tide into the estuary. The dredging activities were conducted in 1990 & 2009 to open the sandbar and allowing the wave into the estuary. The tide flows benefit the livelihood by creating suitable condition for the clams.

Establish buffer zones

Buffer zones need to be re-establish along the coastline and the riverbanks. It will be a combination of healthier mudflat and sandyshore ecosystems along the re-opened creeks, certain distance needs to be maintained until the settlement can be built. Smaller creeks and channels will be connected to the irrigation system for agriculture. Some field will also be developed for agroforestry where the trees can be harvested periodically for economic purposes and the firewoods demands.
The Living Estuary
04
ADAPTIVE DESIGN STRATEGY

(Left)
Figure 4.1 Boat Landing in Azizanya, Ada Foah
Source: Author
04.01 SCENARIO BUILDING

Building the scenarios in the estuary of Volta Delta aims at seeing the extreme plausible conditions caused by certain variables in the future. It can be used to trigger the discussion between different stakeholders to prevent the delta to develop towards an unfavorable situation. The scenarios will also help to determine certain locations which will be affected the most by all scenarios. Adaptive design strategies for more sustainable future will be developed by using design principles which has been determined on previous stage of this research.

This scenario building stage will use three independent variables; 1) population growth 2) economic growth 3) nature conservation; four dependent variables ; 1) water management 2) food production 3) erosion control 4) settlement and mobility; and one constant variable of sea level rise’s rate by 3 mm/year and average rates of coastal erosion of 4m/year; to study the spatial development in the estuary area in the next 50 years.

Independent variable is a factor or phenomenon that is manipulated to influences another associated factor or value of a dependent variable. On each scenario, one independent variable will increase or have positive growth while the other two independent variables will have negative or stagnant growth. The four dependent variables will be used as comparable elements between the three scenarios. The result of this scenario study will present the design strategy on estuary scale based on the main aspects in the dependent variables, and select locations in the most affected areas by the three scenarios to test the strategies in the site specific landscape designs.
The spatial development of the extreme scenarios are built based on the layer analysis of the current situation in the estuary. The layers consist of the water systems, elevation (contour), human settlement and road infrastructures.
SCENARIO 1

Figure 4.4 Comparison map between current situation and the Scenario 1
Source: Author
SCENARIO 1

What will possibly happen in the next 50 years, if the population grows rapidly while the economic sector is not growing/stagnant and there is not much effort in nature conservation?

This scenario is developed based on the high-rate of 2.5% population growth per year in Volta region, Ghana (GSS, 2013). This rate is considered very high with doubling population will happen in 26 years comparing to average doubling time of 170 years for a developed country (National Population Council, 2006).

In 50 years, the population growth could be calculated as follow:

\[ \text{Pop}_{\text{Future}} = \text{Pop}_{\text{Present}} \times (1 + i)^n \]

\[ \text{Pop}_{\text{Present}} = \text{Present Population} \]
\[ i = \text{Growth Rate} \]
\[ n = \text{Number of Periods} \]

(http://pages.uoregon.edu/rgp/PPPM613/class8a.htm)

By this formula, the population will be 3.44 times the current population. This growth could be caused by the natural increase, migration, and better access to the medical facilities. Although even in developing countries where rural to urban migration rates are high, 60% of urban population growth rate is attributed to natural increase (Montgomery, 2008).

In the increasing needs of housing, the settlement will be densified. Settlements will grow along the infrastructure, on higher elevation area. While the labor force; the actual number of people available for work, are abundant; the natural resources will be exploited for food provision purposes, and the demands of fresh water supplies will increase significantly. The economic stagnancy makes agriculture and aquaculture technology stay in modest level. In order to create a proper condition to live and overcome the challenges caused by this scenario, some measures need to be done.

Water Management
To avert a deteriorating condition of land subsidence caused by extraction of ground water to fulfill the fresh water demands, water retention basins need to be provided. With technology and financial limitations, the basins will be made in community-based scale.

Food Production
To provide sufficient amount of food, extensive farming fields will be cultivated. Traditional agriculture and aquaculture techniques will still be applied. The widespread changes in landscape use as native vegetation and forest are cleared for farming may result in a number of profound impact caused by ecological changes (Béné & Russel, 2007). The lagoons will be exploited for aquaculture and salt mining which threat the natural ecosystem. Mangroves cutting for firewood demand will worsen the deforestation of the mangrove forest.

Sea Level Rise and Erosion Control
People will move to live more inland as the current coastal protection will still causing severe erosion and flood for the coastal communities. Economy stagnancy will only enable minor addition of coastal defense.

Settlement Type and People’s Mobility
On the swampy area, the people will start making house on stilts, and the mobility will mostly use small boats as the road and infrastructure will not be significantly improved due to the economy stagnancy.
Figure 4.6 Development in Scenario 1
Source: Author

**Densification**
- densification of the settlement areas
- expansion of agriculture fields and aquaculture ponds
- retention basins and basic irrigation system

**Expansion**
- extension of the settlement area following the road infrastructure
- migration of communities from the eroded coastal area to the safer inland area
- extensive agriculture fields and aquaculture ponds
Figure 4.7 Dependent variables affected by Scenario 1
Source: Author
SCENARIO 2

Figure 4.8 Comparison map between current situation and the Scenario 2
Source: Author
SCENARIO 2

What will possibly happen in the next 50 years, if the economy rapidly grown while the population grows in low rate and there is not much effort in nature conservation?

There are some indications of positive overall economic growth in Ghana, with 9.3% advanced economy year-on-year in the third quarter of 2017 (https://tradingeconomics.com/ghana/gdp-growth-annual) and predictions that poverty levels will continue to decline in the decades to come (Claydord, 2005). Cultural acceptance of more effective reproductive control methods, and changing status of children as not to be significant contributors of family income, and highly cost of child rearing causing the decline in family size. (Boone, 2013).

In this scenario, fertile soil, river and wetland habitat of the estuary will be exploited for intensive agriculture and aquaculture industry, to attain through-out-the-year harvest. With less attention of nature conservation, industrialization yields water and air pollutions which could effect in the extinction of species in the native ecosystems. Road-based transport and large-scale infrastructure is seen as a precondition for changes in the economy, scale of production and access to larger markets.

Water Management
Along with industrialization in agriculture and aquaculture sectors, advance irrigation systems will be established with pumps and sluices system. The waste management from the polluted water by the industries will be provided by water purification technology. Regular dredging activity will allow bigger ship mobility in the estuary with new ports for people and good’s transport.

Food Production
Intensive farming technology in agriculture will be enhanced along with food processing industry. Formal and rigid agriculture pattern will be applied as result in irrigation efficiency. Dredging activity will provide additional fertile soil from the river for the expansion of agriculture fields. New roads and ports will support distribution for agriculture and aquaculture products. The abundant food production will serve food supply for other regions.

Sea Level Rise and Erosion Control
The coastline and riverbank will be dominated with hard edges and hydraulic infrastructures as erosion and flood defense.

Settlement Type and People’s Mobility
Industrialization will attract people to live and work in the estuary area. With improvements in the building technology, densification of the settlement area makes the formal settlement pattern and higher housing building be constructed to accommodate more people to live in the city. The tourism facilities no longer offer the serenity of nature ambiance, rather shift to provide facilities for business purposes. New road infrastructures accommodate higher amount of cars and public transport for people’s mobility.
Infratrusture
- Erosion control with hard structure in combination between dikes and groynes
- Construction of transportation and industrial infrastructure

Intensification
- Intensification of agriculture fields and large scale fishing techniques for higher productions
- Processing industry for agriculture and aquaculture products
Figure 4.11 Dependent variables affected by Scenario 2
Source: Author
SCENARIO 3

Figure 4.12 Comparison map between current situation and the Scenario 3
Source: Author
SCENARIO 3

What will possibly happen in the next 50 years, if the nature conservation become the priority in the estuary's development, while the population and economy grows in low rate?

From the current situation, this scenario could be happened if the nature is given more space to grow. The fresh water flow from the river will be increased by regulating the existing dams to keep the river mouth open so that the balance in the brackish water area can be maintained. In this situation, the current population will be slowly move northwards to give more space for the coastal vegetation to take over the coastal area. The similar action will be done along the riverbank. This situation will maintain the natural processes in the estuary and generate the natural protection to lower the vulnerability from the erosion and floods.

This scenario will influence more the bigger city nearby as the nature conservation will prevent improvements of current livelihood which still really depends on the nature resources. Thus, the urban planning and design for the bigger city will be needed to overcome the migration from rural to urban area.

Water Management
By allowing more fresh water from the river to the estuary, could slowly open and reconnect the creeks from the river. Periodic floods from the river could help seedlings distribution of the mangroves to grow.

Food Production
The traditional fishermen will still use traditional way of catching the fishes to maintain the natural ecosystem habitat.

Sea Level Rise and Erosion Control
Native ecosystems will play role as buffer zone to protect the coastline and riverbanks from erosion and flood.

Settlement Type and People's Mobility
The low rate of housing demand and modest level in building technology will keep traditional and low-rise housing constructions. The ecotourism will grow with more activities related to the nature. As the infrastructure doesn't improve much due to the economy stagnancy, the mobility of the local communities and the ecotourism’s visitors will use more the small or traditional boats.
Figure 4.14 Development in Scenario 3
Source: Author

**Water Regime**
- Reopening natural creeks
- Floods the wetlands periodically
- Relocation of settlement on the vulnerable areas

**Re-established Ecosystem**
- Expansion of mangrove forest
- Coastal dynamics with erosion and accretion on the east side
Figure 4.15 Dependent variables affected by Scenario 3
Source: Author
04.02 DESIGN STRATEGY ON ESTUARY SCALE

From the extreme scenario study, the difference in the measure required in the 4 main aspect of dependent variables represented where this extreme state has different livability limits. By comparing the four dependent variables (see Fig.4.16), the common ground are set to be proposed as a strategy design on the estuary scale to address the challenges of coastal erosion and sea level rise, population growth, economic growth and efforts to maintain the balance in nature conservation into the following four sectors:

WATER MANAGEMENT
To bring and distribute more fresh water from the upstream of the river, which means to reopen some natural creeks and could help to keep the river mouth open. The creeks can be used as part of the irrigation system, while the retention basin will be used as water supply also for daily needs.

FOOD PRODUCTION
Intensive farming with intercropping system can be done by maintaining buffer zone towards the open water systems.

EROSION CONTROL
Although there is necessity of relocation from the east part as the most vulnerable area in the estuary, the reestablishment of natural ecosystem is needed to maintain the water dynamics so that it won't highly impact the wider communities.

SETTLEMENT & MOBILITY
For settlement development, certain distance needs to be kept without any permanent structure to give room for the water dynamics. As the creeks will be reopened, combination of road and water transport will be facilitated.
Fig. 4.21 Combined Strategies on Estuary Scale
Source: Author
The location of the sites are selected to test the combination of design principles and strategies into site specific landscape design. Three sites are located within the most affected areas by the three scenarios. They have differences in the type of landscape configuration, communities and spatial relationships between settlement towards the natural landscape. All sites are located in Ada Foah, which is more populated area to be compared to the east side of the river mouth. Choosing the sites on the same side of the river will allow us to see the spatial relation between them.

Characteristic of the sites:
1. It has a relation between the river and the sea, existing groynes, and fishing communities.
2. It has a relation between the river and the sea, combination between settlement and tourism facilities, and the lost wetlands.
3. It is located on the town fringe. It has a relation between the water inlet from river, and combination between settlements and floodplain agriculture.
05
DESIGN
IMPLEMENTATIONS

05.01
Local Analysis (ADA FOAH)
Fig. 5.1.2 Water Dynamics
Source: Drawn by Author

Fig. 5.1.3 Ecosystem Dynamics
Source: Drawn by Author
WATER DYNAMICS

In Ada Foah side, the erosion happens both on the sea side, and the river side. During the high outflow in the rainy season, the river flow will strike the corner of the landform before it turns to the east towards the river mouth. It creates erosion on the riverbank where people use it as fishing boat landing sites.

The boulder groynes and sand nourishment has been constructed on the sea side. But over the time, the groynes and the sands start to be washed away by the strong waves. Fully hard edges on the sea side are not preferable, as it will prevent the sea turtle to land on the beach. On the river side, sand sacks and boat planks were used by inhabitants to hold the soil (see Fig. 5.1.4). To prevent further erosion on both sea and river sides, it needs continous maintenance on the groynes, establishment of plant species on the sand dunes to hold the sand longer, and long term prevention of river erosion (See Fig. 5.1.2).

ECOSYSTEM DYNAMICS

In Ada foah, we can find some small lagoons with stagnant water in the area between the fishing villages close to the river mouth. In these wetlands, the mangroves were mostly cut. People use the area to dump their household waste, as is considered as abandoned place where settlement can not be built (see Fig. 5.1.5).

On the northwest side, less periodic floods from the creeks reduce the natural distribution of the mangrove seedlings towards the larger area of the wetlands. The waste water from the shrimp pond industry close to the beach doesn't have any treatment before it flows out straight to the river. It pollutes the open drainage which flows through the settlements.

Recovering the wetlands to overcome these problems not only will benefit the native ecosystem, but could also create better living environment for the inhabitants (See Fig. 5.1.3).
Ada Foah is a coastal town in Ada East District, second most populated district in the Volta Delta Region with the average population density of 262/km². There are 4 main types of economic activities in the coastal and riverbanks area. (1) The fishing communities are located on the south east part of the area close to the river mouth. (2) The farming communities live more inland where the vegetable crops farming mostly located on the higher land as the fresh water are easier to be extracted from the ground water. (3) An investment of large shrimp pond can be found on the south part, in an axis with the main market which operates weekly as a main trading place in the area. The market are also located near the passenger boat docks on the riverbanks. (4) Tourism facilities such as hotels, private villas, restaurant, boat and kayak rentals are located on the riverbanks.

Fig. 5.1.6 Types of economic activities in Ada Foah
Source : Drawn by Author
Road Infrastructures

The road infrastructure is mainly located in the town center and stops before it reaches the fishing communities islands close to river mouth. (1) The main road connecting Ada Foah to Big Ada and the main junction at Kasse, up north to the highway. In Ada Foah, it is the main road to reach the market and the passenger boat site.

(2) the second line connects the main road to the shrimp pond industry and continue to the coastline towards the Songor lagoon. (3) the third line lays on the backbone of the town, connect the town to the agriculture fields which also benefit for the distribution of the harvested crops. And the last, (4) the road line facilitates new development of tourism facilities. (See Fig. 5.1.7)
Fig. 5.1.8 Landscape pattern & configuration
Source: Drawn by Author
Landscape & Space Configuration

In the relation of topography and morphology of the site, the main development and facilities of the located together with the farming field with formal pattern. On the northwest lays low area with the natural curvy lines from the creeks and floodplain, with clustered small community on the patches of higher area on the wetlands. Natural curve islands with small lagoons towards the river mouth occupied by the coastal communities. (See Fig. 5.1.8)

The domination of vegetation types gradually change from the wetlands towards the coast, with more variety of mangroves and woodlot plants on the wetlands towards domination of coconut trees on the coast. Enclosed space are mostly can be felt in the settlement area where the buildings mostly built close to each other, surrounded by fence or clustered by trees for shading and wind breaks. Open spaces mostly found on the agriculture fields, towards the sea with less houses and in between the islands on the bridge between small lagoons and the vast river. (See Fig. 5.1.9)
In the rural areas and fishing communities along the coast of Volta Delta, Atakpame house is one of the common type of building constructions can be found. The ‘Atakpame’ methods refers to a rectangular wall made of wet mud balls, and laid out by the builder with pegs and string. The mud is prepared in a pit dug near the building site. It is mixed with water, molded into balls shape with 200mm diameter after is kneaded with bare feet. The mud balls will be laid in the courses of up to 600 mm in height and covered with palm leaves to give time for each course to set and dry out gradually before the next course is added. The wall thickness is generally about 300mm with opening for windows and doors are made during the construction process. Five courses of mud will create a wall height of approximately 2.50m. To support the roof construction, short forked sticks are driven into the top of the wall to lay and tie the roof framework. Holes at every 600mm at the top can be made when the last course is still wet as another way to support the roof. Ropes will get through the holes for fixing the wall plate of the roof framework (Essienyi, E, AHI West Africa Associate).

A family house consists of several rectangular buildings with various function. The buildings are arranged around an inner court. Inner court is one of important elements in the house unit where a lot of activities are taken place. At the inner court, we can find the fish smoking pit, place to wash the dishes, place to put sacred area to pray, as well as a place for the children to play. Clam shells are commonly used to harden the soil at the inner court to make it more convenient to be used during the rainy season (see Fig. 5.1.11).
Figure 5.1.12 Building materials
Source: Author

- Thatch roof
- Sun-dried brick
- Clam shells
- Coconut leaves
- Clay wall
- Wooden post
- Fishing nets
- Fishing boat planks
- Woven palm leaves
- Mangrove wood
In the small garden located close to the house, people plant the fruit trees such as papaya, mango and soursop, and medicinal plants such as bitter leaf and noni to cure malaria for domestic use on the manured soil. In the neighborhood, coconut trees dominate the vegetation types while mango trees can also be found in some area more inland. Fig. 5.1.13 shows the comparison of spatial quality could be created by the type of plants growing in the area in the average optimum height.

Fig. 5.1.13 Plant species
Source: Drawn by Author
05.02
STRATEGIES & DETAIL DESIGNS
Guiding the development in a vulnerable area, means we need to zone where the development will be allowed. As we learned from the topography of the site, to maintain the stability and balanced of development, the settlement densification needs to be zoned on the higher area, and restricted on the vulnerable area towards the river mouth and the creek. It can be done by using road infrastructure to direct the development, and transition zones from the settlement towards the natural landscape to edging the town fringe.

This zoning can keep the vulnerable area to give more space for the nature systems. Another measures in following the zoning strategy are to improve the economic axis of the town, and establishing green connection between the 2 outer zones.

Figure 5.2.1 Framework and Zoning
Source : Author
2. GROWING SPACES

The design will not be applied in one period of time, but is a gradual application that gives space for improvisation by local people in using the new spaces. It starts with a small-scale intervention that provides space and trigger functional and systemic change for various activities (1). The next intervention is aimed to integrate a wider system. The interconnection of the two interventions forms a wider space with the dynamics of use by inhabitants that also grow (2). The next step will utilize natural processes which can either expand the space or expanding the influences (3).

This fluid-tending change will keep the integration between the three systems of water, ecosystem and human system in a balance by also providing a vision of added value of function and aesthetics to open wider opportunities for economic improvement.
3. CIRCULAR SYSTEMS

The nature balance is always occur in a continuous circular relationship towards an equilibrium. This concept needs to be maintained in the relationship between design intervention, the influence of nature and the benefits gained back by humans. Knowing how a design intervention affects the cycle is expected to give an idea of how mutual relationships between its components can always be improved, and could be quickly identified which sector needs to be adjusted once one of the components lose it roles.
SITES

Figure 5.2.4 Sites
Source: Author
SITE 1:
Compromising the Erosion

Site 1 is located on the sand spit close to the river mouth. In this location, artisanal fishing communities settled by relying their livelihood to the traditional fishing in the sea. The character of topography in this area is dominated by island-shaped sandy area connected to a strip that is an extension of the main land (see Fig. 5.2.6). In between the islands, we can find small lagoons connected to the river. To prevent further erosion on the sea side, the groyne made of boulders and sand nourishment has been constructed in 2012, while on the river side, no protection has been made. The use of sand bags to prevent erosion is only done individually (see Fig. 5.11, p 104). Therefore, in compromising the erosion, the design intention for this site is to anticipate further erosion on the riverside, as well as maintaining the protection on the seaside.

The lagoons have many benefits for the inhabitants, among others to lay their small fishing boats, also to catch fish for domestic needs. Thus, in an attempt to nourish the riverbanks, it is necessary to keep the connection between the lagoons towards the river. In addition, the design should be able to improve the accessibility of the communities towards the beach which is now hampered by the high sand nourishment.

The nourishment of the riverbanks and the reduction of the force from the river flow towards the land can be achieved by dredging the river on the far side of the land and put the sediment to shallow the riverbanks. This shallow riverbed will
reduce the velocity of the flows. For long term protection, additional sand nourishment can be put in certain distance from the riverbanks as islands (see Fig. 5.2.8). The sand will be gradually distributed by the river and tides flows and slowly nourish the riverbanks.

The sands that are placed in certain angle and distance could deflect the flows of the river current towards the deeper bed. Permeable groynes will be constructed on the riverbanks and catch the distributed sands (see Fig. 5.2.8). This intervention design was made as the result of the experiment with sands and water in a dynamic model (See Appendix 2, p. 189). The shallow riverbed and narrow path above the permeable groynes can be integrated with clam farming that can be extended towards the river along with the increase of the sediment (See Fig. 5.2.14).

The spatial disconnection towards the beach can be facilitated by constructing a building with multiple functions (See Fig. 5.2.11). The building can capture and store the rainwater with underground water storage that will be accessible
for the villagers with a hand pump. This access to the water will be complimentary to the main access for drinking water provided by the government by pipe. In providing clean water, a filtering system with sand and gravels is installed in the core channel, before the water reaches the underground storage. A maintenance door will be provided to maintain the system.

The water catchment building will have 3 floors that could be used for various communal activities, for example informal education. The top floor can be seen from the beach, so that this building could function as landmark from both sides. This building can also be used as watching site towards the turtle beach to support the ecotourism program, as well as monitoring activity for the coastal erosion. For construction of the building, local materials will be used (see Fig. 5.2.10). The familiarity in using the materials will allow the community to be involved in the construction process. By providing benefits for the inhabitants, it will be easier to involve them in the application of a planting program to maintain the existing sand nourishment (see Fig. 5.2.12).
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Figure 5.2.9(a) Site 1 - Section
Source: Drawn by Author
Figure 5.2.10 Water catchment building
Source: Author
Figure 5.2.11 View from existing sand nourishment
Source: Author
Fig. 5.2.12 Involvement of the communities in developing the space.
Source: Author
Galatea paradoxa clam.

The Galatea paradoxa clam is one of the major protein sources for people in Lower Volta and have centuries been the basis of the fishery artisanal and livelihood sources for 1000-2000 people (Amador, 1997). On a national scale, the clam harvesting activity is worth up to 4.8-9.6 million Ghana Cedis (US $ 3.31 - 6.72 million) annually (Adjei-Boateng et.al., 2012). The clams shells themselves can be used for various purposes. As source of calcium for poultry feed, material for paints, alternative stone chipping in concrete, and pavement material such as terrazzo floors (Adjei-Boateng et. al., 2013). During the site visit, it can also be seen in Ada Foah that local people also use it to harden the inner court of their house to avoid muddy surface during the rainy season.

As the result of regime change of the water flow from the Akosombo and Kpong Dam, the distribution of G.paradoxa is currently restricted to a very narrow stretch of the south Volta River, between Agave-Afedume (15km from Volta Estuary) and Ada Foah (5 km from the estuary) comparing to the pre dam period where it stretched between Sogakope and Akuse (between 20 and 95km from Volta estuary) (Amador, 1997 and Lawson, 1963 in Adjei-Boateng 2012).

Although it was documented as fresh water clams, but the brackish water condition in the estuary could actually provide suitable condition for the clams to grow. It was proved from the distribution shift and that the Dredging activities carried out by the Volta River Authority (VRA) in 1990 and 2009 affected the resurgence of the clam fishery at some portion of the Lower River (Adjei-Boateng et. al, 2012). From the research conducted by Adjei-Boateng et. al (2010) the result indicate that G.paradoxa will be suitable to be cultured in the river situation with its filter feeding activity dependent on the water current rather than in stagnant pond. The effect of substrate type between sandy and muddy soil on growth was not significant. However, the substrate type affect the survival, with sandy substrate yielding better than the muddy soil.

The clams are harvested in traditional ways by hand collecting in shallow areas and diving for experienced divers in deeper areas. This activity is carried out in the fishing season (March-December) while the closed season (December-March) harvesting clam is prohibited to give time for clam to perpetuate themselves. Beside this period, no fishing Tuesday and optional fishing on Sunday are regulated by local beliefs and taboo (Abarike et. al., 2015). Tuesday is used as market day to sell the clams.

The population of G.paradoxa is threatened as a result of habitat alteration and overfishing, so that development in aquaculture methods are needed for more sustainable clam fishery. Clam farming that has been developing is done by seeding the juvenile clam in demarcated areas with sticks do shallow area of the river for periods of ranging from 6-8 months to be harvested during the closed season (Adjei-Boateng et. al., 2012).
The permeable groynes will be installed gradually. It is started with the first L-shaped with short distance from the riverbanks (1). As the sedimentation occurred, the structure can be taken off and re-used for the extension of the structure (3&4).
Example of brushwoods as permeable structure to reduce the currents force and increase the chance of sedimentation in building with nature project in Demak, Indonesia.
A healthy living environment can increase the community resiliency. Managing the water run off in the settlement area can be one of the way to achieve it. In the house scale, the rain water can be harvested by installing roof gutter made of bamboo to let the water collected in a big clay pot. Filtering layers of gravel and sands can be installed in the pot to get the clean water for daily use (see Fig. 5.2.16).

In an integrated communal space, in the surrounding of communal fish smoking area, fruit trees will be planted to filter the smoke for better air quality. The communal area will be facilitated with the underground rain water storage to protect from high evaporation rates. The water will also be filtered by layers of sand and gravels and extracted by pump. Half part of the surface to infiltrate the water could be open for maintenance. The shaded area with coconut trees can be utilized for social space and collective activities (see Fig. 5.2.17).

In between the house, New path can be constructed by using local material with the combination of clam shells, gravels, and sand. The modular of the path will includes the gutter as the way to drain the water during heavy rainy season. And it can be made by the communities. The path could make better access for the communities by using bikes to bring the fish or other trading products to the market (see Fig. 5.2.18).
Figure 5.2.17 Communal space
Source: Author

Figure 5.2.18 Modular pathway
Source: Author
The wetlands in between the villages close to the river mouth are mostly now turned into wastelands or unproductive swamps covered with reeds or weeds (see Fig. 5.1.20). The white mangroves have been destroyed by sea intrusion (Christina, 2015), only patches of red and black mangroves can be found in the remaining wetlands (see Fig. 5.2.21). This area is flooded during the wet season, and some area are utilized as shrimp ponds. However, the wetlands can be very useful in reducing the threat of flooding in the settlement area as well as providing habitat for various species to live. With a sustainable management, the wetlands also provide resources of livelihood for the communities.

To recover the wetlands in between the villages, the intervention can be done in some stages (see Fig. 5.2.22). In the transition among the stages, the new spaces created by the intervention can already be utilized for various activities and open to adaptation for a change following the needed space for certain activities.

The intervention is started with re-profiling the topography. The methods of cut and fill the land will allow the basin to contain more water and the excavated soil will be used to stabilize the surrounding area to protect the existing or new area for settlement. Gradual sloping of the wetlands towards the water body will provide suitable habitat for various vegetation to grow (see Fig. 5.2.25). Red mangrove will grow closer to
Fig. 5.2.23 Development of the interventions in time
Source: Author
the water, black mangrove and reeds on the swampy soil, and grass on the higher area which during the dry season will allow more space for cattle grazing. The existing creek connecting the wetlands towards the river needs to be cleared from weeds to let the water flows into the new constructed water basin. In this stage, wooden deck towards the water can be constructed to create access for the communities to catch the fishes for domestic consumption.

In the second stage, connection between the wetlands and the river will be improved by constructing new channel, and widen the existing creek. The diurnal tidal dynamics will bring opportunity for the ecosystem succession and allow fish
Fig. 5.2.26 Phasing in opening the new channel
Source: Author
c) grown plants & new activities
migration into the water basin. The combination of cocolog and boulders helps to stabilize the soil adjacent to the existing settlement. The coconut fiber in cocolog can be suitable substrate for the shrubs and ground cover to grow and help in holding the soil. The new connection create possibilities for small boat access from the water basin to the river. Over the time, coconut trees can be planted along the channel to enhance its interesting atmosphere and the shaded spaces will attract more various uses (see Fig. 5.2.26).

With a restored ecosystem, and improved living environment, the intervention also aims to improved the livelihood. The fishing activity has its peak season during august to October and medium season during April to June. And tourism will having the peak season along with the marine turtle breeding season from September to January. The intervention is expected to complement the cycle by pond fishing, and boosting the tourism by offering more option to enjoy during the tourist stay time (see Fig. 5.2.27).

The boat routes with recovered landscape in between the villages can be integrated with facilities for ecotourism such as path, platform and pavilion on the water for walking tour, with a chance to enjoy the mangroves and the basin with more fish and birds (see Fig. 5.2.32 & 5.2.33).

The brackish water environment, clayish soil with shaded area by the red mangroves create suitable condition to grow the mangrove oyster. In current situation, the oyster farming is not as popular as harvesting the clam on the river, but the availability of the species on the mangrove roots can be potential new economic activities to be developed (see p. 145). Community center with market that could be managed by the local people can support the new economic activities and compliment the tourism facilities that already been developed along the riverbanks. The new market will include space for selling food, crafting souvenirs, etc. and the community center will have space for workshop and training with informal education to improve knowledge and skill of the local communities (see Fig. 5.2.29).
Fig. 5.2.29 Site 2 - Section 2  
Source: Author
Mangrove Oyster (Crassostrea gasar/ C.tulipa)

The mangrove oyster, Crassostrea gasar is found along the west coast of Africa between Senegal and Angola (Ajana, 1980). During site visit, oyster was seen attached to mangroves roots in the wetlands area around Fuvemeh and Anyanui. Based on information obtained from Wildlife Division of Keta Municipal, to collect these oysters, people cut roots of mangroves with oyster attached and then boiled to dislodge the oyster. This boiling process also opens up the oyster to expose the meat. The meat is sold stacked on a piece of stick.

If compared to G.paradoxa clam harvesting, harvesting oysters is less popular for livelihood source. The price obtained by the same weight ratio is lower when compared to the clam's. This condition also in line with the unavailability of information, as well as research papers that discuss the use of oyster in the Volta estuary.

However, the potential of oyster cultivation can not be underestimated. This is evident from the start of research on oyster farming and measures of more sustainable management in Densu estuary, Ghana. (Janha, et al., 2017). With improvements in the processing, the quality of species, size and better distribution method, the potential for mangrove oyster cultivation can be possible as an alternative livelihood that can be further developed.

Local communities in Casamance River in Senegal is developing the oyster culture with rack technique with string and bags in the mangroves area. Similar condition in social economy and environment, this methods on mangrove oyster farming can illustrate the techniques that can be started to test in Volta estuary. Differences in habitat and soil types of swamp muddy area, where the oyster will grow, makes the cultivation will not overlap with clam culture in sandy riverbanks on the estuary.
Fig. 5.2.32 Site 2 - recovered wetlands and possible activities
Source: Author
Fig. 5.2.33 Site 2 - recovered wetlands and possible activities
Source: Author
Guiding development in a vulnerable area needs division of zoning where the development will be allowed. In developed countries such as north America and west Europe, the concept of urban containment has been developed and implemented since the 1970s. Urban containment defines as the policy of limiting sprawl by restricting development outside a designated zone, which in broader view would include the aims on in-town development (Gabrielson et. al., 1997). In general, urban containment policies is used by using at least three types of tools to shape the metropolitan growth. Greenbelt and urban growth boundaries to affect the ‘push’ factor, while the urban service areas to affect the ‘pull’ factors. (Jabareen, 2006). As the strategy of urban containment works successfully in the matured urban societies, how about in Ghana situation?

Owusu (2012) discussed the urban containment strategy in Accra made in 1993 as it appear to failed in fulfilling its former intentions. A mixed-concept plan involving three concept - urban consolidation, twin-city and multi city structure- was proposed as a strategic plan for Greater Accra Metropolitan Area (GAMA) (see Fig. 5.2.35). It also extensively used the greenbelt and natural boundaries as limit of the urban development. However, current shape and size of GAMA shows that it is growing in all direction except to the south as occupied by the ocean. The weak control of the government and the institutions to the implementation of the strategic plan is one of the reason that resulting the urban sprawl even without the availability of adequate infrastructure and service.
Although Ada Foah is a much smaller town comparing to Accra, it has similar character in the development of low density settlements and weak political conditions in the application of any top down planning, a design to implement improvement in the infrastructure and service areas become something needs to be considered carefully. In areas without investment attractiveness as high as Accra, natural boundary is still possible to inhibit the development of informal settlements. In addition, to increase the economic value of the land as a productive landscape can help to convince the people to preserve the boundary zone between the settlement and buffer area.

In site 3, the natural branch of the Volta River was connected towards the Songor lagoon, and was used as boat routes for the transportation from the salt mining activity in the lagoon to the Volta river. From this branch, the surrounding creeks distribute the fresh water to the vast wetlands. But after the construction of the dam and reduction of the water discharge during the rainy season, the periodic floods on the wetlands no longer occur. (see Fig. 5.2.36)

The creeks are now mostly dry or covered by weeds which prevent the limited water flows further. The wetlands were turned into floodplain agriculture and shrimp pond in some parts. These practices has not considered the sustainable methods of cultivating the landscape in the vulnerable area. Closer to the main road, there are some indication of settlement expansion with clearings of the vegetation, and construction of local roads. Although the development in this area is growing rather
Fig. 5.2.39 Development of the interventions in time
Source: Author
slow, but without any guidance on managing the development in this area, the deforestation of the riverbanks and expansion of the settlement area could bring bigger threats from the water dynamics (floods, land subsidence, etc.) for wider communities in the future.

Depart from this issues, the site 3 explores the possible intervention in the transition zone on the Ada Foah town fringe that can prevent the settlement growth too close to the main creeks, but still provide new opportunity for economic benefit for the communities.

The natural boundary with low-lying topography can maintain the safe distance as a buffer zone. The colonization of natural pioneer species, biodiversity succession, and the complimentary planting of seedlings to rehabilitate the mangrove ecosystem will be successful after restoring an appropriate functional hydrology and topography to the surrounding system (Bosma et al., 2014).

If the strategy of adaptation to operate the Akosombo dam can restore periodic flood in the floodplain area to a certain rate that still prevent flooding in the coastal communities in the estuary area (less than 2.300 m³/s (Roest, 2018)), the opportunity to recover mangroves on the creek banks will be possible by using natural spread from the periodic flood by opening new waterways to allows the water spread further inland (see Fig. 5.2.39).

Recovery ecosystems that need to involve the community can be done if the program is also able to provide financial benefits as well as basic needs of surrounding communities. Therefore, silvo-fishery with a healthy ratio between mangrove conservation and the shrimp pond will be integrated as a transition zone between nature and the settlement. A community center for developing the program will be located near to the existing main road to provide efficient accessibility for the goods supply and distribution. Over the time, the expansion of this new small scale industry can be allowed by maintaining the same distance of buffer zone towards the main river branch.

Towards the existing local road, the soil from digging the pond will stabilize the soil and woodlot of Acacia as substitution species for firewood will be planted. Brackish agriculture will be tested on the open landscape in between the woodlot and shrimp farming. It is cultivated with better access of the water with new waterways (see Fig. 5.2.40).

From this intervention, the combination of natural boundary and integrated system of silvo-fishery maintain the town fringe protected as well as profitable for the local communities.
Figure 5.2.40 Site 3 - Section 1
Source: Author
Fig. 5.2.41 View from the shrimp pond towards the woodlot area
Source: Author
Fig. 5.2.42 View from the shrimp pond
Source: Author
DEVELOPMENT IN TIME

In developing these three sites, gradual but constructive adaptive processes in both nature and human systems could benefit each other in a circular balance of its living systems. Similarly, the application of the three sites will not be all at once, but in stages on a long term basis.

The visionary strategic plan (see Fig. 5.3.1) shows the overview of the development direction of the three sites. This plan is not intended as a blueprint design, but rather as a guidance in how the design proposals of each site work together on a larger scale. The development of the designs doesn’t have definite ends, but rather allow adaptation to certain changes by natural processes and social economy progression of the communities.

Figure 5.3.1 Visionary strategic plan
Source: Author
The Living Estuary

Fig. 5.3.2 Timeline of the design implementation

Source: Author
Priority needs to be given to the actions to prevent further erosion both at the sea and river side. In the first 3 years, the application on site 1 takes precedence, including dredging the river and placement of sand nourishment (see Fig. 5.3.3). The permeable groynes need to be constructed as the distribution of the sand by the river and the tides occurs, while on the sea side, the construction of the water catchment building can also be started at the same period. (see Fig. 5.3.4).

On the second phase after the third year, the initial stage at site 2 can take place by re-profiling the land and the opening of the new channel connecting the wetland to the river (see Fig. 5.3.5). Over time, with more stability in implementing new type of livelihood with clam farming, and improved accessibility to clean water, the planting program both to maintain the sand nourishment and recover the wetlands can be applied (see Fig. 5.3.6).

The development to maintain the town fringe takes place in the latest phase with consideration that the nature dominance and topography boundary will still naturally hampers the expansion of human settlements. This phase will be started with program to open the creeks to allow the water reach further inland (see Fig. 5.3.7).

Along with the growth of the new type of livelihood, community based home industry will facilitate the diversification of the products. New market close to the coastal communities will support the growth of economy activity (see Fig. 5.3.8). At site 3, the shrimp ponds have been established, and the woodlot with acacia will be ready to be harvested as fire wood for its first rotation period. (see Fig. 5.3.9).

The dependency of each site could actually open new opportunity, for example, the re-established wetlands with its ecosystem and newly grown coconut trees along the beach can create new route between site 1 and 2 to boost the ecotourism sector (see Fig. 5.3.10).

In general, we can see on Fig. 5.3.2 that nature and human processes can be started after the first intervention and lasting through time to benefiting each other. In addition, the continuity of informal education needs to be given to the local communities both for the adults and the young ages. The informal education will emphasize the awareness of the importance to maintaining the native ecosystems in their living and economic activities, as well as introduction of new skill and knowledge in utilization of the natural resources.
Fig. 5.3.3
- Dodge the site
- Placement of sand movement

0-3rd year

Fig. 5.3.4
- Constructing
- Green space

3-5th year

Fig. 5.3.5
- Opening new channel
- Connect to the river

- Re-profiling
  the embankment
  (cut & fill)
Fig. 5.3.6
5-10th year
- Creosote fencing
- Seagrass planting
- Planting program maintaining sand escarpment

Fig. 5.3.7
10-15th year
- Seagrass rich
- Community score
- Seagrass-based home (shingle island)

Fig. 5.3.8
- New market
Fig. 5.3.11 Ecotourism in Site 1 & 2
Source: Author
“Ensuring that stakeholder engagement is inclusive and collaborative bolsters community buy-in to a shared vision for landscape management, and makes certain that objectives seek to improve and support the full array of services provided by the landscape including social, economic, and environmental” (Thaxton et al., 2015)

The development strategy of this project prioritizes the partnership of multi-stakeholders by using the 5 key elements in the cycle of landscape action by Denier et al. (2015) (see Fig. 5.4.1). The action is started with the cooperative dialogues between the interested stakeholders in the landscape in a multi-stakeholder platform. They then will exchange information and discuss the diverse perspective in systematic processes to obtain a shared understanding of the conditions, challenges and opportunities of the landscape. The next step includes the implementation of the plan to maintain the collaborative commitments. Stakeholders will also monitor the adaptive management and accountability, which will used in the subsequent round of dialogue, exchange of knowledge, and design of new collaborative action (Denier et al., 2015 in Heiner et al., 2017).

In the context of this project, two levels of multi-stakeholders platforms need to be made. The first level is in the scale of Volta Delta, where the action plan in the estuary area will be influenced by the management plan on the delta scale. The meeting of the stakeholders has been done with the result of making a platform to create management plan for the scale of lower Volta basin area. This meeting was attended by the representatives of Water Resources Commission, Volta River Authority, Environmental Protection Agency, Center for African Wetlands, Delta Alliance, and Development Institute. Regarding the development stage of this project, this multi-stakeholders platform will take role in the implementation of the large scale landscape infrastructure including the river dredging activity, sand nourishments, opening new channel and creeks at site 2 and 3.

The second level of multi-stakeholders platform is in the scale of the site. This platform will include local traditional leaders, farmers and fishermen, women, youth, NGOs and community action organizations. The dialogues will create common understanding in between stakeholders, community management and planning regarding to the introduction of new type of economy activities, increase local empowerment and sense of belonging to maintain the new facilities and ensuring the growth, accommodate ideas and facilitate the adaptation of the plan and design to the local viability. The Wildlife Division can undertake the monitoring role in this scale to assure that the intervention and its development will maintain the protection of the Ramsar Site and the conservation of valuable native ecosystems (see Fig. 5.3.2).

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**Fig. 5.4.1 Landscape action cycle**
Source: Adapted from Denier et al., 2015 in Heiner et al., 2017
06 DESIGN EVALUATION

06.01 Assessment of Ecosystem Services

Ecosystem services is defined by Millennium Ecosystem Assessment (MA) (2005) and the Institution of Environmental Sciences (IES) (2013) as multiple benefit obtained by people from ecosystems. These are the conditions and processes through which natural ecosystems sustain and fulfill human life, which include provisioning, regulating, cultural and supporting services (MA, 2005) (see Fig. 6.1). Provisioning services are the product derived from the ecosystems, for example are food & fiber, fuel, natural medicine, ornamental resources and fresh water. Regulating services are the benefit acquired from regulating the ecosystem processes, such as air quality maintenance, climate regulation, erosion control, water regulation, biological control, etc. Cultural services are non-material benefit from the ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetics experiences. Supporting services are those that are necessary to maintain the other services. The impact of it on people are indirect or occur over long period of time compare to the other services which has direct impact to the people. Some of the example of supporting services are soil formation, nutrient cycling, and provisioning of habitat.

The ecosystem services assessment in the designs is used as indicators that the intervention on each site has re-established and optimized the role of native ecosystems for the inhabitants. The assessment also shows how the human activities in utilizing and managing their environment in sustainable way will enhance the benefit that ecosystems could offer.
In Site 1, the planting program of coconut trees and ground covers along the sand nourishment on the sea side will re-establish the sandy shore ecosystem that could help to prevent further erosion. Coconut trees will provide wood, fiber, and leaf as construction materials, and its fruit as food. It will also provide convenient micro-climate from the shade and air quality. While the micro-climate could reduce the rate of evaporation, the new building also help to provide fresh water for the inhabitant. The turtle beach will maintain the ecosystem cycle by providing nutrient for the sandy soil. On the riverside, the river bed will provide the suitable habitat for clam to be harvested regularly. A healthy ecosystem and facility by the design elements will provide cultural service with ecotourism route, informal education, and identity for the area (see Fig 6.2).
In Site 2, the recovering wetlands will prevent erosion and floods in the surrounding settlement area. The connecting channel towards the river allow fish migration that can benefit the fishing activity. The lush vegetation will shade and provide air quality for its surrounding area. The clayish soil with brackish water and mangrove trees will provide suitable habitat for oyster. On the higher area, Acacia or fruit trees can be planted to provide woods as fuel wood or fruit as food. A recovered mangrove ecosystem can provide long-term supporting service in carbon sequestration. In providing cultural service, the wetlands will attract more birds and more interesting track for ecotourism route.
As in Site 2, the recovered wetland ecosystem with mangroves in Site 3 will prevent further erosion and floods, and long-term supporting service in carbon sequestration. The mangroves could provide nutrient for the fish and shrimp that can migrate from the main river to the creeks. This cycle could be intensify by integrating the mangrove with the shrimp farming, as provision service for food, and sustainable management for fuel wood provision. The planting program of Acacia trees will supplement the fuel wood provision in shorter harvest period. The shade of the trees will create a convenient micro-climate. The introduction of new economic system will support the cultural service for the inhabitant.
In the relation to the UN Goals, the intervention in Site 1 aims to reduce the devastating impact from the coastal erosion and improve the resiliency of the coastal communities (13). The form of intervention element such as a building on the landscape, will have multiple functions. Besides it reconnects the village to the beach, the building will also be able to capture and store the rainwater that can be supplemental supply of clean water for domestic daily uses (6).

The recovering wetlands in Site 2 will allow the re-establishment of native ecosystem both on land and below the water. The similar intention in triggering the growth of native species as ground cover on the sandy soil (14&15). The introduction of new type of livelihood with semi-intensive aquaculture is expected to increase the income stability of the local communities, thus maintain the economic growth (8).

The plantation substitution species of firewood will reduce the deforestation of mangrove forest. The ‘social-forestry’ system where the local communities are involved in the planting, managing, and harvesting the trees will maintain the more sustainable use of the natural resources (12).

The improvement in the economic and environmental sectors over the time will reduce the rates of poverty (1). The stakeholders need to work together with the local official and traditional political structure to establish a good partnership, where the communities also be involved in the development of the projects. The support from the NGOs in empowering and improving both education and the living quality of the inhabitants also crucial in realizing the general goal of this project. (17).
07
REFLECTION
Relevance with the theme of the graduation studio

The studio Flowscape focus on developing innovative spatial landscape architectonic design in transport, green and water infrastructure that could guide urban and rural development and maintain their civic and cultural significant (Nijhuis et al., 2017). The landscape infrastructure facilitates aesthetic, functional, social and ecological relationship between human and nature system with movement and flow at its core.

In relation with Flowscape theme, this project can be one of design-based case study in which the perspective of Lanscape as ecologic, economic and social processes is used as a base in synthesizing the design principles and framework, especially for the vulnerable delta region in developing country.

This project explores possibilities in facilitating the aesthetic and spatial experiences aspect without neglecting the critical aspect in anticipating the impact of coastal erosion with the limitation in financial, political and technological sectors. This project use the combination of natural processes in one hand, and landscape architectonic intervention on the other hand to generate gradual transformation in the region. The transformation is not only in territorial aspect, but also emphasizing the potential of the spatial experiences to add value for new economy activity.

Relevance with the wider context

- Vulnerable delta region in a developing country
  Overexploitation by urbanization in delta region in developed country inspired this project not to take the same path in a such dynamic situation. With the same effort to get back to a balance between development and conservation of natural dynamics, a same approach can not be directly applied. This is due to the difference in the relation of the social economy structure of the society that no longer highly dependent directly to the natural resources. Although for both society, a better quality of the natural system will improve the living quality for its inhabitants.

  The application of spatial planning which could trigger and restrain the development will also be different, where the informal settlement that could grown uncontrollably in a developing country, might not be found in a developed country.

  Volta Delta is one of example of a lot more delta regions in developing countries. With similar limitation and condition, this project depict alternative approach that could be used as guidance of the rural development in a delta region. This project also shows how cultural and social value could be enhanced to offer more various type of economy improvement. Moreover, some technical solutions to incorporate local material and technique are presented to show possible solution in adapting new intervention to the local system.

- Role of landscape architect and spatial design
  At the beginning of this project, I thought that the urgent solution was a very technical, infrastructure solution, where the efficiency to anticipate the main challenge of coastal erosion is the only priority. But along with a broader analysis of its potential and long-term challenger that not only come from the natural dynamics, but also from the human dynamics where the high rate of population growth and the fulfillment of needs that come with it, the role of spatial design in dealing with these challenges become clearer.

  The role of landscape architect in creating spatial design for its possible future can not be
underestimated. Spatial design will give direction of the development. Although there is space for change and adaptation in the development process, but by showing the spatial design, it will give the common understanding of the goal to be achieved. Slow but constructive process is able to optimize the potential of the site. Aesthetic aspect will increase the value of an area and improve the living quality for the local communities.

- Participatory process and multi-stakeholders platform

During the process of this project, some workshops was conducted by DIMI and Delta Alliance (see Appendix 3, p. 195), which involve the discussion with some local authorities and community leaders to discuss about their expectation of the intervention or investment that may come. Although participatory process was not used further in determining the design decisions, the participatory processes and multi-stakeholder platform become important part in the proposed implementation of this project. Partnership between the authorities and local communities aims not only to transform the territory but also the society, to learn from each other for more sustainable project implementation.

Applied Methods and Generalized Framework

- Reading the site and understanding the culture

In the research process, understanding of the site condition both in physical and cultural aspect is crucial. To see landscape as processes, it is important to learn not only about the space it creates, but also how the system of water, ecosystem and social economy works and depend to each other.

Discussion with colleagues from various study field was very helpful. The knowledge from coastal engineering, water management, and marine sciences were useful in grasping the complexity of the delta and coastal system.

In data collection process, the availability of spatial data was very limited. Sometime the provided information doesn't have consistency although they are showing aligned timeline. In facing this challenge, gathering more information from scientific papers from various field of study and making cross-reference map and diagrams were done. Translation of empirical data and technical information from various scientific researches into spatial drawings was one of the important steps to move forward in synthesizing the spatial design principles.

Site visit and interview with local people and authorities helps to understand the culture and social structure of the local communities. This information and understanding added significant insight in deciding the approach in the designs. Hopefully, the analysis result in this research that put the three dynamics together in spatial configuration can give useful input and new layer for future spatial research and design.

- Research methods & generalized framework

The chosen methods in this research are arguably has its strength and weakness. To see the landscape as an interaction between human and nature processes, the method to create type of integration of the dynamic systems and spatial design concept can actually be done in two directions. First, is by analyzing the system in general and then choose the location that can
represent the dynamics of the system to be developed further. And second, is to choose a location based on a general issue and start to investigate the related system in this specific location.

This research use the first method with several reasons. First, the synthesized design principle will cover wider scope in the spatial relation of the water, ecosystem and economy interconnection. Second, in the scenario building stage, we can learn how some major factors in spatial development can influence the decision to make the design and strategy in some common sectors. In this case are water management, food production, erosion control, and settlement and mobility sectors. Third, is that the chosen sites are proved from the scenario study to have significant influence in the future spatial development.

However, each of the system dynamics embody a huge complexity of its own. It takes carefulness to determine the boundary and extract it into spatial principles. The same challenge appeared in determining the variables to be used in building the extreme scenarios. To determine these variables could be better if it involves discussion among stakeholders who will participate in the application of the strategies. This method also need several site to test the combination of some principles, which took more time in the process comparing the application of the second methods.

As the result of this research, the three main concepts in developing site specific landscape design are the main framework that can be used in delta area with similar condition in social and economy sectors. These concepts includes the sensibility in placing the new infrastructure, the growing spaces, and the establishment of circular systems.

Relevance in design, moral sensibility and ethical implementation

- Moral sensibility

The moral issues related to the project comes from some aspects. One of them is the possible conflict of interest that involve various stakeholders. Complication to unify the vision for long-term development may conflicting the determination of actions and strategy which may lead to a hindrance in the development itself. Potential growth of large scale tourism investment and other industrialization sector may also be against the principle of collective economy derived from this research. In addition, limiting the development and placement of hard infrastructure in order to prevent exacerbation burden in a vulnerable area, may generate conflict in the society who would expect the same treatment for the whole area.

This project shows the possibility of partnership between all stakeholders in the landscape, that take long time period to ensure the territorial transformations. However, depart from the issues discussed above, this project aims to create guideline in the land use planning and integration principles. It is expected to influence the decision making and become starting points in the negotiation to take middle ground between economic development and nature conservation.

- Further researches

Although this project was initiated by in-depth analysis and tried to cover the 3 main dynamics sectors, it still needs further research about the feasibility and technical implementation in the main landscape infrastructure part. For example, the implementation of river dredging and placement of sand nourishment which are influenced by many aspects in the water dynamic that still needs more accurate calculation and simulation, and the same thing for the establishment of the ecosystems in helping to prevent further erosion.

However, I think that the project successfully enhance the spatial quality of the landscape by working together with the natural processes, as well as cultural identity of the place. Spatial design is not only about try to solve the technical urgency, but also bring the interconnection of the landscape with the inhabitants as a better living space.
Gradual change in nature and society
With the limitation in financial, technological, and political sectors, comprehensive top-down planning and design might not be suitable in this project. It might not be readily accepted and adapted by the local communities which may lead to unsustainable implementation. Therefore, a gradual transformation in the design strategy will give space and time for the communities to adapt in the changes in their living environment. Similar strategy is used in using the natural processes as part of the design. It may not suitable to put large scale hard infrastructure where people live still dependently to the natural resources.

However, this strategy needs to be accompanied by establishment of better education for the local communities. A better understanding on the system by new interventions, the importance of maintaining native ecosystems, and training skills for new type of livelihood will be needed. Balance in applying local knowledge and new technology is expected to form contextual solution and engage people to participate in the processes.

Circular systems
Improvement in quality of natural ecosystems also means the improvement of people’s livelihood. The circular system is one of important part in this research, where the type of intervention should be able to trigger improvement in natural regeneration that will benefit people in the economic sector. This dependency could bring some challenges where disruption to one system will instantly affecting the others. Especially when we deal with natural processes which we can not fully predict.

In this case, the design needs a flexibility to form resiliency in social-economy sector. Review of the plans and designs is required after certain period of time. The review will become input for subsequent strategy and actions that could change the initial design.

Materialization
The materialization for the architectonic elements of this project has offered a realistic way of its implementation. The adaptation in architectonic style and techniques in utilizing the local materials is intended to allow the involvement of the local communities in the construction process of this project.

Nevertheless, one of the main framework of this project is that the intervention has the flexibility and should be able to adapt and grow with the influence of the users. Open-ended strategy will allow people in the interpretation of applying the design in individual or community scale, while this project aims to show how the unity in the systems can be a direction to create common understanding in achieving the same goal.

In conclusion
The project shows the possible future of integrated landscape to create balance between nature and human system in a dynamic situation of a delta region in a developing country. The project offers ideas of landscape transformation as whole, linking the spatial, economic and ecological systems, as well as technical solutions and vision on how the project may be implemented.

The concept and frameworks resulted in this project are expected to be the starting point of development strategy for the whole Volta Delta coastline in facing the future challenges both from the coastal erosion and urbanization sectors.

The display of possible future in the project aims to start a discussion of decision making between the stakeholders in the reality for the future of the Volta Delta. The project also shows the role of landscape architect and spatial design in developing a vulnerable area with limitations in financial, political and technological sectors.
GLOSSARY

Landscape Architecture
(personal definition)
Improving nature by understanding its characters, dynamic, and processes, to accommodate human activities and enhancing the quality of living environment for now and the future.

Flowscape
(personal definition)
Flowscape means finding interconnection and balance between natural and human systems, in the perspective of movement, time and space. Adding values on both landscape and infrastructure, so they together can interweave in the common means of aesthetic, functional, social, cultural and ecological connections.

Strategy
https://www.memam-website.com/dictionary/strategy
A careful plan or methods to achieve a particular goal, usually over long period of time

Adaptive Strategy
A careful plan or methods to achieve a particular goal, usually over long period of time which has the ability or tendency to adapt to different situations.

Integrative Design
An approach to design which brings together two or more things/systems which usually considered separately to form an effective unit or system.

Scenario
http://www.pagesausauneshore.org/program_documents/pix_future_appendix-x.pdf
Plausible alternative futures—what might happen—under particular assumptions.

River Delta
https://en.wikipedia.org/wiki/River_delta
A river delta is a landform that forms from deposition of sediment carried by a river as the flow leaves its mouth and enters slower-moving or standing water. This occurs where a river enters an ocean, sea, estuary, lake, reservoir, or (more rarely) another river that cannot transport away the supplied sediment.

Estuary
https://rcmrvnrcvos.nav.gov/basics/estuary.html
Estuaries and their surrounding wetlands are bodies of water usually found where rivers meet the sea. Estuaries are home to unique plant and animal communities that have adapted to brackish water—a mixture of fresh water draining from the land and salty seawater.

Lagoon
Water bodies connected to the sea through one or more channels, known as inlets, which often cuts through a narrow barrier island of erodible material.

HARD STRUCTURE

Breakwaters (1)
Primarily protect a shoreline or harbor anchorage area from wave attack. It may be located completely offshore and oriented parallel to the shore (detached breakwaters), or they may be oblique and connected to the shore (emerged & submerged breakwaters type).

Groynes (2)
Structure built perpendicular to the shore and usually extend out through the surf zone under normal wave and water level conditions. They help widen and protect a beach by trapping sand from the alongshore transport system or by retaining artificially placed sand.

Jetties (3)
Structures built at the entrance to a river or tidal inlet to stabilize the entrance as well as to protect vessels navigating the entrance channel.

Seawalls and Revetments (4)
Parallel or nearly to the shoreline at the land-sea interface with the objective of preventing further shoreline recession. Seawalls are usually massive and rigid, while a revetment is an armoring of the beach face with rock armor of artificial units.

source: Bosboom & Stive, 2010
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APPENDIX

1. REFERENCE STUDIES

Reference studies are used as input to formulate design principles in several dimensions. Development strategies projects will be used as references in creating framework to stimulate sustainable future development. Building with nature techniques were studied to collect the technical approach to use the natural processes in the similar condition with the project. Spatial programs reference studies are used to study more possibilities to develop the specific function in the area.

1. DEVELOPMENT STRATEGIES

Criteria in choosing the reference projects were based on the character of the project. The reference projects are deltas which has similar condition in the climate and development stage in a developing countries. With the challenges of population and economic growth, the development doesn't have much direction and long-term vision in guiding it towards sustainable future development. The similar climate makes the structure and type of vegetation in the area more comparable.
River and Road Framework

**River and Road as Warp and Woof**
Interweaving Ecologies and Economies in Banjarmasin’s Delta
(Derden, D. & Geenen, G. 2013, in Shannon & Meulder, 2013)

**Location:** Banjarmasin’s Delta, Indonesia

**Problem & Challenges:**
- Undergoing transformation from water-based to generic road-based transportation as requisite for development in economy sectors.
- New scale of urban fabric and program over the existing low-lying and flood prone periphery city character.
- The transformation happens without long-term strategy or vision.

**Aim:**
To explore visions for Banjarmasin that could guide its sustainable development in spatial and socio-economic sector. To strengthen the potential of the landscape by recreating a vibrant blue and green system to restructure existing, and guide the new urbanization.

**Strategies:**
- Recreate a relationship hierarchy between river and roads as complimentary infrastructure and fundamental identity of the city, to open new opportunity in economies and ecologies sustainability and structuring the territory’s future growth.
- Zoning the different landscape
- Recover waterways, canals, and drainage systems to improve its function related to the development of industrial areas.
- Develop complementary platform and multifunctional green structure along the water-based and road-based transport systems.
- Improving naturalized landscape with mangrove afforestation and usage of native brackish plants to stabilize soil, prevent erosion and enrich the indigenous riparian wildlife.
Forest Urbanism

Mangroving Ca Mau, Vietnam
Water and Forest as Development Frames
(De Meulder, B. & Shannon, K. 2013)

Location: Ca Mau, Vietnam

Problem & Challenges:
- Dramatically reduced mangrove ecosystem by agriculture, urbanization and industrialization development.
- Land domestication by a complex canal system, large protective sea dikes and manipulation in topography which eliminating the gradient between wet and dry, disrupts fish migration, natural flood cycle and natural process of erosion and sedimentation.

Aim:
Used the forest and afforestation process as mediating figure to protect the fragile coast and work with the delta dynamics, heal the salinated landscape and improve the life quality in the urban area.

Strategies:
Forest urbanism – the interweaving of urbanism and afforestation.
- Investigating the fundamental characteristics of the territory to interweave the man-made activities in the natural dynamic settings.
- Afforestation of the mangroves from coast to coast to prevent erosion, rebalance water salinity and improve food production, and along the major waterways and creeks.
- Implementing ‘social forestry’ by involving the community participation in the planting, managing and harvesting the forest as economic returns in the management of natural resources.
- Using cut and fill principles in re-profiling the city and countryside.

Re-profiling the city and countryside
BUILDING WITH NATURE

DELTFLAND SAND ENGINE
Nourishing Coastlines and Opportunities
(De Vriend et. al., 2012)

Location: Ter Heijde, province of South Holland, The Netherlands

Problem & Challenges:
- Eroding sandy shore of low-lying country's economic heartland by the combination effect of reduced supply of river sediment, land subsidence and rising sea level.
- Increased in the needs of regular coastal nourishment that will be doubled in 11 years.
- Opportunity to provide other benefits in the future for nature and recreation as well as countering coastal retreat.

Aim: Provision of long-term coastal safety along with promoting nature and recreation development, and testing innovative methods of coastal nourishment.

Strategies:

CONCENTRATED NOURISHMENT

- Large amount of sand to be placed in one location and to be gradually redistributed across and along the shore by the wind and waves, to reduce the footprint and disturbance to the ecosystem by gradual change in the seabed topography.
- The hook-shaped was inspired to provide resting areas for the seals (at the end of the spit), and the shallow lagoon for the platfish.
- Distribution of pioneer dunes by the waves and wind.
- Provision of platform for visitor center and observation tower to facilitate public interest.

Adaptation and Application conditions:
Site specific factors: national coastal policy, established practice and the availability of sand. Rate of erosion along with the project design lifespan. (sand volume)
PERMEABLE DAMS
Mimicking of the Mangrove's root system
(Tonneijck et.al, 2015)

Location : Demak, Central Java, Indonesia

Problem & Challenges :
• Mangrove conversion for aquaculture, groundwater extraction and infrastructure development exacerbate severe erosion and related flooding hazards.
• Ineffectivity of the structure, cost, and adaptability to climate change of the conventional hard-infrastructure, and its failure to provide the economic, environmental and social benefits that could be offered by a healthy mangrove coastlines.

Principles :
• Permeable structures as sediment traps to let the sea and river flows, reduce the risk of the waves instead of reflecting them.
• To use local materials such as bamboo, twigs or other brushwood.
• Permeable dams should be constructed advancing step by step towards the sea and placed in the back of the area to be restored.
• Once the accretion provide sufficient elevation and erosion process has stopped, natural colonization of the mangroves are expected.
• The durability of the permeable dams construction should be long enough for mangroves to take over, which is a sum of the sediment accretion rate (2 – 5 years) and rate of mangrove recovery (3 – 5 years).
• In front of the targeted area of mangroves recovery, more permanent permeable structures are required, to form the primary sea-defence to reduce the wave energy until the muddy shore is restored.
• Mud nourishment and dredging systems can be combined to increase the sediment amount in the coastal fundament.

MANGROVE NATURE PARK
Location: Pantai Indah Kapuk, Jakarta, Indonesia

Programs :
1) Hanging wooden bridge
2) Cottage
3) Mini Outbond
4) Wooden Pathway along the forest
5) Bird-watching tower
6) Multifunction plaza
## CONCLUSION

### Design Strategy

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### Building with Nature

| Distribution of preceded nourishment by the natural water flows |
| Add and Distribute |
| Placement of permeable structures to slow down the current and settle the sediment that will slowly grow. |
| Chat and Grow |
Adaptation as Design Tools

Principles in the design strategies, techniques, possible spatial experiences and programs derived from the reference studies are used as inputs to formulate the design principles in the type of interrelation between the water, ecosystem and anthropodynamics (see p. 73), as well as in the design implementation stage as tools in creating site specific landscape designs (see p. 123).
2. DYNAMIC MODELS

In the design development with the dynamic of erosion and sedimentation processes, dynamic model can be used to test the initial design hypothesis.

The research used two experiments of dynamic models with different scales. Experiment 1 was conducted to test and understand the more effective sand nourishment placement for a predetermined purpose, i.e., to nourish the intended riverbanks but still keeping the inlet of the existing small lagoon open and connected to the river (see p.191). Experiment 2 was conducted to explore the possible design for the permeable groynes which are placed in a particular position along the riverbank to capture sediment and allow the utilization of new functions that support the local economy. Three sets in experiment 2 explored the design variations with a different angle, distance, and shape. (see p.192)

The methods used in conducting this experiment are as follows:
1. clay model preparation
   clay is molded to form the shape of the islands on the top of a printed map with a plastic sheet in between.
2. Placement of the sand and catchment structure (to represent the permeable groynes and mangrove roots).
3. Determining variables, to be compared from each set of test
4. Mimicking the flows

This stage is done by pouring the water from one side and moving the model up and down from both ends to simulate the river and tide currents from opposite directions.

Although the experiment will not be accurate regarding calculation of exact rates, capacity and water velocity, but as tools to design, this experiment was very helpful in understanding the general logic and impact in dealing with sand and water dynamics. This experiment result was also used as discussion tools with a colleague from coastal engineering, to create a better understanding of the system to achieve the design goals. The result of this experiment is presented on the design implementation in SITE 1 (p. 123).
TEST 1
Sand nourishment in one large area in a distance in front of the tourism facilities.

In this test, the sand placed almost parallel to the flow of water does not make the sand distribution to the riverbank effectively. The river flow is not too strong, it will create a situation around the nourished area which actually could slow the current velocity. And even though it can be distributed to riverbank, it will take a long time while the flow on the river itself will accelerate and increase the erosion rate in the riverbank before the sand reach it.

TEST 2
Sand nourishment in multiple areas at a certain angle with a distance from the riverbank.

In this test, the sand that is positioned with a certain angle can deflect the direction of river flow thus reducing the potential for erosion on the riverbank. Loose sands are able to be distributed which also causes siltation that shallow the river beds and reduce velocity of the current.

With a certain distance the boat can still be landed close to the houses and use coconut trees to secure it from the river stream. In the initial phase, permeable groyne is able to slow down river currents on the island’s edges.
TEST 3
sand nourishment was put attached to the main islands

EXPERIMENT 1

Selected Intervention

In this test, the sand can be well distributed by the stream flow. However, to distribute it along the riverbank, silting will also occur on the waterway leading to lagoons which are undesirable. In the initial phase, large addition of sand at one point will make a long distance to land the fishing boats from the houses and vegetation that can keep the boat in place. It is also not expected given the tendency of the fishermen who always wanted to make sure his boat was safe from being swept away by river streams or tides.

From the three types of sand nourishment positions tested, it was concluded that by considering the efficiency of sand distribution with the help of natural flow from the river flow and maintaining the accessibility of the fishermen to his fishing boat, sand nourishment will be placed at a certain distance from the riverbank in two positions to reach the intended locations. Permeable groynes will be placed close to the lagoons waterway, to slow the flow of the river and block the silting at the mouth so that the waterway connecting it to the river can be maintained.
EXPERIMENT 2

The experiment is aimed to find out the sedimentation processes produced by a particular structure with variations of angle, distance and shape. This experiment also to test the possibility of functions and programs that can be utilized by the local community.

The experiment was carried out using a water and sand medium with a riverbank representation using clay and permeable groyne represented by nails. The movement of the water was made in the form of alternating movement representing river stream and tides that have the opposite direction.

Possible programs
- Sedimentation
- Riverbank representation
- Clay
- Permeable groyne
This thesis project is part of an interdisciplinary project initiated by DIMI (Delta, Infrastructure, and Mobility Initiative) in collaboration with Development Institute and Delta Alliance Ghana Wing. The series of this program started with a site visit and workshop on the 8th-14th of October, 2017 in Sogakope, Ghana. This workshop involved 11 students from TU Delft with various study programs including landscape architecture, water management, hydraulic and coastal engineering, and technology and policy management, and 15 other students from Ghanaian universities, among others University of Ghana, Central University, and KNUST University with various study programs such as architecture, geography, and marine sciences. The workshop also included discussions with the local authority and traditional leaders in 2 municipalities, Ada East and Keta. Site visit was conducted along the Volta Delta coastline and wetland areas, coastal communities, a traditional market, farming fields and short interview with the local communities.

SITE VISIT

The first site visit was conducted in group in October, 2017. The result of this site visit became the starting point in determining the area to be elaborated in the research. After doing the research with desk analysis and the synthesis of design principles, it is understood that second visit needs to be done for further understanding to specific site condition.

The second program was the Mid-term presentation on the 25th of February, 2018. This presentation is held to exchange the findings and present the individual research progress of each students in TU Delft. The second site visit was done individually in February 2018 to collect spatial experiences and more information related to the prevailing systems in the culture of the local communities and technical aspect of the landscape. This visit also aimed to test the possibility to implement the design principles that has been formulated based of the desk analysis. The result of the second visit was used to develop the site specific landscape designs.

The third program was an integrated workshop conducted on the 14th -18th of May, 2018 at the TU Delft. The program included an integrated presentation of students from TU Delft and Ghanaian universities at a seminar involving the stakeholders and government representative from Ghana and the Netherlands. A workshop about designing with sediments, and an integrated workshop of the students to formulate vision ideas for the Volta Delta completed the series of the program.