Vulnerability and Resilience Assessment of the Ayeyarwady Delta, Myanmar

Full assessment report

ALTERRA WAGENINGEN UR

Deltares Enabling Delta Life

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Delta Alliance

Delta Alliance is an international knowledge-driven network organization with the mission of improving the resilience of the world's deltas. With increasing pressure from population growth, industrialization and a changing climate, it is more important than ever that these valuable and vulnerable locations increase their resilience to changing conditions. Delta Alliance brings people together who live and work in deltas. For more information on Delta Alliance and to download this report go to: **www.delta-alliance.org**

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Abbreviations

AADMER	Agreement on Disaster Management and Emergency Response
ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
BANCA	Biodiversity And Nature Conservation Association
BOBLME	Bay of Bengal Large Marine Ecosystem Project
BSPP	Burma Socialist Program Party
CIA	Central Intelligence Agency
CITES	Convention on International Trade on Endangered Species
DHP	Department of Hydropower Planning
DPSIR	Drivers-Pressures-State-Impact-Response
DMH	Department of Meteorology and Hydrology
DoF	Department of Fisheries
DRR	Disaster Risk Reduction
DTW	Deep Tube Wells
EU	European Union
FAO	Food and Agricultural Organisation
FFI	Fauna and Flora International
FREDA	Forest Resource Environmental Development and Conservation Association
GBM	Ganges-Brahmaputra-Meghna
GDP	Gross Domestic Product
GPS	Global Positioning System
GWP	Global Water Partnership
HYV	High Yielding Varieties
ID	Irrigation Department
IDE	International Development Enterprise
IRRI	International Rice Research Institute
JICA	Japan International Cooperation Agency
OECD	Organisation for Economic Co-operation and Development
MADB	Myanmar Agricultural Development Bank
MAPDRR	Myanmar Action Plan on Disaster Risk Reduction
MAS	Myanmar Agricultural Services
MCA	Multi-Criteria Analysis
MEB	Myanmar Economic Bank
MERN	Myanmar Environmental Rehabilitation Network
MFTB	Myanmar Foreign Trade Bank
MICB	Myanmar Investment and Commercial Bank
MMRD	Myanmar Marketing Research & Development Services
MFA	Myanmar Farmers Association
MFI	Micro-Finance Institutions
MPA	Marine Protected Areas
MRF	Myanmar Rice Federation
MSE	Micro and Small Enterprises
MSE	Microfinance Supervisory Committee
MSTRD	Myanmar Scientific and Technological Research Department
NAPA	National Adaptation Programme of Action to Climate Change
NGO	Non-Governmental Organisation
PONJA	Post-Nargis Joint Assessment report
RIMES	Regional Integrated Multi-hazard Early warning System
RRD	Relief and Resettlement Department
SPDC	State Peace and Development Council
STW	Shallow Tube Wells
UN	United Nations
UNDP	United Nations Development Program
UNCDF	United Nations Capital and Development Fund
WCS	Wildlife Conservation Society
WHO	World Health Organisation
WRI	Water Resources Institute
WRUD	Water Resources Utilization Department
YCDC	Yangon City Development Committee

Contents

1 Introduction

1.1 Context

This report responds to the request of the Regional Coordinator of the Bay of Bengal Large Marine Ecosystem Project (BOBLME) and the Global Water Partnership, to realize a vulnerability and resilience assessment for the Ayeyarwady Delta in Myanmar, comparable to the "Comparative Assessment of the Vulnerability and Resilience of 10 Deltas" executed by Delta Alliance in 2010/2011 for 10 other deltas in the world. This study was realized by a team from Deltares and Alterra in close cooperation with experts in each of the deltas (Bucx et al, 2010). This assessment of the 10 deltas was extended to 14 deltas in 2014, including the Ayeyarwady Delta. This full assessment was preceded by a scoping phase in 2013.

Continent	Country	Delta	No
Africa	Egypt	Nile	1
	Kenya	Tana	11
	Mozambique	Incomati	2
	Mozambique	Zambezi	12
Asia	Bangladesh	Ganges-Brahmaputra-Meghna	3
	China	Yangtze	4
	Indonesia	Ciliwung	5
	Myanmar	Ayeyarwady	13
	Vietnam	Mekong	6
Europe	The Netherlands	Rhine-Meuse	7
	Romania	Danube	8
N-America	United States of America	California Bay-Delta	9
	United States of America	Mississippi River Delta	10
Z-America	Argentina	Parana	14

Figure 1.1 Comparative Assessment of the Vulnerability and Resilience of 14 deltas.

The BOBLME Project is interested in this delta assessment, as it provides a baseline of the current state of the Ayeyarwady Delta as a basis for sustainable development of the Ayeyarwady

delta. Moreover, it provides the possibility to compare the Ayeyarwady Delta to other deltas in the world in order to identify similar problems, possible solutions, lessons learned and opportunities for collaboration. At the request of the BOBLME project special attention has been given to the fishery and aquaculture sector. Building on the vulnerability and resilience assessment, the study also provides an inventory of current and potential adaptation measures and an overview of knowledge gaps.

The Global Water Partnership (GWP) has also shown a keen interest to undertake activities in Myanmar within the framework of the preparation and implementation of the "Enabling Delta Life Initiative": a joint Global Program of Action on Deltas of GWP and Delta Alliance. GWP, therefore, is co-financing the delta vulnerability assessment. In addition, the Myanmar representatives and partners of GWP play an active role in the realization of the assessment.

Rationale

The Ayeyarwady Delta fans out from the limit of tidal influence at Myan Aung to the Bay of Bengal and Andaman Sea. The delta region is densely populated, and plays a dominant role in the cultivation of rice on rich alluvial soils as low as just 3 meters above sea level, although it also includes a large number of fishing communities in a vast area full of rivers and streams. It is mainly populated by farming and fishing communities in several villages besides market towns, mostly located along the main rivers.

On 2 May 2008, the delta suffered a major disaster, devastated by Cyclone Nargis, which reportedly killed 84,537 people with 53,836 people missing, and left about 2.4 million affected. Total damage and loss is approximately 11.7 trillion Kyats, i.e. 4.1 billion US$ (Ministry of Social Welfare, Relief and Resettlement, 2012).

Following this flooding disaster there was a clear need for an assessment of the vulnerability and resilience of the Ayeyarwady delta.

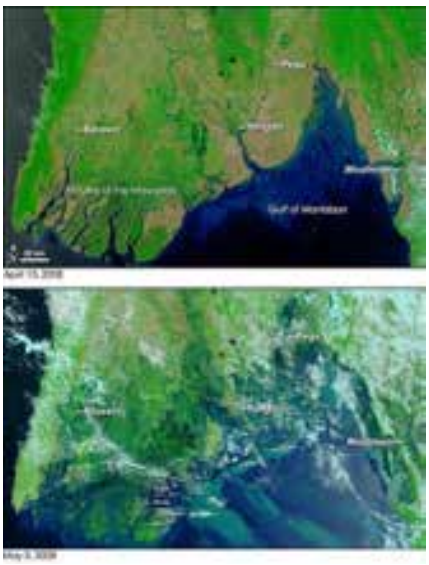


Figure 1.2 Overview of the Ayeyarwady Delta before and after by Cyclone Nargis, impacting severely around 50,400 km^2 of the low-lying delta (NASA images courtesy the MODIS Rapid Response Team. Caption by Rebecca Lindsey).

The vulnerability assessment process

Since it was unknown how much data and information would be available and whether the right experts could be found to contribute to the project a phased approach has been applied:

- phase 1: scoping phase with an identification mission (2013);
- phase 2: full description and vulnerability assessment of the Ayeyarwady Delta (2014).

After phase 1 a go – no go decision had been built in on the basis of the possibilities and constraints identified during phase 1. In case of a go-decision a more detailed proposal would be developed for phase 2 based on the findings of the identification mission.

1.2 Results Phase 1

The objectives of the phase 1 scoping mission were:

- Identify the possibilities and constraints of conducting an assessment of vulnerability and resilience of the Ayeyarwady Delta;
- Prepare a plan for conducting a full assessment of vulnerability and resilience;
- Preliminary description of the vulnerability and resilience of the Ayeyarwady Delta.

The mission fulfilled all the objectives of the mission and the results have been reported in:
'Driel, W.F. van & T.A. Nauta, 2013. Vulnerability and Resilience Assessment of the Ayeyarwady Delta in Myanmar, Scoping phase. Bay of Bengal Large Marine Ecosystem BOBLME) Project, Global Water Partnership (GWP) and Delta Alliance. Delft-Wageningen, The Netherlands'.

As a result of phase 1 the mission recommended to realise also the second phase of the vulnerability assessment.

The conditions for a full assessment were evaluated as favourable:

- All parties involved during the mission confirmed the need for such an assessment;
- The Irrigation Department of the Ministry of Agriculture and Irrigation has been given full support to the scoping mission and is prepared to give the same support to phase 2;
- During the workshops also delegates from other ministries declared to be interested and committed to contribute to phase 2;
- The GWP representatives and partners in Myanmar were very dedicated to contribute to the full assessment;
- The MyFish project team offered to cooperate with the team that will realize the full assessment;
- The consultancy firm NEPS with 13 engineers retired from governmental services has a lot of knowledge on the delta (institutional memory) and has been involved in many studies and implementation projects. If needed, this firm could play a role in phase 2 of the assessment;
- The team has collected already quite some literature, data and other information. The willingness to provide additional data on request is great. More data will become available within a few months within the framework of a Dutch funded project on the IWRM data collection (Deltares and TUDelft, 2013).

The mission recommended also to differentiate the full assessment to four distinct different zones of the Ayeyarwady Delta. During the scoping mission it became clear that for instance the degree of salt water intrusion has a major influence on the agricultural activities in the delta. Moreover, there is a very distinct difference (in terms of land and water use, livelihoods, economic activities, vulnerability, storm surges) between the urbanised region around Yangon and the rural part of the

delta. For a useful vulnerability assessment it was recommended that the Delta should therefore be divided in 4 different zones:

- The Lower delta, permanently under influence of salt water intrusion;
- The Middle delta, under seasonal influence of salt water intrusion;
- The Upper delta, beyond the reach of salt water intrusion;
- The Urbanised delta around Yangon.

1.3 Proposal for phase 2

Objectives

For phase 2 a number of objectives were proposed:

- Elaborate a full assessment of the vulnerability and resilience of the Ayeyarwady delta according to the delta assessment approach as applied in the Delta Alliance project 'Comparative Assessment of the Vulnerability and Resilience of 10 deltas' addressing four distinct different zones:
    a. The Lower delta, permanently under influence of salt water intrusion;
    b. The Middle delta, under seasonal influence of salt water intrusion;
    c. The Upper delta, beyond the reach of salt water intrusion;
    d. The urbanised delta around Yangon.
- Make a comparative analysis related to the other 10 deltas already studied.
- An additional proposed objective for phase 2, which will be crucial in the long run, is the development of technical expertise within Myanmar to underpin the sustainable development of the Ayeyarwady delta. The mission will address this objective by identifying the knowledge gaps for sustainable delta management.

Proposed activities

To reach the objectives the following activities were foreseen:

- Compile a comprehensive delta description according to the delta assessment approach, based on already available literature, data and on expert knowledge. The description resulting from the scoping phase 1 (chapter 3 of the scoping mission report) will be refined and complemented. Distinction will be made between the four distinct zones.
- Describe all relevant aspects regarding drivers, pressures, state, impact, responses and knowledge gaps for the occupation, network and base layers and for governance. The preliminary findings of phase 1 as described in chapter 4 of the scoping mission report will be checked, refined and complemented for the four zones.
    a. Overview of adaptive measures currently applied in the Ayeyarwady delta;
    b. Overview of methods and tools to support delta management;
    c. Lesson learned on delta management;
    d. Research gaps and related information needs.
- Make 'summary blocks' of the main issues of the delta description.
- Develop the Delta Scorecard for each of the four zones of the Ayeyarwady Delta including a brief description.
- Compile on the results of the four zones an overall assessment and Delta Scorecard for the Ayeyarwady Delta.
- Make a comparative analysis related to the 10 deltas assessment report.

Identification of a pilot project for the 'Enabling Delta Life Initiative'

In addition to the above the mission has been asked by GWP and the Delta Alliance to identify a pilot project on the impacts of salinity intrusion, that could be formulated and submitted for inclusion in the Enabling Delta Life Initiative: a joint GWP and Delta Alliance Global Program of Action on Deltas. This proposal will be submitted as a separate document.

Reporting

The final result will be a report with a comprehensive delta description and a vulnerability assessment for each of the four zones as well as for the whole Ayeyarwady delta, including a brief comparative analysis related to the 10 deltas assessment report.

1.4 Undertaken activities

Mission to Myanmar

After some preparatory work in The Netherlands the second phase of the Vulnerability and Resilience has started with a field mission to Myanmar Assessment from 2 -13 June 2014 by Mr. Wim van Driel (Alterra) and Mr. Tjitte Nauta (Deltares). During the major part of the mission they have been accompanied by Dr. Zaw Lwin Tun (Director Irrigation Department and National coordinator of GWP), Mrs. Hla Oo Nwe (Deputy Director Design Branch Irrigation Department), Mr. Phyo Myint (Irrigation Department, Ayeyarwady Region) and Mrs. Maria Arantza Pi Gonzalez (research assistant, intern, Alterra / Wageningen University). The mission report has been submitted to BOBLME/FAO and GWP in August 2014.

The mission started with the participation in the Myanmar – Dutch seminar 'Developing Myanmar waters sustainably: from vision to implementation' in Nay Pyi Taw on 4 June 2014. This seminar contained also a specific breakout session on deltas during which the most important topics for the Ayeyarwady Delta were identified. During the mission three workshops have been organised with the support of the Irrigation Department in respectively Pathein (7 June), Hinthada (10 June) and Yangon (11 June). In total more than 100 people have participated in these workshop representing at provincial and national level several ministries, as well as universities, research institutes and NGOs. Several presentations were given by these organisations. During the roundtrip Yangon – Pathein – Hinthada – Yangon several interesting places and objects were visited, giving a good impression of the most urgent issues in the Delta.

During the mission a meeting took place with the staff of the MYFish project in order to discuss the objectives and activities of the MYFISH project and to discuss the most important challenges regarding the fisheries and aquacultural sector.

Multi-criteria analyses

During the mission the procedure and the content for a stakeholder survey using multi-criteria analyses have been developed. On the basis of the scoping study of 2013, the results of the Nay Pyi Taw seminar (2014) and further study of the documentation a number of key issues were identified:

- Salinity intrusion;
- Lack of infrastructure and asset management;
- Mangroves and delta degradation;
- Adverse water and environmental quality;

- Public health;
- Flooding and lack of drainage;
- Livelihood limitations;
- Lack of knowledge and innovation.

A stakeholder survey has been carried out during the three workshops in Pathein, Hinthada and Yangon. The survey has continued after the mission by addressing more representative universities, research institutes and NGOs. The stakeholders and multi-criteria analysis proved to be very helpful in streamlining the workshops and was welcomed by all participants as a structured way to move forward from a vision on the delta to much needed actions.

Data collection

The research assistant, Mrs. Maria Arantza Pi Gonzalez, has stayed for three months (June – August, 2014) in Myanmar to collect additional information, reports and data by visiting and interviewing many organisations. This information appeared to be essential for a well-documented assessment of the Ayeyarwady Delta.

Field surveys

In collaboration with the MYFish project, the research assistant also organised three stakeholder workshops in the Delta with farmer-fisherman to discuss with them the main threats for their activities, the solutions that they see and the measures that should be taken.

The actual assessment

The analyses of all the data and information gathered, the actual assessment and the report writing were carried out in The Netherlands from September till December 2014.

1.5 Guide to this report

This report presents the findings of the phase 2 activities. Chapter 1 provides an overview of both phase 1 and phase 2 activities of this project on the vulnerability and resilience assessment for the Ayeyarwady Delta in Myanmar. In Chapter 2 the general methodology for the vulnerability and resilience assessment and the stakeholders participation and multi-criteria analysis is briefly described. In Chapters 3, 4 and 5 the spatial layer model (base layer, network layer and occupation layer) as introduced in Chapter 2 is presented. In these chapters the current situation, the drivers of change and the pressures are described. Governance, including a description of the administrative system, is dealt with in Chapter 6. The stakeholders and multi-criteria analysis as introduced during the project workshops is worked out in Chapter 7. Chapter 8 includes the vulnerability assessment and score card analysis and in Chapter 9 an overview is given of the possible adaptive measures in the Delta. The technical methods and tools identified to support delta management and development are introduced in Chapter 10. In Chapter 11 knowledge gaps are included. The comparative assessment of 14 deltas is included in Chapter 12. This Chapter compares all 14 deltas in terms of the drivers of change, the pressures, governance and possible adaptive measures. It also includes a comparison of delta score cards and research gaps and opportunities for knowledge exchange and collaboration. Finally, in Chapter 13 and 14 the summary of findings and the extensive list of references is presented. To keep the report readable the synthesis report of the comparative assessment of the 14 deltas and the description of main indicators for drivers, pressures and governance have been included in Annexes A and B respectively.

2 Methodology

2.1 Vulnerability and Resilience Assessment

In the Delta Alliance study 'Comparative assessment of the vulnerability and resilience of 10 deltas' (Bucx et al, 2010) a framework has been developed (Figure 2.1) for describing deltas in a uniform format which enables a comparison of deltas with regard to sustainability and resilience. This framework links the DPSIR approach (OECD, 1993) with a layer model for spatial development (Marchand & Ruijgh, 2009).

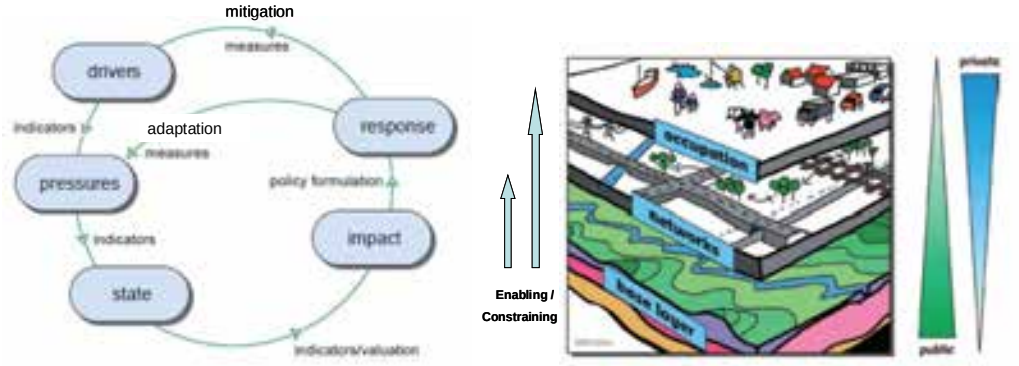


Figure 2.1 DPSIR cause-effect chain analysis (adapted after OECD, 1993) and Spatial Layer Model (VROM, 2001).

The framework also provides a linkage with governance issues and with the different actors and agencies involved in delta development and management.

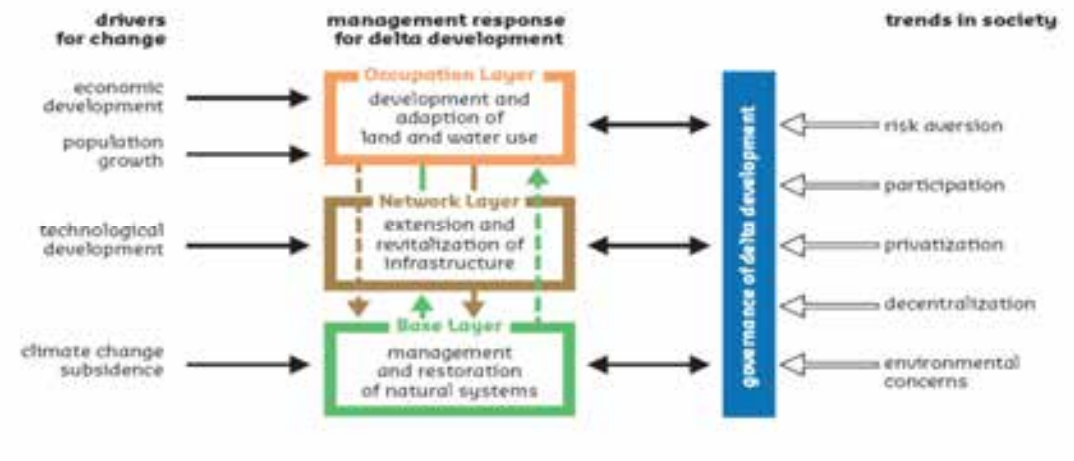


Figure 2.2 Framework for Delta Assessment (integrated the DPSIR and the Layer models).

Population growth, economic development, climate change and subsidence are the main drivers of change in deltas. These developments pose extensive demands on the available natural resources. But also technological development can be seen as a driver of change: it may provide opportunities for more cost-efficient and innovative infrastructure or exploitation of previously untapped natural resources. Box 2.1 provides a general description of the main drivers of change.

Box 2.1 Drivers of change

Population growth: The global population still grows with some 2 percent per year, although there are distinct regional differences. The migration of people towards coastal urban areas often yields in a greater than average growth of the population in delta areas. The number of people to be served and to be protected against natural hazards will increase.

Economic development: Despite the current financial crisis, economic growth may be expected over longer periods of time, resulting in larger demands to be met, higher values to protect, more energy to be generated and more goods to be transported. This may also lead to upstream developments (dams etc.), which are also recognized as important drivers of change for deltas.

Climate change: There is general consensus that the rise of global temperature is inevitable, with its associated (local) impacts on sea-level rise and the hydrological cycle (larger and more frequent droughts and floods).

Subsidence: Most deltas are subjected to the natural geological process of long-term subsidence. Additionally, extraction of groundwater and fossil fuels, may cause significant lowering of the delta surface on the short term. Other short-term processes leading to delta surface lowering at a more local scale are shallow compaction and oxidation of organic sediments, which may also result from human activities.

Technological development: Innovations may open opportunities to enhance the functionality of infrastructure solutions, to extend the lifetime of infrastructure and/or to develop more cost efficient designs.

There are a number of societal trends that affect the organization and outcome of delta planning and development (Box 2.2). Of these trends decentralization and privatization may be viewed as autonomous developments. The challenge is to utilize the advantages of both trends, while minimizing their undeniable drawbacks. This calls for a selective enhancement of governance structures, reflecting the regional scale, an integrated and long-term perspective of more resilience and sustainable delta development.

Box 2.2 Trends in society

Decentralization: brings delta issues closer to the stakeholders involved. Due to lack of national coordination, there is, however, a sincere risk of uncontrolled and/or chaotic developments.

Privatization: Public-private partnerships are becoming the modus operandi for many infrastructural projects and services. Increased efficiency of tax payer's money is a key motive. The risk of privatization, however, is a focus on the short term as well as a neglect of the public interest.

Participation: Involvement of stakeholders and citizens is important to promote societal support of development projects as well as maintenance of infrastructure. Planning may benefit from the tacit knowledge of stakeholders.

Environmental concern: Worldwide concern about a changing climate and environmental degradation has raised the environmental awareness. Sustainability of development has become accepted as a basic policy concept for many deltas.

Risk aversion: Acceptance of risk is decreasing in our modern societies. Hence considerable efforts are made to further reduce or control the risks of natural hazards.

In order to understand how the drivers lead to changes in the pressures and state of the delta, a multitude of relations between human activities, and physical and ecological delta conditions needs to be accounted for. To provide insight into this complex system, a simplified structure is applied in the form of a Layer model. This Layer model recognizes three physical planning layers (Figure 2.1): the Base layer (natural resources including fisheries resources, mangroves), the Network layer (infrastructure, including irrigation systems) and the Occupation layer (zoning of

land use functions and livelihood elements such as agricultural and fishery practices), each with different but interrelated temporal dynamics and public-private involvement. The model indicates a physical hierarchy in the sense that the Base layer influences the other layers through both enabling and constraining factors. For instance, the soil type determines to a large extent the type of agriculture that can be performed in the Occupation layer.

Unfavourable conditions (constraints) posed by the Base layer can to a certain extent be mitigated through adaptations in the Network layer or Occupation layer. For example, farmers can use agrochemicals to improve soil conditions. And dykes can be constructed to protect low-lying land from flooding. But these adaptations to the original physical geography of an area require investments and need to be managed.

The essence of the Layer model is the difference in dynamics and vulnerability between the layers, which results in a logical order in planning for the various layers. The layers enable and/or constrain activities in another layer. Besides for analysing the physical interactions between the layers, the model is also useful in positioning the roles of different actors, such as government agencies, private entrepreneurs and stakeholders. The development and maintenance of infrastructure in the Network layer is traditionally the responsibility of the government. The government also has a main role in the protection and management of the Base layer. Moving towards the Occupation layer the role and influence of the government becomes more restricted and the influences of private parties and citizen's interests become more dominant.

The Layer model is largely compatible with other well-known approaches, such as the ecosystem functions approach (De Groot, 1992; De Groot, 1994; De Groot et al., 2002).

Using the Layer model, it becomes clear that there are three main response themes on which delta management could focus, i.e. the development and adaptation of land and water use (Occupation layer), the extension and revitalization of infrastructure (Network layer) and the management and restoration of natural systems (Base layer), see Figure 2.1. Regarding the Base layer it should be noted that in deltas especially the sediment dynamics (balance) between sea, river and hinterland is important. Many deltas suffer from a sediment deficit, because sediments from the catchment are trapped in reservoirs upstream. Embankments along the delta distributaries prevent flooding and vertical accretion of the delta plain. The disturbance of natural delta sediment dynamics (i.e. lack of sediment) leads to land loss and increased flood vulnerability.

The governance required for sustainable delta development extends over all three layers and is characterized by a mix of government responsibility and private or non-governmental actor roles. The stronger private role in the Occupation layer is most clearly symbolized in the land ownership, which is legitimised through property rights legislation and often embedded in deep values of ownership and values associated with entrepreneurship. Land ownership induces private investments (e.g. farms, houses) and can be traded on the free market. The government can enact its influence through zoning regulations and building codes and, under very stringent conditions, can expropriate land for a public cause of national or local importance (such road networks). Informal and formal arrangements exist for (participatory) planning processes and their legitimacy.

Although in the Base layer the role of the government is strongest, its management is often done in a rather fragmented way. Management responsibilities originate from a deep belief of stewardship to maintain the qualities of water, soils and subsoil natural resources. But the actual management instruments are mostly partially effective or inadequate to stop degradation and quality loss. These instruments are legitimized through national or international laws and obligations and enacted in the form of licences, concessions and covenants.

As the governance is almost one of the most important driving forces in sustainable delta development it is not enough to only discuss roles of government and private sector in each of the layers. The three layer model can be combined with the institutional layer model of Williamson which thus gives a clear picture to link human-environment systems with different modes of decision-making (Marchand & Ruijgh-Van der Ploeg 2009). This helps to classify the different 'agencies' and 'domains' (Agarwal et al. 2002) and improve the multi-level and multi-sectoral cooperation and efficiency.

Figure 2.3 summarizes typical delta issues as a sequence of drivers, pressures, impacts, governance and responses, for each of the three layers.

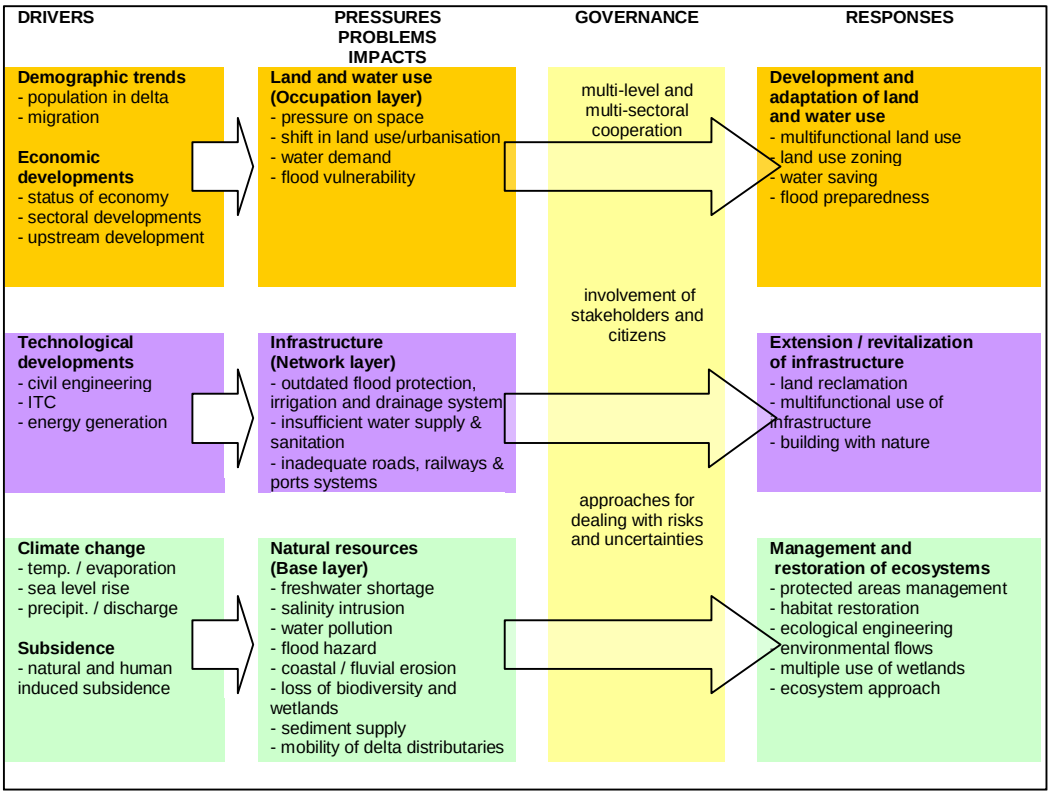


Figure 2.3 Sequence of drivers, pressures, impacts, governance and responses in deltas (note: this is a simplified representation as the vertical interactions between the layers are not included).

2.2 Stakeholder participation and multi-criteria analyses

2.2.1 Introduction to the stakeholders participation and multi-criteria analyses

Over the last years, there has been an increasing advocacy in Myanmar for participatory and pro-active management for sustainable development of resources. It is in this light that it was decided to conduct a simple stakeholders analysis through a number of workshops and interviews to determine the views and opinions of the relevant stakeholder groups in the Ayeyarwady Delta and to collate some first joint ideas for proposed measures for sustainable development and management of the Ayeyarwady delta and mitigation of experienced problems. The stakeholders groups that were consulted are: the Government (central / regional / local), the academe (various

universities), NGO's, Industry (especially small and medium enterprises), agriculture and fisheries.

2.2.2 Methodology

The stakeholders analysis as applied in this Vulnerability and Resilience Assessment for the Ayeyarwady Delta, makes use of two popular and widely adopted methods: the Pair-Wise Comparison and Multi-Criteria Analysis (MCA). These are commonly used methods to determine the relative importance of independent issues of concern and to support the priority ranking of measures to mitigate them. It allows quantitative tests on the effects of the different proposed measures using the weight of selected independent issues of concern, based on the perception of the different stakeholder groups.

Different stakeholder groups may have different ideas about what and how important the different issues of concern are. It is recognised, however, that the importance is determined by the conditions at different times and different places. The ultimate choice of proposed measures to be implemented will depend on how the stakeholders value the different issues of concern. Public participation will always give semblance of ownership of the project by the affected stakeholders and more importantly determine at the early stage the acceptability of the proposed measures to be developed or implemented within the region.

There were two distinct objectives of the stakeholders analysis: first, to validate a number of identified issues of concern as indicators for sustainable development of the Delta, and second to establish linkage with the stakeholders to ensure joint ownership in the further development and management of the Delta and mitigation of experienced problems. Describing the current situation in the Delta during these workshops and then being clear about the challenges to be addressed, establishes the discrepancy between now and the vision for the future, which clarifies the role of the proposed measures prioritization through a multi-criteria analysis (MCA).

The MCA, as presented during the workshops, served to:

- discuss with the decision makers (at central, regional and local level) the best way forward;
- identify the areas of greater and lesser opportunity;
- prioritize the considered measures;
- clarify the differences between the proposed measures;
- help the key players / stakeholders to understand the situation and the impacts of measures better;
- indicate the best allocation of resources to achieve the goals (best value for money);
- facilitate the generation of new and better measures and
- improve communication between the Government and other stakeholders.

The ultimate stage of the decision making process for developing and managing the Ayeyarwady Delta is the actual choice of measures: which measures to prioritize to address the challenges and ultimately meet the targets. Good decision-making requires a vision on what to establish (what are the targets) and a straightforward, transparent and participatory approach to select the measures to meet the targets. Individual decision makers may learn from their own mistakes, but it is felt important that lessons be learned in a more formal and systematic way, and communicated to others, so that they can support future decisions. Multi-criteria analysis (MCA) techniques can be used to identify a single most preferred measure, to rank measures, to short-list a limited number of measures for subsequent detailed appraisal, or simply to distinguish acceptable from unacceptable developments.

The MCA approach makes the selected measures and their contribution to the different criteria explicit, and requires the exercise of systematic (expert) judgment. The main role of MCA is to deal with the difficulties that decision-makers encounter in handling large amounts of complex information in a consistent way. As such, it is felt that the Ayeyarwady decision-makers (DM) may gain valuable time to start implementing much needed measures on further development and management of the Ayeyarwady Delta in a proper and systematic way.

Decision-making about proposals for future actions should follow the following sequence (see also Figure 2.4):

- identifying objectives on what to establish;
- identifying a long list of proposed projects or project ideas (measures) for achieving the objectives;
- identifying the criteria to be used to compare the various measures;
- ranking / scoring of the importance of the criteria;
- analysis and ranking of the measures and as a follow up development of simple terms of references could be prepared for most promising measures (project fact sheets).

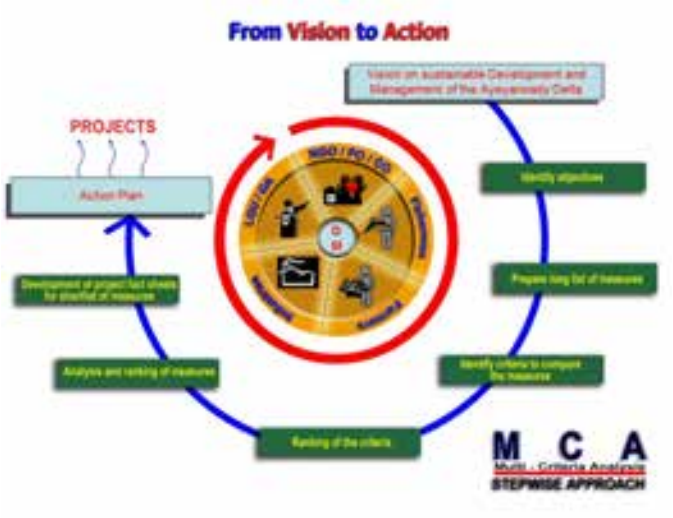


Figure 2.4 MCA stepwise approach (DM: Decision Makers); Interaction with the stakeholders is considered a prerequisite throughout the process.

The MCA approach, that is adopted in the Ayeyarwady Delta study, has many advantages as compared with the seemingly informal and quite random selection of measures that are currently considered (from 'stove-piping' towards integrated approach), as:

- it is systematic, inter-active and explicit (and appeared easy to explain to the invited stakeholders who were involved in the workshops);
- the choice of objectives and criteria that the decision-makers use are open to analysis and to change if they are felt to be inappropriate;
- scores and weights used are also explicit. They can also be cross-referenced to other future sources of information on relative values (e.g. by using model simulations), and amended if necessary;

- it provides an important means of communication within the Government and between the Government and the wider community / stakeholders;
- available and developed expertise can optimally be utilized and shared and
- projects identified in such a way will much less reflect the government of the day and the randomness of decision-making (less politically determined, less trial and error).

3 Base Layer

3.1 Description current situation

3.1.1 Geographical Situation

Myanmar known as the golden land for its fertile land and rich natural resources lies between latitude about 10ºN to 28ºN and longitude 92.5ºE to 101.5ºE. A horse shoe shaped high mountain ranges cap the country. Wide plains and river valleys are commonly seen in the central part. There are three parallel chains of forested mountain ranges that run north to south. The four major river systems, the Ayeyarwady, the Chindwin, the Sittaung and the Thanlwin cover the country (see Figure 3.1). The main artery of Myanmar and its important, commercial water way is the Ayeyarwady River. Torrential rains and floods occur in the mountainous areas and low lying places like the Ayeyarwady Delta, and droughts in rain shadow areas in the central region of the country (Zaw Lwin Tun & Hla Oo Nwe, 2010).

Figure 3.1 Major river basins in Myanmar.

Figure 3.2 Ayeyarwady region.

The delta system of the Ayeyarwady River extends in a great alluvial fan from the limit of tidal influence near Myan Aung (18°15'N) to the Bay of Bengal and Andaman Sea, 290 km to the south. This alluvial plain is bounded to the west by the southern Rakhaing Yoma range and to the east by the Bago Yoma. The city of Yangon, situated on the southernmost spur of the Bago Yoma, lies at the south-eastern edge of the delta. Most of the delta area falls under the present Ayeyarwady region (see Figure 3.2), the remaining part in Yangon Region and Bago Region.

3.1.2 Climatic Conditions

The monsoonal climate in the delta leads to an average annual rainfall of about 1,500-2,000 mm in the north increasing to 2,500 mm in the southeast and 3,500 mm in the southwest. Over 90 percent of the rain falls between mid-May and mid-November. During the monsoon season, the maximum and minimum temperatures in the coastal zone are about 37°C and 22°C, respectively. There are often strong winds from the south and southwest, causing rough seas. Cyclones can cause serious storm surges. The period from mid-October to mid-February is generally dry and cool. Temperatures rise after February, and April and early May are characterized by hot, variable weather with pre-monsoon squalls.

3.1.3 Soils and Sediment

The entire delta area is overlain by a thick layer of recent alluvium brought down by the Ayeyarwady River. Three main types of soil have developed: meadow gleyey clay soils, meadow swampy soils and saline gleyey soils.

Despite the large sediment load delivered annually to the gulf by the Ayeyarwady and Thanlwin (Salween) Rivers, the coastline has been largely stable for 156 years, advancing at an average rate of no more than 0.34 km per century since 1925. The long-term average rate of increase in land area across the study area between 1925 and 2006 is 4.2 km^2/year, but this masks a period of more rapid accumulation between 1925 and 1989 (8.7 km^2/year), followed by a period of net erosion at a rate of 13 km^2/year until 2006 (Hedley et al., 2010). It is suggested that the coastline encompassing the Ayeyarwady Delta and the Thanlwin (Salween) River is more or less in equilibrium, and that sediment deposition currently balances subsidence and sea level rise.

However, planned extensive damming projects may cause considerable losses in sediment supply, which may lead in combination with sea level rise and (natural or human induced) subsidence to a retreat of the delta. Loss of sediment may have also impact on the fertility of the agricultural land. On the contrary, sediment influx may increase as a consequence of deforestation and land use changes in the fragile upstream areas.

3.1.4 Subsidence (natural or human-induced)

Most deltas are subjected to the natural geological process of long-term subsidence. Additionally, extraction of groundwater and fossil fuels may cause significant lowering of the delta surface on the short term. Other short-term processes leading to delta surface lowering at a more local scale are shallow compaction and oxidation of organic sediments, which may also result from human activities. So far, no data on subsidence in the Ayeyarwady Delta are available. The establishment of a structural ground water extraction and subsidence monitoring system should be considered for subsidence prone areas zones such as Yangon Region, where due to increasing urbanisation, population growth and industrial development the ground water extraction can be expected to increase due to higher fresh water scarcity.

3.1.5 Water resources

3.1.5.1 River system

The discharge in the Ayeyarwady River is at its lowest in February and March and there is a sharp rise in April-May as a result of melting snow in the upper catchment, followed by a further steep rise in May-June with the onset of the monsoon. The maximum flow occurs in July or August. Most waterways are un-engineered natural water courses, and there is no extensive system of dredged canals, the only major canal being the Twante canal which links Yangon with the western part of the delta.

The tide in the Ayeyarwady Delta is diurnal. The tidal variation shows a distinct pattern of spring and neap tides. The tidal influence enters deep into the delta, which offers opportunities for tidal irrigation by boosting the fresh water.

Dangers to Myanmar's water resources include i) pollution from mining, agriculture and industry, ii) overexploitation during the dry season with competing uses between hydropower generation, domestic water supply, and agriculture, iii) siltation of reservoirs and iv) extreme variations in river flows resulting from shifting cultivation and loss of forest cover (ASD, 2013).

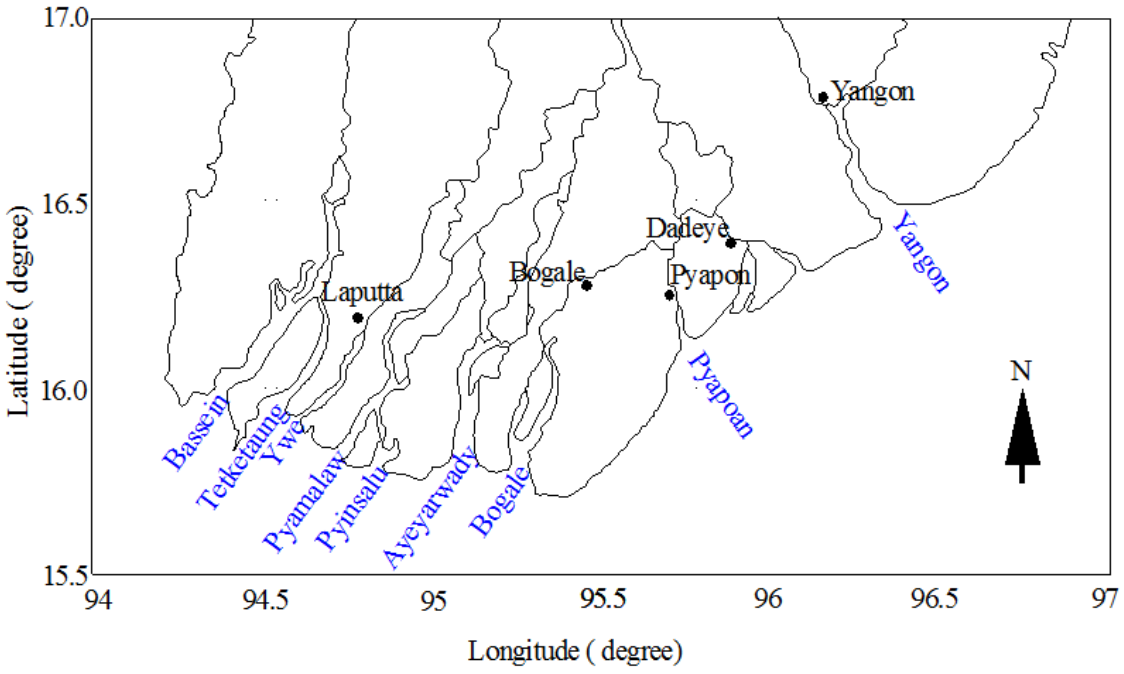


Figure 3.3 River network in the Delta.

3.1.5.2 Drinking water resources

Water scarcity and salinity

Water scarcity has become a daily challenge in Myanmar's Ayeyarwady Delta in the dry season, especially in the Lower and Middle Delta. Thousands are still struggling after the damage to water sources caused by Cyclone Nargis in May, 2008. Since most villages do not have access to piped water and nearby tidal rivers are often saline, the delta's inhabitants traditionally source drinking water from rainwater harvesting, communal water ponds and tube and open wells. The ponds help villagers during the dry season, which stretches from November to May, but can be insufficient. Many ponds and wells were heavily salinized when a 3m tidal surge inundated much of the low-lying area when the Nargis cyclone struck the Lower Delta.

Arsenic and saline contamination of ground water

Groundwater is widely used as a water resource in the Ayeyarwady Delta. The salinity of the groundwater is affected by the flood and high waves through cyclones or monsoons (Miyaoka et al, 2012). However, surface water – groundwater interaction differs per season.

Arsenic contamination of drinking water sources is an emerging public health issue in Myanmar. In early 2000, Save the Children UK's (SC UK) Water and Sanitation Programme identified arsenic contamination of groundwater in rural parts of the Ayeyarwady Delta (Tun, 2003). Since that time, there has been growing interest, concern and action related to arsenic testing, communication and mitigation in Myanmar. However, the magnitude of arsenic contamination of groundwater sources in Myanmar is still rather unknown, as no comprehensive studies have been conducted. Recommendable activities are:

- retesting and confirmation of arsenic levels of water sources;
- arsenic education/awareness raising;
- community mobilization and immediate protection measures;
- identification and implementation of alternative drinking water sources.

The arsenic in groundwater is of geological origin, and that contamination of an aquifer can be flushed out by groundwater recharge. Arsenic contamination depends of factors such as: depth of tube well, type of aquifer, topography, groundwater flow and hydraulic gradient, mineral composition of the aquifer and its boundary layers, and the deposited age of the water- bearing formation (Tet Nay Tun, 2001).

The groundwater in some areas under confined conditions can be found divided into three aquifers. The first aquifer corresponds to the dug-well depth 20-50ft is presumed to be less safe in faecal contamination. The second aquifer is around 50-250ft in which the majority of the arsenic contaminated water was found and also rich in iron. The third aquifer around 200-500ft seems to be free of arsenic or contains low levels of arsenic. Most of the STWs (Shallow Tube Wells) are constructed in the second aquifer (Tet Nay Tun, 2001). Drilling into the third aquifer is much more costly and requires advanced drilling technology.

Water pollution

The disposal of untreated domestic wastewater, especially from the larger villages and the towns, will lead to increased oxygen demand and deteriorating hygienic conditions of the surface waters. Also the increase in the use of fertilizers and pesticides in agriculture as well as the growth of industrial and mining activities will further affect the water quality in the delta with a range of additional parameters (heavy metals, organic micro-pollutants and oils).

The absence of clear rules, regulations and monitoring in the sector creates an obstacle in taking legal action in many cases. It would therefore imperative to establish workable standards by starting with a set of essential parameters that are of particular significance in the context of Myanmar. This must be complemented by appropriate enforcement mechanisms (Department of Health, 2000).

3.1.5.3 Water resources for agriculture

Myanmar has many areas that offer ideal conditions for agriculture amongst which the Ayeyarwady Delta.

Rainfall amounts vary considerably from one region to another from highs of 4,000–6,000 mm annually along the coastal reaches and in the mountains of Rakhine and Tanintharyi, to as low as 500–1,000 mm in the Central Dry Zone. With such low levels of rainfall, there is insufficient precipitation to produce a rice crop. Rice cultivation in the relatively heavily populated Central Dry Zone depends therefore on irrigation, even during the monsoon season.

In contrast, excessive rainfall in other regions of Myanmar, notably in the Delta Region, often results in flooding, the loss of standing crops, and the displacement of significant portions of the population. Therefore, while Myanmar undoubtedly benefits from its water resources, these resources are neither unlimited nor always beneficial. Serious drought conditions may occur in some regions and, at other times, excessive rainfall and flooding damages the production base and community livelihoods.

Only a small portion (3%–10%) of the country's water resources is used. Agriculture accounts for about 90% of the total water use, with domestic water supply and industry accounting for the remaining 10% (These figures exclude hydropower generation.) Most water is surface water, with groundwater use amounting to only 9% of the total (despite its potential for dry season irrigation), (ADB, 2013).

Irrigated agriculture is dependent on an adequate water supply of usable quality. Water quality concerns have often been neglected because good quality water supplies have been plentiful and readily available. This situation is now changing in many areas. Intensive use of nearly all good quality supplies means that new irrigation projects and old projects seeking new or supplemental supplies must rely on lower quality and less desirable sources (Myint, 2013).

Despite irrigation being the main use of water, most rice is produced as a rain-fed crop during the monsoon season. Water control infrastructure is needed in the highly productive Delta Region to prevent salinity intrusion and flooding and to improve drainage.

Irrigation facilities cover close to 2.3 million ha, or about 19% of the country cultivated area. However, only some 900,000 ha are irrigated during the dry season, with the balance of coverage serving to provide supplementary irrigation during the monsoon season. The largest irrigated area is served by pumps (mainly farmer operated) directly from the river or drainage canals or from groundwater, which covers 38% of the total irrigated area. The second-largest area is surface irrigation from dams and weirs (57% managed by the government and 43% by farmers), which covers 29% of the total irrigated area. In terms of responsibility, pumped irrigation and groundwater are the responsibility of the Water Resources Utilization Department, while dams and weirs are the responsibility of the Irrigation Department both of the MOAI.

In addition to irrigation infrastructure, embankments in the Delta Region, which include drainage facilities, have been strengthened to protect large areas from flooding and salt intrusion. Prior to Cyclone Nargis, there were some 318 flood protection works, both government (88%) and private (12%), protecting a total of 1.2 million ha of cultivable land. Many of these structures were badly damaged during Cyclone Nargis, leaving much of the most productive part of the country vulnerable to catastrophic weather impacts.

3.1.5.4 Water resources for fisheries and aquaculture

The fisheries of the Ayeyarwady Delta are among the most diverse and complex found anywhere on earth. The dynamic natural environment of the delta sustains habitats and ecosystems that range from fully marine, through brackish to entirely freshwater. Much of the Delta area is influenced by tides. The productive soils and abundance of water create conditions for a highly productive and diverse fauna, although large parts of the Delta are now a simplified agro-

ecosystem of rice fields, plantations and degraded mangrove areas linked by rivers and canals. (Gregory & Saw La Paw Wah, 2009).

Gregory & Saw La Paw Wah (2009) describe in their report on a 'Participatory Rural Assessment of Delta Livelihoods and the Value of Fishing Assets in areas affected by Cyclone Nargis' that these fishery practices take place in three main ecological zones in the delta which are related to the distance to the sea and to the salinity level:

- a floodplain zone characterized by freshwater or a very low salinity maximum, the presence of freshwater fish species, large scale fencing for fishing and an unknown percentage of migratory species;
- an estuarine zone characterized by multiple waterways, temporary brackish water, typically estuarine species, degraded mangroves along waterways and a patchwork of rice fields, trees and villages;
- a coastal front characterized by a very flat land, quasi-permanent brackish water, salty soils, almost no vegetation and fishing activities targeting the coastal and marine zones.

Water resources control infrastructure also includes about 180,000 ha of aquaculture ponds, primarily in the Delta Region, requesting good quality water. This is a growing industry with ample potential for expansion leading to foreign exchange earnings (ADB, 2013).

3.1.5.5 Surface water quality and pollution

Due to various policy reforms the agricultural sector changes the way it operates and functions. As a result agricultural inputs, such as chemical fertilizers and pesticides are increasingly distributed either partially or wholly by the private sector (Zaw, 2011). Moreover, the utilization rate of chemical fertilizers in the delta happens to be the highest among the agricultural regions in Myanmar. This will result in an increasing state of pollution.

Water quality concerns are also being raised with regard to mining activities and the growth of cities and industrial zones. The disposal of untreated domestic wastewater will lead to increased oxygen demand and deteriorating hygienic conditions of the surface waters and the increase in industrial and mining activities will further affect the water quality in the delta with a range of additional parameters (heavy metals, organic micro-pollutants and oils).

Figure 3.4 below shows the different locations where the water quality is monitored. There are actually few observation locations in the Ayeyarwady Delta. The quality standards of FAO guidelines are followed for interpretation of the water quality for irrigation (Myint, 2013).

Figure 3.4 Locations of water quality control in (and near) the Ayeyarwady Delta.

In the Tables 3.1 en 3.2 the water qualities in two different periods are shown: dry season and rainy season.

Table 3.1 Present Status of Introduction of the Standard and Regulation on the Water Quality from Rivers, Dams and Reservoirs during the dry season. Investigation Branch, Irrigation Department, Yangon (Myint, 2013).

WATER QUALITY ANALYSES DURING THE DRY SEASON IN THE AYEYARWADY DELTA											
Parameter	Unit	Irrigation water Quality Standard (FAO Guideline)	Pyinmana, Sittaung River 2012	Taungoo, Sittaung River 2012	Sittaung River, Sittaung Bridge 2012	Nay Pyi Taw, "surface" Paunglaung Dam 2012	Nay Pyi Taw, Madam Dam 2011	Bago Region, Yenwe Dam 2010	Bago Region, Bawni Dam 2007	Bago Region, Swa Dam 2007	Yangon Region, Ngamoeyeik 2011
Calcium Ca	me/l	0-20 me/l	1.35	0.95	0.56	1.44	1.45	0.48	0.12	0.55	0.24
Magnesium	me/l	1-5 me/l	1.11	1.25	0.88	0.80	0.92	0.72	0.23	0.64	1.44
Sodium	me/l	0-40 me/l	0.95	0.42	0.45	0.17	1.35	0.72	0.09	0.25	1.42
Potasium	me/l		0.23	0.12	0.04	0.05	0.15	0.12	0.03	0.05	0.06
Carbonate	me/l	0-0.1 me/l	ND	ND	0.40	ND	0.20	ND	ND	ND	ND
Bicarbonate	me/l	0-10 me/l	1.20	1.20	1.20	1.40	2.80	1.60	0.20	1.29	0.40
Sulphate	me/l	0-20 me/l	1.92	1.01	0.02	1.45	1.05	0.22	ND	ND	2.62
Chloride	me/l	0-30 me/l	0.40	0.37	0.30	0.30	0.40	0.20	ND	ND	1.67
Total Hardness (T-H)	ppm		123.00	110.00	72.00	112.00	168.50	-	-	-	84.00
Iron	ppm		0.40	0.25	1.20	-	-	-	0.50	ND	-
Total Dissolved Solids (TDS)	ppm	1-2000 ppm	186.24	128.00	117.12	108.80	240.00	-	61.44	122.88	198.40
Soluble Sodium Percentage (SSP)	%		26.1	13.33	23.32	6.91	27.72	35.00	19.15	16.79	44.94
Sodium Adsorption Ratio (SAR)	-	0-15	0.86	0.40	0.53	0.16	1.04	0.90	0.22	0.33	1.54
Residual Sodium Carbonate (RSC)	me/l		0.00	0.00	0.16	0.00	0.00	0.40	0.00	0.10	0.00
Ph			7.55	8.00	7.05	7.64	8.11	7.34	6.60	7.10	7.32
Electrical conductivity (Ecw)	µmhos/cm	0-3000 µmhos/cm	291.00	200-00	183	170.00	375.00	149.00	96.00	192.00	310.00
Turbidity	NTU		252.00	243.00	426.00	6.00	105.00	-	-	-	10.00
Temperature	C		26.70	27.50	28.80	29.60	30.10	-	-	-	28.70
Dissolved Oxygen (DO)	mg/l		6.55	5.49	5.68	-	-	-	-	-	-
USDA Classification			**C2S1**	**C1S1**	**C1S1**	**C1S1**	**C1S1**	**C1S1**	**C1S1**	**C1S1**	**C1S1**

ND=Not detected

Table 3.2 Present Status of Introduction of the Standard and Regulation on the Water Quality from Rivers, Dams and Reservoirs during the rainy season. Investigation Branch, Irrigation Department, Yangon (Myint, 2013).

WATER QUALITY ANALYSES DURING THE RAINY SEASON IN THE AYEYARWADY DELTA											
Parameter	**Unit**	**Irrigation water Quality Standard (FAO Guideline)**	**Pyinmana, Sittaung River 2012**	**Taungoo, Sittaung River 2012**	**Sittaung River, Sittaung Bridge 2012**	**Nay Pyi Taw, "surface" Paunglaung Dam 2012**	**Nay Pyi Taw, Madam Dam 2010**	**Bago Region, Yenwe Dam 2009**	**Bago Region, Bawni Dam 2008**	**Bago Region, Swa Dam 2008**	**Yangon Region, Ngamoeyeik 2010**
Calcium Ca	me/l	0-20 me/l	1.42	1.25	0.75	0.86	1.40	0.54	0.16	0.61	0.32
Magnesium	me/l	1-5 me/l	1.15	1.30	0.92	0.72	1.90	0.72	0.22	0.82	0.40
Sodium	me/l	0-40 me/l	1.00	0.49	0.55	0.11	1.35	0.60	0.04	0.15	0.38
Potasium	me/l		0.25	0.09	0.05	0.05	0.17	0.03	0.01	0.01	0.05
Carbonate	me/l	0-0.1 me/l	ND	ND	0.40	ND	0.20	ND	ND	ND	ND
Bicarbonate	me/l	0-10 me/l	1.00	1.20	1.20	1.20	2.80	1.86	0.43	1.58	0.40
Sulphate	me/l	0-20 me/l	1.99	1.15	0.01	0.79	1.01	0.09	ND	ND	1.04
Chloride	me/l	0-30 me/l	0.40	0.49	0.30	0.30	0.43	ND	ND	ND	0.07
Total Hardness (T-H)	ppm		128.50	127.50	83.50	80.00	165.00	-	-	-	36.00
Iron	ppm		0.40	0.30	1.00	-	-	-	-	-	-
Total Dissolved Solids (TDS)	ppm	1-2000 ppm	191.36	150.40	131.20	92.16	230.40	-	-	-	70.40
Soluble Sodium Percentage (SSP)	%		26.18	15.65	24.23	6.25	28.01	31.58	-	-	33.04
Sodium Adsorption Ratio (SAR)	-	0-15	0.88	0.43	0.60	0.24	1.05	0.75	0.09	0.18	0.63
Residual Sodium Carbonate (RSC)	me/l		0.00	0.00	0.00	0.00	0.00	0.59	0.05	0.15	0.00
Ph			7.63	7.90	7.25	7.25	7.99	6.84	7.07	8.04	7.37
Electrical conductivity (Ecw)	µmhos/cm	0-3000 µmhos/cm	299.00	235.00	205	144.00	360.00	197.00	83.00	212.00	110.00
Turbidity	NTU		201.00	217.00	237.00	34.00	130.00	-	-	-	1.00
Temperature	C		28.90	29.10	29.30	28.80	29.80	-	-	-	29.00
Dissolved Oxygen (DO)	mg/l		6.42	5.25	5.49	-	-	-	-	-	-
USDA Classification			**C2S1**	**C1S1**	**C1S1**	**C1S1**	**C1S1**	**C1S1**	**C1S1**	**C1S1**	**C1S1**

ND=Not detected

3.1.5.6 Groundwater

Aquifers

Myanmar has 11 different types of aquifers, which have depending on their lithology and depositional environments, groundwater disparities in quality and quantity. Groundwater resources have barely been tapped, in contrast to those of the neighbouring countries Bangladesh and India.

Groundwater use

Water use in Myanmar has been on the increase particularly in the agricultural and industrial sectors. The following table shows the water use in different sectors for the year 2008-09.

Table 3.3 Water use by different sectors In Myanmar in 2008/2009 (WRUD, 2014).

	Surface water	**Groundwater**	**Total**
Domestic	1.15 (3%)	2,55 (68%)	3,7 (8%)
Industrial	1.17 (3%)	0.33 (9%)	1.5 (3%)
Irrigation	41.97 (94%)	0.85 (23%)	42.82(89%)
Total	**44.29**	**3.73**	**48.02**

It appears that as much as 89 per cent of water use is tapped for irrigation purpose, about 8 per cent is for domestic consumption and 3 per cent is for industry (WRUD, 2014).

Ground water quality

The problems of arsenic contamination and salinity have already been mentioned in the paragraph on drinking water supply.

3.1.6 Flood hazard in the Ayeyarwady Delta

Flooding has always been one of the major hazards in Myanmar. Floods are most common during the rainy season. Myanmar usually receives 90% of its rainfall between mid-May and October. The threat of flooding usually occurs in June, July, August and late September to October with the highest risk in August around the period of peak monsoon rains (UN-Habitat).

Zaw Lwin Tun and Hla Oo Nwe (2010) report that the natural hazard risk varies from moderate to high across the country, characterized essentially by small and medium scale but frequent hazard events. Historical data indicate that during 1996-2005, fire is the most frequent disaster and accounts for 71 percent of the disasters within the country. Storms and floods account for 11 percent and 10 percent of the disasters respectively while other disasters including earthquake, landslide, etc. accounts for 8 percent of the disasters. More recent disasters have included the 2004 tsunami, the 2005 landslides in the mountainous region, and Cyclone Mala in 2006. However, Cyclone Nargis in 2008 is by far the most devastating natural disaster in the country's

history, and has brought to the fore the extreme vulnerability, in particular of the country's coastal regions and delta areas, to such low-frequency but high-impact natural hazards.

Figure 3.5 Flooding in Bago (Arantza Pi Gonzalez, 2014).

3.1.6.1 Types of floods

The types of floods that occur in different areas of Myanmar are riverine floods, flash floods, urban and localised floods and flooding due to cyclone and storm surge.

- Riverine floods: These are the most common type of floods in Myanmar. They take place when the monsoon troughs or low pressure waves superimpose on the general monsoon pattern resulting in intense rainfall over significant strategic areas of the river catchments.
- In Ayeyarwady and Chindwin rivers, the flooding occurs when intense rain persists for at least 3 days over the headwaters of the rivers in northern Myanmar. Most of the flooding in the lower Ayeyarwady and the delta is occurred by Chindwin, when its flood coincides with upper Ayeyarwady floods. In Sittaung and Thanlwin rivers, floods are duly caused by rainfall associated with low pressure waves (the remnants of typhoons and tropical storms of South China Sea) moving from east to west across the country.
- Coastal floods: Tropical storms from the Bay of Bengal trigger storm surges and cause floods along the Rakhine coastline during the pre- and post- monsoon period.
- Urban and localised floods: In the cities and towns, localised floods occur from time to time. This is due to a combination of cloudburst, saturated soil, poor infiltration rates and inadequate or poorly built and/or badly maintained infrastructure (such as blocked drains). In the rural areas, breakage of water resistance structures, such as dams, dykes and levees destroy valuable farm lands.
- Flash floods: Flash floods, frequent in the rivers, are caused by the heavy rainfall striking at the head water region for a sustained period of 1-3 days. In the central and delta regions in the southern part of the country, river bank erosions accidents are frequent incidents (UN-HABITAT).

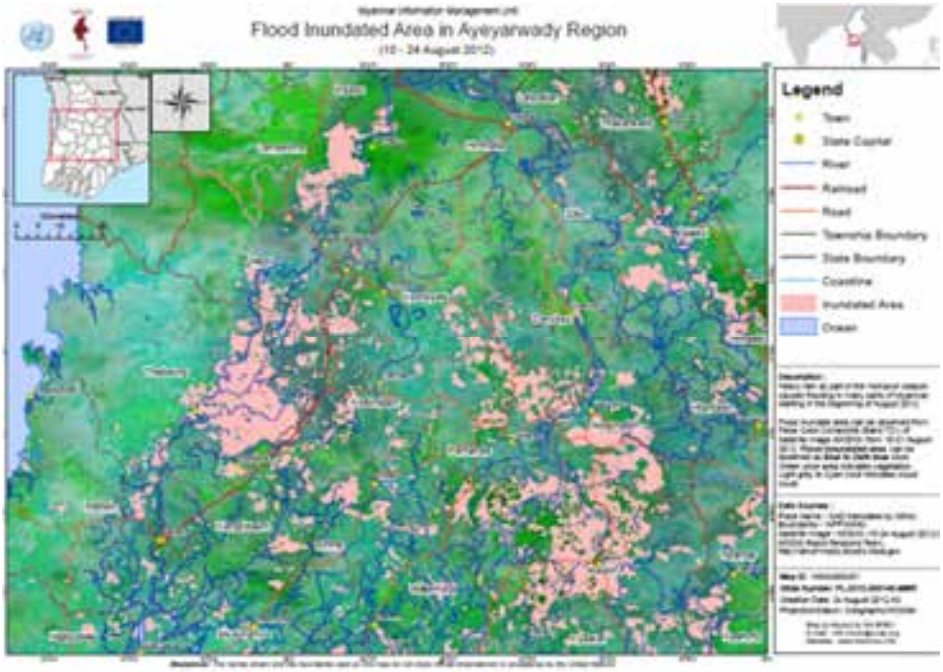


Figure 3.6 Area flooded - August 2012.

3.1.6.2 Historical riverine floods

The Chindwin River is the largest tributary of the Ayeyarwady River. The Chindwin River has floods several times in a year from the onset of rainy season to the end of the Monsoon. Most of the flooding in the lower Ayeyarwady and the delta area is due to the Chindwin River and when it coincides with upper Ayeyarwady floods, severe flooding occurs in the delta area.

In the Ayeyarwady River basin, farm land, towns and cities situated in the low lying area are protected by embankments from flooding since 1880-1881. The protection of west and east bank of Ayeyarwady River in the delta area was completed in 1929-1930. In the year 1909, the Burma Embankment Act, covering the whole area of Myanmar, was enacted. At the same time a manual on the care and maintenance of embankment was released. At that time, the heights of embankment were designed to protect 20 years return period only.

In the year 1974, a flood with a return period of about 90 years reaching the height of R.L 47.5 ft (14.48 m) at Hinzada on the left bank of Ayeyarwady occurred and a vast area of land and a number of towns along the river were flooded and many crop areas in the delta were inundated. Again in the year 1991, the Hteinngu embankment which was constructed in the year 1872 on the Ngawun River, a branch of Ayeyarwady River, was breached between mileage 19/6 and 19/7 near Hteinngu village.

The impact of the damage was disastrous: 1,146,000 ha of paddy land, 68,000 ha of other crops and 74,740 houses flooded, 74,674 animals drowned and 326,926 people from 269 villages from 8 townships affected. A detailed study was made on the causes of failure and in the year 1992, the embankments in the delta area were redesigned with a free board of 5 ft (1.52 m) higher than the original design. The embankment was reconstructed by using heavy machineries. In the year

1997, flooding of the Ayeyarwady River occurred again and the water level rose to the height of R.L 47.6 ft (14.51 m) at Hinzada, which was 0.1 ft (0.03 m) higher than the 1974 flood level. During that flood, the Ngawun embankment near Kywetekone village, the head reach was breached despite the earlier strengthening of the embankment after the 1974 flood.

Figure 3.7 Floods in the Ayeyarwady Delta.

Table 3.4 Major Floods in the Past (1997-2007) (Source: Zaw Lwin Tun & Hla Oo Nwe, 2010).

Sr.	Location / township/ Ward/division /state	Division/ State	Date	No. of village tracts and villages	No. of affected Households	No. of affected families	Affected population	Deaths	Loss (x100,000 kyat)
1	Homalin	Sagaing	8/7/1997	5 villages in 2 wards	9,916	99,950	59,594	-	99
2	Homalin	Sagaing	25/9/1997	63 villages	3,867	3,867	28,399	-	238
3	Paungpyin	Sagaing	11/7/1997	5 villages	6,652	6,652	44,143	2	-
4	Mawlaik	Sagaing	13/7/1997	16 villages	3,622	3,622	21,897	-	-
5	No. 10 Myopaw	Kachin	9/7/1997	10 villages	4,254	4,471	30,615	4	33
6	Kahyan	Yangon	7/6/1997	-	1,189	1,189	5,878	-	-
7	Bago	Bago	7/7/1997	All villages in 6 townships	6,629	6,629	33,768	50	-
8	Kayin	Kayin	1/8/1997	All villages in 5 townships	18,804	18,855	109,840	-	-
9	Hpa-an	Kayin	13/81991	6 villages	2,669	2,669	14,488	-	-
10	Kyauktaw	Rakhine	10/7/1997	-	1,030	1,030	5,983	-	50
11	Wundwin	Mandalay	2/6/2001	Thetaw village	463	1,164	2,172	42	-
12	Monywa	Sagaing	18/8/2002	-	9,178	9,460	48,746	-	2,535
13	Salingyi	Sagaing	18/8/2002	-	1,647	1,702	10,216	-	-
14	Kani	Sagaing	19/8/2002	-	2,042	2,207	12,048	-	2,447
15	Kyaikmaraw	Mon	19/8/2002	-	829	829	4,686	-	414
16	Shwepyithar	Yangon	8/9/2002	-	886	886	4,541	-	-
17	Hkamti	Sagaing	3/7/2003	-	1,230	1,536	8,131	-	-
18	Kyaukse	Mandalay	7/7/1997	All villages in 4 wards	1,443	1,763	7,045	-	351
19	Sagaing	Sagaing	11/9/2006	6 villages	770	791	5,372	-	-
20	Kyaukpadaung	Mandalay	9/10/2006	2 villages	14	18	97	16	-
21	Bhamo, Shwegu, Myitkyina	Kachin	24/7/2007	-	600	600	3,167	-	-

3.1.6.3 Coastal floods by cyclones and storm surges / Cyclone Nargis

The coastal region of Myanmar is prone to cyclones and accompanying storm surges. April, May and October to December are considered to be the cyclone months as per last 100 years record. The category three Cyclone Nargis struck Myanmar on 2nd and 3rd May 2008, making landfall in the Ayeyarwady Division, approximately 250 km south-west of Yangon, and affecting more than 50 townships, mainly in Yangon and Ayeyarwady Divisions, including Yangon, the country's largest city. Cyclone Nargis was characterized by wind speeds of up to 200 km/hr accompanied by heavy rain. The damage was most severe in the delta region, where the effects of the extreme winds were compounded by a 12 ft (3.6 m) storm surge. 90 percent of the deaths were caused as a direct consequence of the storm surge. The Cyclone Nargis was the worst natural disaster in the history of Myanmar, and the most devastating cyclone to strike Asia since 1991. As of 24th June 2008, the official death toll stood at 84,537 with 53,836 still missing, and 19,359 injured.

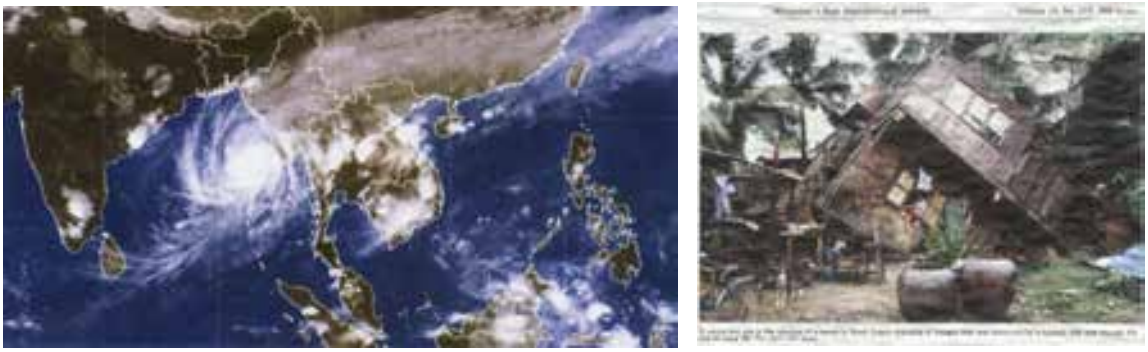


Figure 3.8 Cyclone Nargis.

Assessment data show that some 2.4 million people were severely affected by the cyclone out of an estimated 7.35 million people living in the affected townships. The cyclone affected area of the Ayeyarwady Delta covers some 23,500 km^2. The disaster caused widespread destruction to homes and critical infrastructure, including roads, jetties, water and sanitation systems, fuel supplies and electricity. A large number of water supplies were contaminated and food stocks damaged or destroyed. The winds tore down trees and power lines, while the accompanying storm surge submerged countless villages (Zaw Lwin Tun & Hla Oo Nwe, 2010).

Other recent cyclones that hit Myanmar are Cyclone Mala (April 2006) and Cyclone Giri (October 2010).

3.1.7 Tsunami's

The intensity of tsunami's in terms of round-up and the extent of inundation in the Ayeyarwady Delta, as indicated by computed tsunami amplitudes, was comparatively lower than in other countries in the region during the 2004 Indian Ocean Tsunami. In other coastal areas in Myanmar (North and South) the amplitudes are slightly larger than in the Ayeyarwady Delta, because the shallow delta extending offshore caused an increment of the tsunami wave amplitude (Ministry of Social Welfare, Relief and Resettlement, 2012).

3.1.8 Salinity intrusion

An estuary is a source of food and a transport link between a river and a sea. The estuary therefore has characteristics of both the river and the sea, being a unique environment influenced by tidal movements of the sea and freshwater flow of the river. Tides transport salt-water in and out of an estuary and mix it with fresh river water. The mixing process in an estuary is complex and dependant on the estuary characteristics. Tide-driven and density-driven mixing are the most important mechanisms. The river flow drives the density-driven circulation, accompanied by vertical salinity stratification. Tidal pumping appears to be an important tide-driven mixing mechanism. Tide-driven and density-driven mixing causes salinity to intrude further inland. The salt intrusion can reach a large distance from the coastline and affect water-use activities in the estuary (Nguyen Anh Duc, 2008).

The Hydrology Branch of the Irrigation Department is responsible for the monitoring of the salinity intrusion. Salinity intrusion measurements are done at the river mouths of Ayeyarwady Delta once a year at the end of the dry season (March), when the salinity intrusion is at its maximum due to low river flows, and more precisely on the dates on which high tide water levels occur. The measurement consists of identifying the location to which the 1 ppt salt concentration penetrates the rivers. The 1 ppt concentration is defined as the suitability limit for irrigation water. The locations are registered in a GPS to mark the exact location on the map. All the measurements are done manually; there is currently no permanent monitoring station (Khon Ra, 2014).

Figure 3.9 below shows the locations the yearly maximum intrusion of the 1 ppt salinity concentration for the period 2009 - 2013. It is obvious that the Lower Delta and to some extent also the Middle Delta suffer more from salinity intrusion than the Upper Delta.

Figure 3.9 Map of the yearly maximum intrusion of the 1 ppt salinity concentration in the Ayeyarwady Delta for the period 2009 - 2013 (Hydrology Branch, Khon Ra, 2014).

Figure 3.10 presents the progressive salinity intrusion in the delta during the dry season.

Figure 3.10 Average salinity intrusion in the Ayeyarwady Delta (1 ppt line).

3.1.9 Coastal and river bank erosion

Riverbank and coastal erosion is one of the major issues in the Ayeyarwady Delta. River bank erosion takes mainly place in the Upper Delta, where the river geomorphology is still very dynamic. Bank erosion causes sedimentation in the river beds building up local barriers which can provoke localized flooding danger. Coastal erosion is mainly due to mangrove destruction and the decrease in sediment load caused by the construction of dams upstream. There is a lack of legislation, regulation and enforcement to avoid the settlement of (mainly fishermen communities on the erosion (and flooding) sensitive coasts and river banks. Regular displacement of people and casualties are the result.

3.1.10 Nature and Wetlands

Myanmar is undergoing a rapid transition from one of the world's most isolated countries to an emerging democracy and opening up to the world through increased international investment. Hence, environmental conservation in parallel with economic development opportunities is one of the greatest challenges for Myanmar in the 21st century (Wildlife Conservation Society, 2013). Human encroachment, commercial overexploitation of animals and fish, agricultural expansion / conversion of wetlands and logging are seen as the greatest current threats. However, expected environmental and water quality deterioration will add to this soon. But as will be described below also over the last decade's severe degradation of these natural resources has already taken place.

3.1.10.1 Mangrove forests

The natural vegetation of the lower, tidal delta is mangrove forest (today 46 percent of the total area of mangroves in Myanmar are found in the Ayeyarwady Delta), but this has been heavily exploited and are largely in a degraded state due to human activities such as wood harvesting and coastal development. Most of the remaining forest is in various stages of regrowth. Four types of forest are recognized (Salter, 1982):

1. low mangrove forest, colonizing soft mud submerged at every tide; characterized by species of Ceriops, Avicennia, Kandelia and Bruguiera;

2. tree mangrove forest, developing on mud banks inland of low mangrove forest and at the edges of tidal streams; dominated by species of Rhizophoraceae;
3. saltwater Heritiera forest, on the landward side of the above two types, but still flooded at every tide; dominated by Heritiera tomes;
4. freshwater Heritiera forest, a closed evergreen high forest, flooded at high tide by only moderately brackish water; comprised mainly of Bruguiera and Heritiera.

Mangroves in Myanmar appear to be classified as primary or secondary areas (FAO, 2003; Wildlife Conservation Society, 2013). Primary areas are protected under jurisdiction of the Ministry of Environmental Conservation and Forestry; they are not available for aquaculture and are essentially forest reserves. Significant jurisdiction of the secondary areas seems to be devolved to the Department of Fisheries for availability to conversion to aquaculture. The delineation of primary and secondary areas does not appear to be very clear and even primary forests are exploited by the local communities.

3.1.10.2 Functions of mangroves

Processing excessive salt in the water absorbed is one of the biggest challenges in the salty environment in which mangroves live. Mangrove plants have developed several methods, according to the species, to desalinate ocean water. They may exclude the uptake of salt at the root level, or remove excess salt at the leaf level, by using salt excretion glands by cuticular transpiration at the leaf level, or by accumulating the salt in leaf tissues and then shedding the leaves (Killmann, 2005). This mangrove vegetation plays generally an important role in coastal protection. Mangroves also help protect coral reefs, sea-grass beds and shipping lanes by entrapping upland runoff sediments. This is a key function in preventing and reducing coastal erosion and provides nearby communities with protection against the effects of wind, waves and water currents (Killmann, 2005).

Mangrove forest ecosystems provide a wide range of services at the local and national levels. Fishermen, farmers and other rural populations depend on them as a source of wood (e.g. timber, poles, posts, fuelwood, charcoal) and non-wood forest products (food, thatch – especially from nipa palm – fodder, alcohol, sugar, medicine and honey) (FAO, 1994).

Mangroves support the conservation of biological diversity by providing habitats, spawning grounds for fish, nurseries and nutrients for a number of animals as monkeys, king cobra and white elephants, last one are extinguished due to the degradation of the mangroves (Maung, 2013). Assessments of the links between mangrove forests and the fishery sector suggested that for every hectare of forest cleared, nearby coastal fisheries lose some 480 kg of fish per year (MacKinnon and MacKinnon, 1986).

Mangrove ecosystems are also used for aquaculture, both as open-water estuarine mari-culture (e.g. oysters and mussels) and as pond culture (mainly for shrimps). Because of its high economic return, shrimp farming has been promoted to boost the national economy and alleviate poverty in several countries. This activity is often an answer to the financial constraints on many farmers and local communities and represents a source of employment (Killmann, 2005).

3.1.10.3 Degradation of the mangroves in the Ayeyarwady Delta

The mangroves of the Ayeyarwady Delta have been seriously degraded over time due to overexploitation of the resource and to the conversion of land for rice fields and shrimp (and fish) ponds, an activity promoted by the government as a way to ensure self-sufficiency in food production.

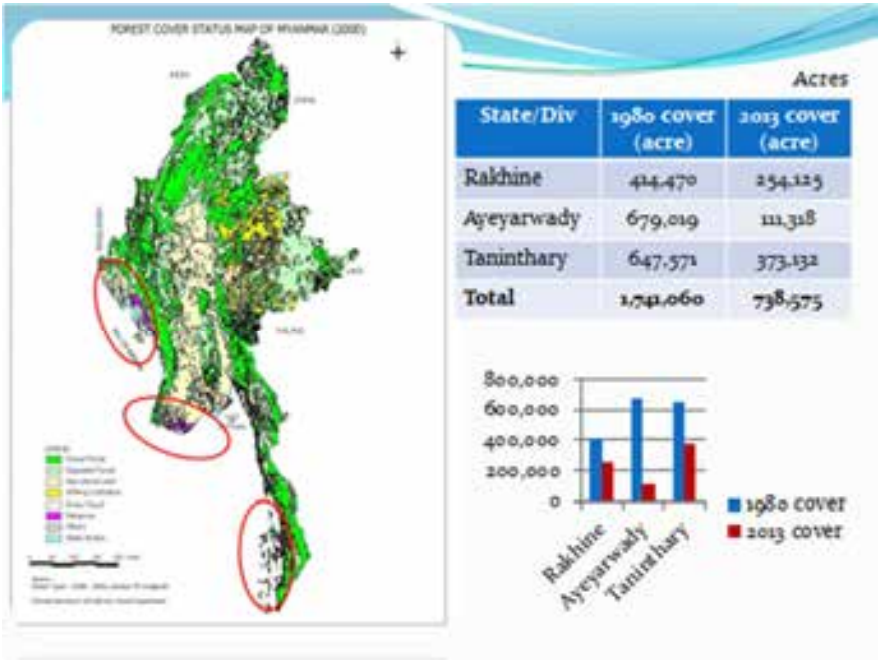


Figure 3.11 Status of mangrove forest in Myanmar (Maung, 2013).

As shown in figure 3.11 the area covered by mangroves has decreased from 679.019 acres to 111.318 acres in the period between 1980 to 2013. The figures suggest that during the past 33 years about 83% of the mangroves in the Ayeyarwady Delta have been lost (Maung, 2013).

Table 3.5 Conversion of mangroves in to agricultural fields and shrimp ponds between 1980 and 2013 (Maung, 2013)

Division / state	**Total mangrove (1980)**	**Other land use (ac)**			**Current mangrove (2013)**
		Agriculture	Shrimp pond & other	Total	
Ayeyarwady	679,019	265,917	301,784	567,701	111,318

According to the project manager Win Maung of MERN (Myanmar Environmental Rehabilitation Network) the quality of the remaining 17% of the mangroves in the Ayeyarwady region is not good and cannot be used to produce seeds for replantation. The same phenomenon is seen at the regional level: Asia suffered a net loss of more than 1.9 million hectares since 1980, mainly due to changes in land use from 1980 to 1990 (Killmann, 2005).

According to Maung (2013) the main causes changing the mangroves in the Ayeyarwady Delta are:

- Settlement;

- Charcoal burning and fuel;
- Paddy field;
- Shrimp farming;
- Salt pans;
- Home garden.

The main cause of loss of mangrove area in the Ayeyarwady Delta has been overexploitation and the development of shrimp farms. Because of its high economic return, shrimp farming has been promoted to boost national economies, as a potential source of income for local communities and as a means of poverty alleviation. However, this activity has caused loss of habitat and of ecosystem services provided by mangroves, and may damage surrounding areas through pollution caused by the chemical products used (Maung, 2013).

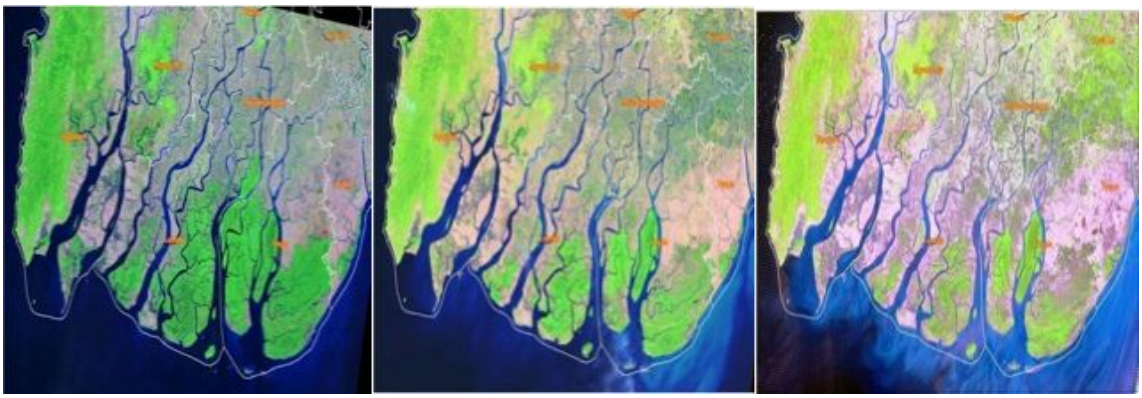


Figure 3.12 Change of mangrove cover over time in the Ayeyarwady Delta (Maung, 2013).

Other mangrove areas have been clear-cut for urban or tourist development. The decrease in freshwater input or the interruption of flows caused by the construction of dams and diversion of water for irrigation may increase soil salinity, damaging the surrounding mangroves (Maung, 2013).

Mangroves have also been fragmented and degraded through overexploitation for wood forest products and pollution. Indirectly, habitats have been lost because of dam construction on rivers, which often diverts water and modifies the input of sediments, nutrients and freshwater. Even though dense mangrove forests can be important in coastal protection, natural disasters should also be listed among the possible causes of degradation: several tropical countries are frequently hit by cyclones, typhoons and strong winds, and the trees in the front lines may be damaged and/or uprooted during these catastrophes (Killmann, 2005).

Mangroves have often been undervalued and viewed as wastelands and unhealthy environments. The high population pressures frequently present in coastal zones have in some places led to the conversion of mangrove areas for urban development. Killmann stated in 2005 that if deforestation of mangroves were to continue, it could lead to severe losses of biodiversity and livelihoods, increased salt intrusion in coastal zones and the siltation of coral reefs, ports and shipping lanes, with consequent losses of income from tourism and the loss of knowledge of mangroves and their use as recreational sites for coming generations. In view of the figures above one can wonder whether that stage has not already been reached.

3.2 Drivers of change

Summary of drivers of change for the Base Layer

Climate change:

The Myanmar's National Adaptation Programme of Action (NAPA) to Climate Change (Ministry of Transport, 2012) includes the climate change predictions as presented in Table 3.6

Table 3.6 Climate change predictions (Source: Ministry of Transport, NAPA, 2012)

Climate change predictions for 2001-2020 include:	Climate change predictions (compared to 2001) for 2021-2050 include:	Climate change predictions (compared to 2001) for 2051-2100 include:
• an increase in temperature of ~ 0.7˚C in the Ayeyarwady region; • an increase in clear sky days in Northern and Central Myanmar exacerbating drought events; • highly variable rainfall changes throughout the country with however only small increase in the Ayeyarwady region, and • an increase in floods and droughts resulting from variable rainfall conditions.	• an increase in temperature of 1.4 ºC in the Ayeyarwady region • an increase in rainfall of approx. 250 mm in Ayeyarwady Delta; • periods of heavier rains, and • longer dry spells.	• an increase in temperature of 3.5 ºC in Ayeyarwady region; • an increase of approx. 450 mm of rainfall in Ayeyarwady region; • a weakened monsoon climate supported by decreased cloud coverage, and • an increase in drought periods across most of Myanmar.

Sea level rise

In Slangen et al. (2013) updated projections for twenty-first century regional sea-level changes are given for two sea level change scenarios (A and B) based on the IPCC-RCP climate scenarios 4.5 and 8.5 with a temperature increase of 1.2˚C–2.7˚C and 2.7˚C–5.4˚C, respectively, between 1986–2005 and 2081–2100.

In total scenario A yields a net global mean sea-level rise of 0.52±0.19 m (mean±1σ) between 1986–2005 and 2081–2100, while scenario B yields a net global mean sea level rise of 0.70±0.26 m for the same period.

According to the Asian Development Bank (ADB), "many more people" in Southeast Asia died as a result of natural disasters between 2001 and 2010 than during the previous decade, primarily due to the 2004 India Ocean tsunami and 2008's Cyclone Nargis, whose aftermath showcased the Myanmar government's inability to respond to extreme weather. Although not directly to be related to climate change, the devastating Cyclone Nargis hit Myanmar with resulting waves of more than 6 meters in May 2008, the strongest ever (U Nyan Win, 2010) killing 138,373 people and leaving about 2.4 million affected. Total damage and loss was estimated at approximately 11.7 trillion Kyats, i.e. 4.1 billion US$ (Ministry of Social Welfare, Relief and Resettlement, 2012).

Subsidence

Most deltas are subjected to the natural geological process of long-term subsidence. Additionally, the expected increased extraction of groundwater and fossil fuels may cause significant lowering

of the delta surface on the short term. Other short-term processes leading to delta surface lowering at a more local scale are shallow compaction and oxidation of organic sediments, which may also result from human activities such as ground water pumping for drinking water supply of fish and shrimp ponds. However, so far, no real field observation data have been found on subsidence in the Ayeyarwady delta. Syvitski et al (2009) estimated a Relative Sea Level Rise (= Sea level rise plus compaction/subsidence minus delta aggradation trough sedimentation) of 3.4 – 6 mm/year, and categorised herewith the Ayeyarwady Delta as a delta in peril: 'reduction in aggradation plus accelerated compaction overwhelming rates of global sea-level rise'.
The construction of more dams upstream will decrease the sediment load in the rivers and therewith the aggradation rate of the delta.

Technological developments

Research focuses are set on agriculture, biotechnology, renewable energy, health, internet technology and marine science and technology[1]. According to the World Energy Council, in 2007, Myanmar had coal resources estimated at around 2 million tons, 447.7 TCF of natural gas and 206.9 million barrels of oil. The hydropower potential of Myanmar's four main rivers is estimated at 40,000 megawatts, of which only a small portion has been harnessed. The Myanmar government is undertaking ventures to exploit these energy resources, both as a basis for accelerated overall economic development and for direct social benefit to their residents[2]. Technological developments will also take place for the exploitation of gas and oil reserves.

Research gaps

Apart from statistical data on for instance agricultural production there is not much recent scientific information available on the Ayeyarwady delta, mainly due to the fact that in the last 20 years not much research has been done and most of the monitoring programs have been halted. Therefore research gaps exist for all drivers of change.

During three Delta Alliance workshops held in respectively Pathein, Hinthada and Yangon in June 2014 the key issue 'knowledge development and innovation' scored among the participants second highest (after flooding) out of 8 key issues for the delta.

In face of climate change developing countries are facing different weather patterns than in the past. More knowledge has to be developed on how e.g. hydrological systems will change. Apart from the NAPA (Ministry of Transport, 2012) study not much research has been done on the extent and impacts of climate change.

Concerning flood prevention there is a lack of information and insufficiencies in capacity. The relatively low level of technological capability and the requirement of appropriate training is a significant barrier to technology transfer and development.

1 Facts on Science, Technology and Innovation. South Asia and European Union (SEA-EU-NET) http://www.sea-eu.net/facts/sea/myanmar

2 http://www.myanmarenergyinvestmentsummit.com;
http://www.worldenergy.org/documents/ser2007_final_online_version_1.pdf

3.2.1 Climate change (temperature, precipitation, sea level rise)

Climate

The predicted rainfall and temperature (Ministry of Transport, NAPA, 2013) trends are given in Figure 3.13.

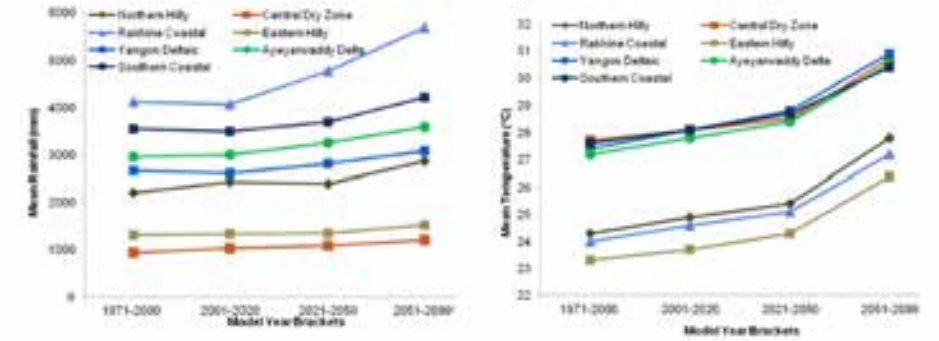


Figure 3.13 Predicted rainfall and temperature trends for the seven physiographic regions in Myanmar (PRECIS model).

Sea level rise

In Slangen et al. (2013) updated projections for twenty-first century regional sea-level changes are given for two sea level change scenarios (A and B) based on the IPCC-RCP climate scenarios 4.5 and 8.5 with a temperature increase of 1.2˚C–2.7˚C and 2.7˚C–5.4˚C, respectively, between 1986–2005 and 2081–2100. In total scenario A yields a net global mean sea-level rise of 0.52±0.19 m (mean±1σ) between 1986–2005 and 2081–2100, while scenario B yields a net global mean sea level rise of 0.70±0.26 m for the same period. A value of 95 cm sea level rise (mean+1σ, rounded to 5 cm) of scenario B projections is proposed as the high scenario for impact and adaptation assessment of coastal areas for the year 2100 relative to 2005. It is not an upper-end scenario; higher values are possible, but have low probability. A value of 35 cm (mean-1σ, rounded to 5 cm) of scenario A projections is proposed as the low scenario for the year 2100 relative to 2005. A central value of the range between the high and low scenario is 65 cm.

For intermediate time periods no regional sea level change projections are available, so interpolated curves of sea level change between present and 2100 should be derived. A rough estimate is derived by using shape of the projected temperature curves (mean of all models), since most processes are temperature dependent. The sea level change scenarios are relative to the year 2005. For all relevant basins the same scenarios are taken. The final results of the projections are too little distinctive to justify different scenario levels (Table 3.7).

Table 3.7 Overview of current and projected sea level rise for several scenarios

Aggregated basin	2005	2010	2020	2050	2100
	Current Sea Level Rise	Sea Level change scenarios	Sea Level change scenarios	Sea Level change scenarios	Sea Level change scenarios
Andaman region	3.0 mm/year	high: 4 cm central: 4 cm low: 4 cm	high: 12 cm central: 12 cm low: 12 cm	high: 38 cm central: 31 cm low: 24 cm	high: 95 cm central: 65 cm low: 35 cm

Vulnerability to climate change

According to the Asian Development Bank (ADB), "many more people" in Southeast Asia died as a result of natural disasters between 2001 and 2010 than during the previous decade, primarily due to the 2004 India Ocean tsunami and 2008's Cyclone Nargis, whose aftermath showcased the Myanmar government's inability to respond to extreme weather. Although not directly to be related to climate change, the devastating Cyclone Nargis hit Myanmar with resulting waves of more than 6 meters in May 2008, the strongest ever (U Nyan Win, 2010) killing 138,373 people and leaving about 2.4 million affected. Total damage and loss was estimated at approximately 11.7 trillion Kyats, i.e. 4.1 billion US$ (Ministry of Social Welfare, Relief and Resettlement, 2012).

The NAPA of Myanmar indicates also that the Ayeyarwady Region is the most vulnerable region of Myanmar (see Figure 3.14). If population density is taken into consideration then only the Yangon Region (which is also partly located in the delta) is more vulnerable than the Ayeyarwady Region.

According to the NAPA (Ministry of Transport, 2012) Myanmar is very vulnerable to climate change as a result of the following compounding factors (Lian, K. K. and L. Bhullar, 2010):

- employment and the national income is dependent on climate-sensitive sectors such as agriculture, forestry and natural resources;
- human populations and economic activities are concentrated in the coastal zone as well as in low-lying lands and are therefore exposed to long-term climatic impacts such as sea-level rise as well as an increase in cyclones and storm surge/flooding;
- exposure to both geological and meteorological hazards (e.g. earthquakes, floods, cyclones and tsunamis) as a result of the country's southwest location within the Bay of Bengal;
- high poverty levels which affect the capacity of the country to respond to climate change related impacts; and
- limited technological capacity to prepare for the impacts of climate change or the consequences of climate change related events.

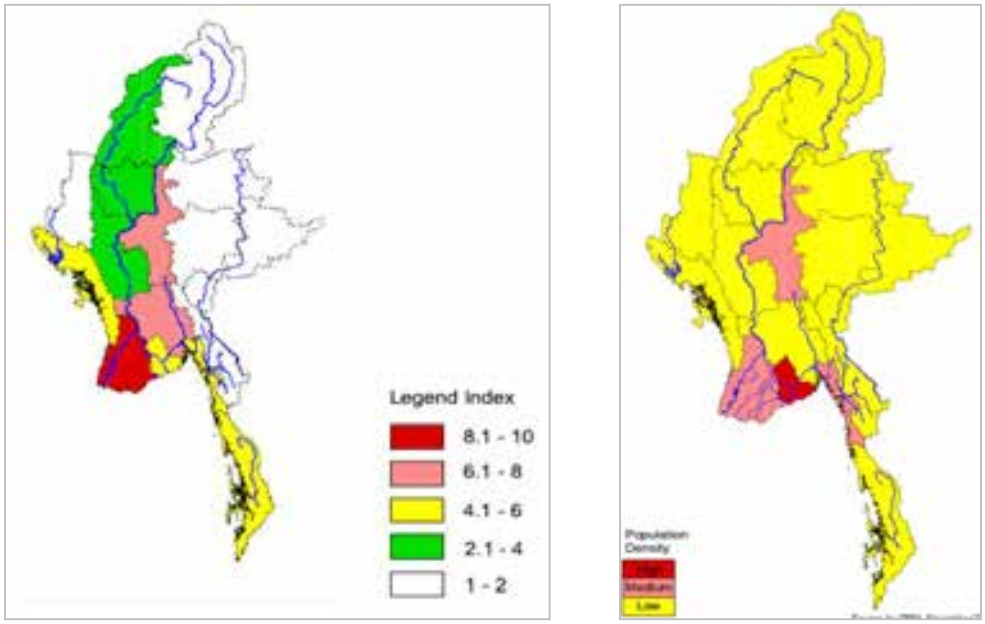


Figure 3.14 (right) Myanmar's overall climate change vulnerability index (taking into account areas and socio economic sectors most at risk); and (left) climate change vulnerability index for Myanmar considering population density.

3.2.2 Subsidence (natural or human-induced)

Most deltas are subjected to the natural geological process of long-term subsidence. Additionally, extraction of groundwater and fossil fuels may cause significant lowering of the delta surface on the short term. Other short-term processes leading to delta surface lowering at a more local scale are shallow compaction and oxidation of organic sediments, which may also result from human activities. So far, no data on subsidence in the Ayeyarwady Delta are available. The establishment of a structural ground water extraction and subsidence monitoring system should be considered for subsidence prone areas zones such as Yangon Region, where due to increasing urbanisation, population growth and industrial development the ground water extraction can be expected to increase due to higher fresh water scarcity.

3.2.3 Research gaps

In face of climate change developing countries like Myanmar are facing different weather patterns than in the past. They cannot rely on 200 years of past data to prepare for the following years. Bringing a new kind of uncertainty: dry areas get much drier, wetter areas get much wetter, and there is greater unpredictability of rainfall. More knowledge has to be developed on how e.g. hydrological systems will change. New infrastructure needs to be planned accordingly. Apart from the NAPA (Ministry of Transport, 2012) study not much research has been done on the extent and impacts of climate change.

Concerning flood prevention there is a lack of information and insufficiencies in capacity. The relatively low level of technological capability and the requirement of appropriate training is a significant barrier to technology transfer and development. However, training alone is not enough. Training and awareness-raising is most effective when the newly trained staff can apply their skills. In turn, this requires adequate financial support.

Not all floods are disasters and disasters are complex events. Due to the floods, economic losses were huge. Natural and man-made changes continue to alter the ecology and affect the environment. Lessons can be learnt from both successful and failed experiences with structural, non-structural and hybrid structural strategies. Coordination between all involved agencies and departments is needed (Zaw Lwin Tun & Hla Oo I, 2010).

3.3 Pressures

Summary of pressures in Base Layer

Impact of climate change on water resources

Climate change-induced changes to hydrological cycles will deteriorate water quality, quantity, and accessibility. Several sections of the hydrological cycle are vulnerable to climate change: flooding, contamination of water resources, erosion and limited replenishment of waterways, increase of risk of flash floods as well as decrease ground water recharge. Conversely, increases in drought events will increase utilisation pressures on ground water for expanding irrigated agriculture. Rising sea-levels, however, will lead to salt-water intrusion. (NAPA, Ministry of Agriculture and Irrigation, 2012).

River hydrology and hydrodynamics

Given all the projected water uses (hydropower, irrigation, drinking water supply, navigation, industrial and mining abstractions) water allocation priority problems may arise and an impact on the minimum environmental flow requirements may exist. Expected longer dry spells may cause shortage at the end of the dry season. Water balances and allocation studies are necessary to address these future water resources problems.

Drinking water: quality and quantity

Water scarcity will become more and more a daily challenge in Myanmar's Ayeyarwady Delta in the dry season, especially in the Lower Delta where the river water (and often also the groundwater) is saline. Due to sea level rise and changing hydrodynamics of the rivers saline water will further penetrate into the delta.
Arsenic contamination of drinking water sources is an emerging public health issue in Myanmar. However, the magnitude of arsenic contamination of groundwater sources in Myanmar is still rather unknown.

Water and soil pollution

Agricultural inputs, such as chemical fertilizers and pesticides are increasingly being used. The utilization rate of chemical fertilizers in the delta happens to be the highest among the agricultural regions in Myanmar. This will result in an increasing state of pollution. Water quality concerns are also being raised with regard to mining activities and the growth of cities and industrial zones. The disposal of untreated domestic wastewater and the increase in industrial and mining activities will further affect the water quality in the delta with a range of additional parameters (heavy metals, organic micro-pollutants and oils).

Flooding (flood hazard)

Myanmar is prone to cyclones, mainly during the months April, May, October, November and December. The coastal region such as the Lower Ayeyarwady Delta is also prone to storm surges. Poor water control and drainage works contribute to periodic flooding and crop losses.

The effect of an increase in rainfall and its intensity is the increase in run-off, enhancing the risk of river floods, flash floods and urban floods. Deforestation contributes to these processes. It can also damage vulnerable crop and can create flash floods from the surrounding mountain ranges in the lowland areas of the delta (Hassman, 2013)

Impacts dam construction and deforestation on delta dynamics

Due to planned extensive damming projects losses in sediment supply are expected to occur, leading to possible retreat of the delta. This process will be further enhanced due to potential sea level rise (Salmivaara, 2009). Decreased sediment yields may also be caused by the increased sand mining activities in the river beds. Decreased sediment yield has significant impact on the agriculture on the floodplains as the river brings less nutritious sediment to the croplands. On the contrary, it is believed that the sediment influx in the Ayeyarwady River may be increasing as a consequence of deforestation in its fragile upstream landscape and widespread land use changes across the basin.

Salinization / salt water intrusion

Salinity and its seasonal intrusion gradients are dominant factors for coastal system, fisheries, agriculture and drinking water supply. Therefore, any changes on present spatial and temporal variation of salinity will affect the biophysical system of coastal area.

Coastal and riverbank erosion

Riverbank and coastal erosion is one of the major issues. River bank erosion takes mainly place in the Upper Delta, where the river geomorphology is still very dynamic. Coastal erosion is mainly due to mangrove destruction and the decrease in sediment load caused by the construction of dams upstream. There is a lack of legislation, regulation and enforcement to avoid the settlement of (mainly fishermen communities on the erosion (and flooding) sensitive coasts and river banks.

Mangroves and biodiversity loss

Moreover, they are also vulnerable to accelerated climate change and sea level rise, as they pose major new challenges to biodiversity conservation and nature in general. The root causes of these threats are low conservation awareness, poverty, poor livelihood conditions (lack of alternatives), weak systematic biological monitoring systems, low grassroots support for conservation and weak law enforcement. Environmental conservation in parallel with economic development opportunities is one of the greatest challenges for Myanmar in the 21st century (Wildlife Conservation Society, 2013).

Research/knowledge gaps

During the Delta Alliance missions in July 2013 (Driel and Nauta, 2013) and June 2014 the following research and knowledge gaps have been observed:

- Need for overview of all hazards and consequences;
- Hydrological and monitoring data;
- Water balances and allocation studies are necessary to address future water resources problems;
- Information on Ayeyarwady tributary behaviour and characteristics;
- Trends, programs, leading to water quality problems. Baseline conditions;

- Knowledge on arsenic contamination of groundwater;
- Monitoring system needed for anthropogenic subsidence and groundwater exploitation;
- Size of loss of wetlands;
- Potential impacts of climate change and sea level rise on mangroves and biodiversity conservation.
-

Impact of climate on water resources (directly derived from the NAPA)

Climate change-induced changes to hydrological cycles will deteriorate water quality, quantity, and accessibility. Several sections of the hydrological cycle are vulnerable to climate change. The rate of snow and glacial melt is expected to increase resulting in changing river flows and unpredictable flooding events. The late onset and early withdrawal of the monsoon period will result in large quantities of rain falling over short periods. This will result in flooding, contamination of water resources, erosion and limited replenishment of waterways. Furthermore, changes in river flow and discharge will increase the risk of flash floods as well as decrease ground water recharge. Vast areas of lowland regions will be regularly inundated as a result of flooding events. Conversely, increases in drought events will increase utilisation pressures on ground water for expanding irrigated agriculture. Rising sea-levels will lead to salt-water intrusion into groundwater supplies particularly as existing water levels decrease. Ground water supplies will be particularly vulnerable to saline intrusion during the dry season as a result of low water volumes in river systems. Furthermore, regardless of the quantity of water available increased temperatures from climate change will increase evaporation rates, raising the concentration of dissolved salts in the water often deeming it unsuitable for drinking purposes (Ministry of Agriculture and Irrigation, 2012).

River hydrology and hydrodynamics

Many sectors are increasingly making use of the water resources of the Ayeyarwady River: hydropower, irrigation, drinking water supply, navigation, industrial and mining abstractions. In view of the further economic development of Myanmar in all these sectors water allocation priority problems may arise and an impact on the minimum environmental flow requirements may exist. Expected longer dry spells may cause shortage at the end of the dry season. Water balances and allocation studies are necessary to address these future water resources problems. In addition, due to more extreme water events also more extreme discharges may be expected.

Drinking water: quality and quantity

Drinking water scarcity will become more and more a daily challenge in Myanmar's Ayeyarwady Delta in the dry season. Due to sea level rise and changing hydrodynamics of the rivers saline water will further penetrate into the delta.

Industrial water use is increasing in urban areas, special economic zones and other areas, affecting water availability in these areas and, perhaps of even stronger concern, the water quality. Mining activities have already shown to negatively impact on the water quality in Chin State (Deltares and TUDelft, 2013).

Arsenic contamination of drinking water sources is an emerging public health issue in Myanmar. However, the magnitude of arsenic contamination of groundwater sources in Myanmar is still rather unknown. Activities such as: i) more deep well tubes reaching non-arsenic aquifers, ii) retesting and confirmation of arsenic levels of water sources, iii) arsenic education/awareness raising, iv) community mobilization and immediate protection measures and v) identification and implementation of alternative drinking water sources, may lower the this pressure. The absence

of clear rules and regulations in the sector creates an obstacle in taking legal action in many cases. It is imperative therefore to establish a workable standard by starting with a set of essential parameters that are of particular significance in the context of Myanmar. This must be complemented by appropriate enforcement mechanisms (Department of Health, 2000).

Water and soil pollution

Due to various policy reforms the agricultural sector changes the way it operates and functions. As a result agricultural inputs, such as chemical fertilizers and pesticides are increasingly distributed either partially or wholly by the private sector. Moreover, the utilization rate of chemical fertilizers in the delta happens to be the highest among the agricultural regions in Myanmar. This will result in an increasing state of pollution.

Water quality concerns are also being raised with regard to mining activities and the growth of cities and industrial zones. The disposal of untreated domestic wastewater will lead to increased oxygen demand and deteriorating hygienic conditions of the surface waters and the increase in industrial and mining activities will further affect the water quality in the delta with a range of additional parameters (heavy metals, organic micro-pollutants and oils).

Flooding (flood hazard)

Myanmar is prone to cyclones, mainly during the months April, May, October, November and December. The coastal region such as the Lower Ayeyarwady Delta is also prone to storm surges. During Cyclone Nargis, 90 percent of the 140,000 deaths were caused as a direct consequence of the storm surge. There is no evidence that this risk would decrease in the future. Poor water control and drainage works contribute to periodic flooding and crop losses.

The effect of an increase in rainfall and its intensity is the increase and larger variability in run-off, enhancing the risk of river floods, flash floods and urban floods. Deforestation contributes to these processes. It can also damage vulnerable crop and can create flash floods from the surrounding mountain ranges in the lowland areas of the delta (Hassman, 2013).

Myanmar has limited technology for remotely and automatically forecasting extreme weather events. This reduces the time available for local communities to take necessary actions and preparations relative to Early Warning Systems in other more developed countries. However, even in cases when technology has been effective in providing sufficient lead-time for local communities to prepare, lives have still been lost and property damaged. This is as a result of three main reasons: i) warnings do not reach communities in remote areas; ii) communities do not know how to respond; iii) communities do not understand or cannot interpret the warning received. For example during Cyclone Nargis communities in the Ayeyarwady Delta refused to respond to warnings as they did not understand/realise the magnitude of the threat (NAPA, Ministry of Transport, 2012).

Impacts of dam construction and deforestation on delta dynamics

Due to planned extensive damming projects losses in sediment supply are expected to occur, leading to possible retreat of the delta. This process will be further enhanced due to potential sea level rise (Salmivaara, 2009). This could impact the densely populated delta region and Yangon, and further exacerbate the impacts of extreme events such as Cyclone Nargis in 2008. Decreased sediment yields may also be caused by the increased sand mining activities in the river beds. Decreased sediment yield has significant impact on the agriculture on the floodplains

as the river brings less nutritious sediment to the croplands. This could furthermore increase the need to use fertilizers, and thus, cause potential water quality problems.

On the contrary, it is believed that the sediment influx in the Ayeyarwady River may be increasing as a consequence of deforestation in its fragile upstream landscape and widespread land use changes across the basin. Irrigation canals appear to be silting up 2-3 times the rate that was assumed when the systems were being designed; any irrigation rehabilitation would therefore require a serious reconsideration of sediment management.

Coastal and riverbank erosion

Riverbank and coastal erosion is expected to increase, due to more extreme river discharges, sea level rise and more extreme weather events, mangrove destruction and the decrease in sediment load caused by the construction of dams upstream. The risk of coastal erosion will also increase due to large-scale destruction of coastal ecosystems (e.g. mangroves and other coastal ecosystems) resulting from increasing human populations, infrastructural developments (e.g. shrimp farming), over exploitation (timber and fire wood), and pollution that affects the water quality. Apart from a lack of spatial planning processes and procedures, there is a lack of legislation, regulation and enforcement to avoid the settlement of (mainly fishermen communities on the erosion (and flooding) sensitive coasts and river banks.

Mangroves and biodiversity loss

Especially the mangrove forests are highly valuable but also under high pressure from encroachment and exploitation and are largely in a degraded state due to human activities such as wood harvesting (mainly for the production of charcoal) and coastal development (paddy fields and shrimp/fish ponds). This pressure will increase due to population growth and economic development. The effects of climate change on biodiversity are already evident in Myanmar. For example, shifts in the range as well as migration patterns of certain species of insects, marine/terrestrial mammals, birds and fish of have been observed. Climate change is likely to affect both the distribution and composition of forests in Myanmar (NAPA, Ministry of Agriculture, 2012).

An increase in sea-level will provide a higher base for storm surges and other extreme climate events. It is known that sea level rise and increased water temperatures are projected to accelerate coastal erosion and cause degradation of the mangroves and more offshore coral reefs, which in turn will negatively influence fisheries productivity (Wildlife Conservation Society, 2013).

4 Network Layer

4.1 Description current situation

4.1.1 Importance of the network layer

In an ADB News release of 16 December 2014 it was correctly stated that investment in connectivity infrastructure is a key factor in creating better access to economic opportunities, reducing costs, promoting trade, and attracting private investment into diverse geographic areas and sectors.

The release continued by saying that Myanmar is one of the least-connected countries in the world in terms of telecommunication, transportation, and logistics. In 2012, fixed and mobile telecommunication line penetration rates stood at less than 1% and 7% of the population, respectively. The road density in Myanmar is less than one fifth of the average in ASEAN countries. The country's inland waterways network, which is important for freight traffic, is also underutilized due to an ageing fleet of vessels and neglected ports facilities. Myanmar has been experiencing an influx of investors in recent years. Investments, however, have been concentrated in the oil, gas, and other mineral sectors, as well as light manufacturing. Private sector financing for much-needed infrastructure projects to boost connectivity remains a challenge due to an underdeveloped banking sector and capital market, and a lack of alternative funding sources.

4.1.2 Roads, ports and waterways in Myanmar

Road transportation is an important way of transportation in Myanmar. Most towns and cities are accessible only by land route. Myanmar has approximately 3,200 of paved roads and 24,000 km of unpaved roads. There are three main highways or corridors running north-south in Myanmar. In terms of importance and traffic they are: Yangon – Mandalay (695 km), Yangon – Pyay (288 km) and Western Union Highway, Pathein – Monywa Highway, which connects towns and cities on the west of Ayeyarwady River. The road network of the Ayeyarwady Region is underdeveloped due to the existence of many rivers and creeks and the high costs involved for the construction of bridges.

The country's waterways is also an important traditional mode of transportation to many remote areas of the country. Of more than 12,800 kilometers (7,954 miles) of waterways, 3,200 kilometers (1,988 miles) are navigable by large commercial vessels (World Bank, 2000). However, in many of these waterways sedimentation problems occur. Also a large number of towns in the Ayeyarwady Delta are reachable by rivers. Outside the monsoon season transport over sea south of the delta is possible; during the monsoon this is too dangerous.

Myanmar has 5,099 km of railway, however only a few towns and cities are connected by railway lines. There are currently no railway links to adjacent countries. Inadequate infrastructure as roads, bridges, canals, railways, ports and communication facilities impedes economic growth. Myanmar's long coastline is home to many natural harbours such as Pathein, Bhamo, Mandalay, Yangon, and Dawe. The government has taken steps to develop new ports and maintain the existing ones, although all the ports are not used to their maximum capacity. A salient geographic feature of Myanmar is its many rivers, especially in the Ayeyarwady Delta.

Since the economic liberalization in 1989, the government started many public works programs. Early in the 1990s the government used forced rural labour to work on these projects. These projects did not bring about major improvement in the infrastructure needs of the country. The result has been that economic expansion was made difficult because in the absence of adequate transportation facilities, distribution of goods and services has been extremely difficult and costly.

Figure 4.1 Road map Myanmar (http://www.mapsofworld.com).

4.1.3 Polders: Embankments, Sluices and Drainage System

The monsoon paddy cultivation in the Lower Delta and part of the Middle Delta is only possible if the land is effectively protected against intrusion of saline water through the construction of polders mainly consisting of embankments, sluice gates and drainage systems. For that purpose the Paddy Land Development Projects 1 and 2 have been realised. Figure 4.2 presents the progressive salinity intrusion in the delta during the dry season.

Figure 4.2 Average salinity intrusions (1 ppt line) in the Ayeyarwady Delta (MYFish, 2012).

Figure 4.3 gives a schematic image of the infrastructure of a polder. In view of the precipitation quantities supplementary irrigation is not needed during the monsoon season. There is also no need to store abundant rainwater during the rainy season. Contrary, due to the heavy rainfall

intensities, the role of the drainage canal is very important. The slide gates of the sluice are kept open from 15 May to mid-September and the drainage is controlled by the flap gates of the sluice to keep the water level of the drainage canals as low as possible. The old river courses are functioning as major drainage channels and small artificial drainage canals are connected as required in the areas with embankment. Whereas in the areas surrounded by polder dikes, artificial drainage canals are predominant.

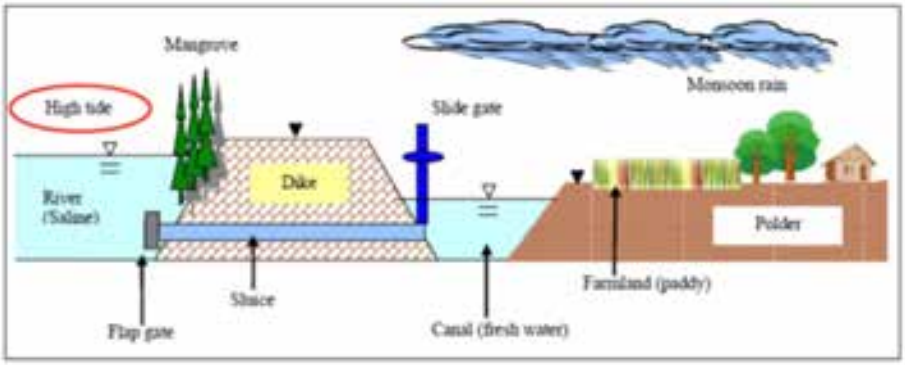
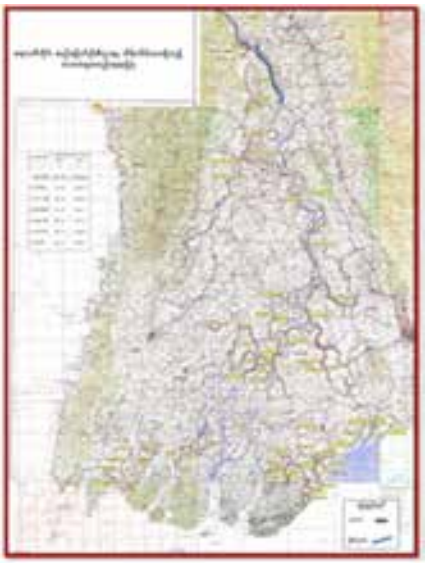


Figure 4.3 Functioning of a polder in the lower delta (JICA, 2011).

In the final stage of the rainy season the slide gates of the sluice located at the end points of the drainage canal are closed to store the fresh rainwater in the drainage canals. However, the salt water intrusion is occasionally still taking place through the degraded slide gates and also through leaking flap gates; hence the water impounded in the drainage canal is contaminated with salty water.



Under the responsibility of the Irrigation Department 163,899 ha of land has been protected by 41 polders and 1024 km of embankments, which often serve at the same time also as rural roads. The flood protection embankments have not only been built around polders but also as linear embankments along several rivers in the Ayeyarwady Delta, mainly in the Upper Delta. Similar embankments have also been constructed in areas that are prone to flash floods. The embankments protect major cities like Hinzada from riverine and flash floods. The embankments function also as a shelter and evacuation place for saving people's life from high floods and storm surges.

Figure 4.4 Embankments (red lines) in Ayeyarwady Region

4.1.4 Irrigation infrastructure

As the average annual rainfall can be more than 3,000 mm and concentrated in the rainy season from May to October, generally no irrigation is practiced for rainy season paddy cultivation in the area. At the end of the monsoon season the fresh rainwater is stored in the drainage canal for irrigation, livestock and miscellaneous purposes for the dry season.

In the Lower Delta irrigation is practiced during the dry season from November to April in a limited number of paddy fields located nearby the larger drainage canals by pumping the water from the canal. Diesel pumps are used and lifted water is conveyed through small ditches or in plot to plot method.

There are also several special polder areas where irrigation water is conveyed from the intake of the upstream reach of the tidal river where the water is fresh and free from salt water contamination (JICA, 2011). For instance in Labutta North polder, the irrigation water in the dry season from October to April is conveyed from the sluice gate intake located 16 miles (26 km) from the north boundary polder dike in the upstream of Ywe River. The irrigation water is conveyed through the feeder canal and it is filled into the drainage canals. Then the irrigation water is to be supplied to the field along the drainage canal by pumping. The project was completed in the year 2000, and the beneficial area is 2,500 acres (1,000 ha). However, it seems that the project did not accomplish the initially proposed target of the irrigation area and paddy production.

Tidal irrigation during the dry season is extensively practiced in the Middle Delta, while in the Upper Delta irrigation takes place by gravity (in case of upstream intake) or pumping.

4.1.5 Energy

Data is scarse, but even the most optimistic estimate say that less than 25 percent of the country has access to electric power (Somani, 2013). Electricity consumption in Myanmar has doubled from 3,303 giga watt hours (GWh) in 2000, to 6,093 GWh in 2012 (USEIA, 2013).

Myanmar's per capita electricity consumption is the lowest among the ASEAN-10 countries, estimated at 100-kilowatt hours (KWh) in 2010 (approximately one-twentieth of that in Thailand). The average annual GDP growth between years 2000-2005 was 5.5% in Bangladesh, 9.4% in China, 6.5% in India, 9.15% in Myanmar and 5.0% in Thailand (WRI 2009), explaining the rapid increase in energy demand in Myanmar and its neighbouring countries (Kattelus, 2009).

Apart from the agricultural sector, the hydropower subsector is the second most important sector in terms of economic development and investment. Dry-season irrigation, especially from river pumping projects, has been successfully increased; as a result, power demand is also increasing annually. Three-quarters of the total supply energy is hydropower. It is not surprising therefore that the country has to 'ration' its power supply to industries during the summer, with scheduled and unscheduled power cuts (Somani, 2013).

According to a report of the Department of Hydropower Planning (DHP), 2006 the hydropower potential of Myanmar is estimated to be as much as 40,000 MW. In 2002, 35 hydropower stations (including 15 medium-scale projects) had been completed with a total 100-estimated generated power of 390 MW, which is almost 1 per cent of potential generated power in Myanmar. The current status according to (Somani, 2013) is the installed capacity 3500 MW of which 60% is reliably available.

4.1.6 Drinking water supply systems

Only the larger villages and towns are provided with a drinking water supply infrastructure. In the rural areas many people still rely on surface water and water harvesting in ponds or tanks. Water scarcity is happening in dry season all over the country. However, access to groundwater for domestic water supply is increasing. Between 1952 and 1976, RWSD (predecessor of WRUD)

constructed 6,261 tube wells serving some 4.5 million rural people. The table below shows the shallow and deep tube wells constructed for drinking water supply from 1952 until 2012 for Ayeyarwady region.

Table 4.1 STW and DTW constructed for drinking water supply (Water Resources Utilization Department, WRUD, 2014).

Shallow and Deep Tube Wells (STW, DTW) constructed for drinking water supply												
State/Region	Before WRUD (1952-53 to 1994-95)				WRUD period (1995-96 to 2012)				Total from 1952-53 to 2012			
	DTW	STW	TOTAL	Population served	DTW	STW	TOTAL	Population served	DTW	STW	TOTAL	Population served
Ayeyarwady	571	2.473	3.044	1.115.905	202	2.008	2.210	404.550	773	4.481	5.254	1.520.455

4.2 Drivers of change

Summary of drivers of change Network Layer

Economic developments

It is expected (and the first signs are clearly visible) that the recent opening of the country will also create new rapid economic developments, which will demand for an upgrade of all infrastructure whether it be the transportation infrastructure and the navigability of the rivers, the irrigation infrastructure or the energy or drinking water supply network.

Technological developments

Many dams have been built in the mountainous areas around the Upper Delta and even more upstream in the Ayeyarwady basin, mainly for irrigation purposes. It is expected that the existing irrigation systems and the polders (to protect the agricultural land from salt water intrusion) will be further upgraded and extended. The annual rice production of Ayeyarwady Region of about 6 million tons accounts for 30 percent of the total production in Myanmar of about 22 million tons annually (FAO, 2001/2002). This situation is mainly due to the increase of farmland area, with a rapid 25 percent increase between 1990 and 1994.

According to the World Energy Council (2007), Myanmar has coal resources estimated at around 2 million tons, 447.7 TCF of natural gas and 206.9 million barrels of oil. The hydropower potential of Myanmar's four main rivers is estimated at 40,000 megawatts, of which only a small portion has been harnessed. The Myanmar government is undertaking ventures to exploit these energy resources, both as a basis for accelerated overall economic development and for direct social benefit to their residents[3].

It can be foreseen that many more dams will be built in the near future as well as for irrigation purposes, as for hydropower and flood mitigation.

Research gaps

Not much recent information is available on the Ayeyarwady delta, mainly due to the fact that in the last 20 years not much research has been done and most of the monitoring programs have been halted. Therefore research gaps exist for all drivers of change.

3 http://www.myanmarenergyinvestmentsummit.com;
http://www.worldenergy.org/documents/ser2007_final_online_version_1.pdf

Not much information has been found on the expected technological and infrastructural developments. To stimulate economic development and foreign investments so-called 'special economic zones' are and will be created in the neighbourhood in Yangon, however outside the Ayeyarwady Delta. The special economic zones and other business developments will likely focus on the urban infrastructure and the availability of fresh water.

During three Delta Alliance workshops held in respectively Pathein, Hinthada and Yangon in June 2014 the key issue 'knowledge development and innovation' scored among the participants second highest (after flooding) out of 8 key issues for the delta.

During the Delta Alliance missions in July 2013 (Driel and Nauta, 2013) and June 2014 the following research and knowledge gaps have been observed:

- Present status and future plans of the transportation sector (Ministry of Public Works);
- Current programs and plans, for drinking water supply and sanitation facilities, etc.

Technological developments: dams

The Ayeyarwady basin counts already many dams, mainly for irrigation purpose, some for hydropower and some for flood mitigation and for a number of dams the functions are combined.

Within the Ayeyarwady River basin region the government of Myanmar has embarked on a strategy to shift reliance on gas to hydropower with the aim to make it the sole source of electricity by 2030, which will result in seven large hydropower developments along the waterway. According to studies by the United Nations and other sources, the hydropower potential of Myanmar is estimated to be as much as 40,000 MW (Simmance, 2013).

Figure 4.5 Myanmar Rivers Network, Dams in Myanmar, "Save Myanmar's Rivers", 2010
http://www.burmariversnetwork.org/resources/publications/13/499.html

4.3 Pressures

Summary of pressures Network Layer

Demand for more transportation facilities (roads, ports and waterways)

The lack of infrastructure is hampering the economic development.

Maintenance and upgrading of agricultural engineering works

In the last four decades important infrastructure has been constructed for agricultural production: dams, diversion weirs, irrigation systems, and polders. There are plans to further increase agricultural production by the construction of new irrigation systems and the upgrading and repair of existing infrastructure.

Need for embankments against flooding

More and upgraded embankments are needed against flooding in the Middle and Upper Delta. Due to the expected increasing extreme weather events this need will increase the coming decades. Some of the existing embankments need maintenance, also in view of changing hydrodynamics of the rivers due to climate change.

Lack of water supply and sanitation

Only a small percentage of the rural population is connected to a public drinking water supply system. Due to climate change and sea level rise the need for drinking water supply systems will only become more urgent, certainly in the areas that are affected by salinity intrusion and arsenic contamination. Urbanisation and industrial development of Yangon (and some major cities in the Delta like Pathein and Hintada) will articulate the need for proper sanitation facilities, waste water treatment plants and water quality monitoring.

Impact of dams

The construction of dams poses a threat to the ecological integrity and flow regime of the river basin. Dams also result in adverse impacts to the flow regime of a river with grave implications to the health of floodplains and delta ecosystems and the ecosystem services they provide to local livelihoods. The construction of dams will also (further) reduce the sediment load of the river and therefor hamper the delta aggradation.

Lack of and ageing infrastructure

Infrastructure to support transportation, water supply, communications, and power supply is generally rather poorly developed. Maintenance of roads, embankments, polder sluices, drainage canals and irrigation systems is a recurrent problem.

Research/knowledge gaps

During the Delta Alliance missions in July 2013 (Driel and Nauta, 2013) and June 2014 the following research and knowledge gaps have been observed:

- Plans for township development (Min. of Border Affairs, DRD);
- Cost-efficient and innovative infrastructure;

- Innovation in agricultural engineering.

Demand for transportation facilities (roads, ports and waterways):

Economic developments request for a strong upgrade of the transportation infrastructure, that improves connectivity, cuts travel times, reduces transport costs and supports economic development and livelihood opportunities for many poor communities. It should help Myanmar to establish new business opportunities in rural areas, which are expected to emerge as a result of the country's ongoing liberalization program.

The delta is Myanmar's main rice growing region and has significant potential for large scale agribusinesses and seafood industries. However the road network's poor condition, due to years of neglect and the impact of Cyclone Nargis in 2008, deters enterprises like cash crops and high-value seafood products which require decent roads to get goods to market on time and in good condition.

Climate-resilient features should be incorporated in the project design, including an increase in the height of parts of the road to improve clearance during seasonal floods and to cope with any climate-related storm surges.

Maintenance and upgrading of agricultural engineering works

During the Delta Alliance field visits in July 2013 and June 2014 it has become evident that much of the infrastructure built under the Paddy I and Paddy II project needs an upgrade, partly because of the impacts of Cyclone Nargis and bad maintenance and partly to make the systems more climate resilient for the future. More infrastructure will also be needed in order to increase the agricultural production. For that purpose there are advanced plans to start up also the Paddy III project.

Need for embankments against flooding

In order to prevent flooding from the river extensive flood protection embankments have already been constructed along several rivers in the Ayeyarwady Delta, mainly in the Upper Delta. Similar embankments have also been constructed in areas that are prone to flash floods. Some of these embankments need maintenance and an upgrade in view of climate change.

More embankments are needed against flooding in the Middle and Upper Delta. Due to the expected more extreme weather events this need will increase the coming decades. During the Delta Alliance workshops in July 2014 'flood protection and lack of drainage' scored among the participants as the most important key issue.

Impacts of dams

The construction of dams poses a threat to the ecological integrity and flow regime of the river basin. Dams also result in adverse impacts to the flow regime of a river with grave implications to the health of floodplains and delta ecosystems and the ecosystem services they provide to local livelihoods. Unnatural changes in the flow regime of a river will result in: riverbank destruction due to increased erosion; altered flood cycles and disruption to the replenishment of wetlands, floodplains and delta ecosystems. This results in a decline of fisheries and aquatic plants dependent on these nutrients rich ecosystems. In addition, water quality will be reduced resulting in a decline of fish species and knock on impacts to the abundance and diversity of bird populations within the basin. Socio-economic conditions will be affected. The changed hydrological regime will reduce the productivity of agriculture, fisheries and the health of forest ecosystems such as mangroves along the Ayeyarwady Delta, which provides nearly 60% of

Myanmar's rice (Simmance, 2013). Moreover, often whole communities that live in the reach of the future reservoir have to be displaced.

It has to be mentioned however, that dams projects can also have positive effects such as the harnessing of a renewable natural resource, lower levels of air and water pollution compared with fossil fuels, increasing water flows in the dry season, lower flows in the wet season and generating electricity to increase industrial output and to raise standards of living. The latter is very important in the case of Myanmar due to the fact that energy shortages are common throughout the country including in Yangon; only 25 percent of the country´s population has electricity. Conditions for sound implementation of new dams imply availability and application of hydrological data and models and extensive (Strategic) Environmental Impact Assessments.

Other positive impacts to be considered are once reservoirs become established they can become important sites for birdlife. Some dam projects have implemented specific habitat restoration measures that can to some extent compensate for their negative impacts.

Need for drinking water supply and sanitation infrastructure

In view of the observed increasing vulnerability of the fresh water supply (caused by climate change, sea level rise, arsenic contamination) investments are needed in appropriate drinking water supply infrastructure. Also the urban and industrial development in and around Yangon will put extra pressure on water availability. Urbanisation and industrial development of Yangon (and some major cities in the Delta like Pathein and Hintada) will articulate the need for proper sanitation facilities, waste water treatment plants and water quality monitoring.

Lack of and ageing infrastructure

Industrial production and expansion are limited due to inadequate production and intermittent supply of electric power. Chronic shortages and frequent disruptions of supply exist. Therefore, state and private enterprises operate far below their capacity. Moreover, very often they have to depend on their own diesel-run power generators to meet their electrical needs.

Poor infrastructures such as lack of proper roads, electricity, limited telephone networks and dependency on the river transport with slower locally assemble boats, limits for instance the Delta MSE (Micro and Small Enterprises) to have easy access to market. Poor access to roads, no electricity, poor access to school, poor access to health care, etc. are also fuelling the prolonged poverty of the fishery (and other rural) households (MMRD Research Services, 2014).

During the Delta Alliance workshops and field trips in July 2013 and June 2014 it has become clear that a large part of the infrastructure is ageing and needs maintenance. This concerns the maintenance of many of the roads in the delta as well as the maintenance of the water management infrastructure: degraded embankments, sediment aggradation in drainage canals, degraded irrigation systems, need for dredging of blocked waterways for navigation, leaking sluices and flap gates, etc.

5 Occupation layer

5.1 Description current situation

5.1.1 Population

Population of the country was estimated at 58.38 million during the census of 2008-2009. Taking into account a growth rate of 1.52 percent the actual population will be approximately 62 million. Ayeyarwady Region, covering a large part of the Ayeyarwady Delta has a population of 8,041,084 on an area of 35,032 km^2, hence a population density of 230 inhabitants/km^2. Ayeyarwady Region can be considered as a rural region with relatively low level of urbanisation. These numbers only concern the Ayeyarwady Region and not the other two regions in which the remaining part of the Ayeyarwady Delta is located: the Yangon Region, including the urban agglomeration of Yangon (some 5 – 7 million inhabitants) and Bago Region.

This population density in Ayeyarwady Region is e.g. relatively low compared to the one of the Mekong Delta (approx. 500 inhabitants/km^2, excluding Ho Chi Minh City) and the Ganges-Brahmaputra-Meghna Delta (more than 1,200 inhabitants/km^2, including large urban agglomerations like Dhaka and Khulna).

5.1.2 Political Changes/History in Delta Management

Mya Than (2000) discusses in his paper the “Changing faces of the Ayeyarwady Delta” the political, social, economic and environmental changes between 1850 and 2000. It seems that political, particularly leadership, and environmental changes are more apparent than any other. To evaluate these changes, his study has taken the chronological approach. Since the period of study is long, it has been divided into four sections. The first section describes and analyses the changes in the pre-British period (under the rules of Myanmar kings) up to 1852. Changes in the Ayeyarwady Delta during nearly one hundred years of colonial rule (1852-1947) have been assessed in the second section and the third section examines the post-independence period (1948-2000). As the post-independence saw several changes in political leadership, it has been divided again into three sub-periods; democracy period, Burma Socialist Program Party (BSPP) period, and the present State Peace and Development Council period (SPDC). For further details reference is made to the original article. More recently, Myanmar has opened up to the outside world and is going through a political transformation.

Since the first version of the Situation Analysis of the Democratic Governance in Myanmar was completed in 2012, the country’s transition has progressed considerably along the Government’s framework of the Four Waves of Reforms[4] (UNDP, 2013):

- Political and democratic reforms;
- Socio-economic reforms;
- Governance and administrative reforms;

[4] President U Thein Sein, Speech to Union ministers, Region/State chief ministers, and deputy ministers (delivered at Naypyitaw, 9 August 2013): http://www.president-office.gov.mm/en/?q=briefing-room/speeches-and-remarks/2013/08/11/id-2536.

- Private sector development.

While the transition towards participatory democracy and rule of law is building on the strong reform momentum which became apparent in 2012, it also reflects several new trends discussed in this analysis (UNDP, 2013). For more information on the political and economic reforms see Chapter 6: Governance.

5.1.3 Economic Development

The country is one of the poorest nations in Southeast Asia, suffering from decades of stagnation and isolation. The lack of an educated workforce skilled in modern technology contributes to the growing problems of the economy over the last decades. The country lacks also adequate infrastructure. Goods travel primarily across the Thai border and along the Ayeyarwady River. Railways are old and rudimentary, with few repairs since their construction in the late 19th century. Highways are normally unpaved, except in the major cities. Energy shortages are common throughout the country including in Yangon and only 25 percent of the country's population has electricity. An Economist special report on Myanmar points to increased economic activity resulting from Myanmar's political transformation and influx of foreign direct investment from Asian neighbours. Agriculture has a major role in Myanmar economy, as it accounts for 41 percent of the Gross Domestic Product (GDP) and 68.9 percent of labour force (UNDP, 2007; CIA World Factbook, 2009).

In March 2012, a draft foreign investment law emerged, the first in more than 2 decades. This law oversees unprecedented liberalization of the economy. Foreigners will no longer require a local partner to start a business in the country, and will be able to legally lease land. The draft law also stipulates that Myanmar citizens must constitute at least 25 percent of the firm's skilled workforce, and with subsequent training, up to 50-75 percent. The draft includes a proposal to transform the Myanmar Investment Commission from a government-appointed body into an independent board. This could bring greater transparency to the process of issuing investment licenses, according to the proposed reforms drafted by experts and senior officials.

In a first ever countrywide study the Myanmar government found that 37 percent of the nation’s population are unemployed and an average of 26 percent live in poverty. Myanmar on January 28, 2013 has announced deals with international lenders to cancel or refinance nearly US$ 6 billion of its debt, almost 60 percent of what it owes to foreign lenders. For instance, Japan wrote off US$ 3 billion, nations in the group of Paris Club wrote off US$ 2.2 billion and Norway wrote off US$ 534 million.

5.1.4 Agriculture

5.1.4.1 Importance of the Agricultural Sector

Agriculture is traditionally a very important driver for the Myanmar economy. Although the Ayeyarwady Region occupies only 5 percent of all national land in the Union, it is known as the rice bowl of the country as it produces most of the rice requirements of the country. Annual rice production of Ayeyarwady Region of about 6 million tons accounts for 30 percent of total production in Myanmar, which is about 22 million tons/year (FAO, 2001/2002). This situation is mainly due to increase of farmland area, especially, 25 percent increase between 1990 and 1994.

Myanmar possesses 17.66 million hectares of cultivable land including net sown area, fallow land

and cultivable wasteland, which is 18 % of the national land, being 67.64 million hectares. Presently, the net sown area in the country is 12.02 million hectares. For expansion of new agricultural land, remaining 0.23 million hectares of fallow land and 5.40 million hectares of cultivable wasteland, can be developed. Most of the agricultural land is currently cultivated by small-scale farmers (JICA, 2013).

Table 5.1 Land use in the Ayeyarwady Region 2012 – 2013 (Source: Irrigation Department).

Type	Area in ha	%
Cultivatable Land	1,818,467	51.91
Forest and Reserved Forest	720,088	20.55
Cultivable Waste Land	149,168	4.26
Virgin Land	23,020	0.66
Other Area	792,447	22.62
Total	3,503,190	100

Agriculture is in fact the principal livelihood in the rural delta, with a maximum number of people engaged in the sector. And it is one of the most common sources of income for the poor households even for those who are landless (MMRD, 2013).

5.1.4.2 *Farm size and high percentage of landless people in the Delta*

In Myanmar all the land belongs to the Nation. Farmers can obtain Land Use Certificates. Inhabitants in almost all rural areas in Myanmar are divided into tiller's right holders and landless people. Almost all tiller's right holders in the delta are into paddy cultivation by employing farm workers except those who own tiller's right of smaller areas. The average farm size per household in Ayeyarwady Delta is 11.2 acres (some 4.5 ha) according to UNDP (June, 2007), which is ranked at 1st among the Union in terms of farmland size per household. It is probably because the settling of immigrants in the delta started only around 100 years ago, so that it was not difficult for people to expand their lands. However, due to the high rate of population increase, the ratio of landless farmers in the delta reaches to not-negligible level. Some people lost their land tiller's right to cover school expenses or medical payment.

Average farm size of land holders who have tiller's right in the sample villages of the JICA (2001) assessment is more than 15 acres per farm household except in Kyaiklat Township. The range of farm size is large in some polders indicating maximum holding area of 200 acres and minimum area of 1.7 acres. There is a big difference between land right holders and landless households in terms of household income. Average household income of the land right holders is more than double than that of landless households.

Landless households account for more than 40 percent of the people in Myanmar, but according to the Post-Nargis Joint Assessment Report (PONJA, 2008) it increases to around 70 percent in all 34 surveyed polders after the cyclone.

The JICA (2011) survey shows that in the area around Lubatta the ratio of households which have the tiller's right on farm land falls between 39.7 percent of villages in Kyaiklatt Township and 22.6 percent of villages in Bogalay Township (70 percent at the maximum and 9.9 percent at the minimum at village level). The majority of households are landless farm workers, accounting over 50 percent on average.

5.1.4.3 Problems on Livelihood and Income Sources

It seems that the landless households are generally much more vulnerable than the householders with tiller's rights. Problems of landless households in the target area of the PONJA (2008) are identified as follows:

- Low level of income: The main problem of landless households is low income and lack of income generation opportunities. Many have an income below poverty threshold of "one dollar per day", which is the target of the United Nation Millennium Development Goal.
- Little opportunity of increasing income: Opportunity of increasing income for landless households is generally limited. Many of landless people are paddy workers and casual labour who do wage work or fishery as fishery worker, while very few landless households get income as tenant of paddy cultivation.
- Lack of skills for production: Landless households have very limited skills. They have low capability to generate income themselves due to low education level and little opportunity for learning modern technology/technique for generating new income. This means they have little knowledge and experience of income generation activities.
- Lack of outside support: Systematic supports from outside for enhancing their capacity is not generally available though there were many direct supports (in-kind, projects) in the years following Cyclone Nargis. Market information has not been collected in the target area and it may cause discrepancy of production/harvest volume and amount of income.
- Limited usable natural resources: Natural resources are limited for landless households. Land is largely used for paddy production and other land use is not common. Water inside polders is actually saline but it becomes fresh again after dike embankments and sluices are rehabilitated.

5.1.4.4 Land acquisition

While recent years have seen growing numbers of reports on land grabs in relation to large-scale strategic projects, the majority of these grabs go back several decades; recent years have seen a decline in incidents (DFID & FCO, 2013). Precise numbers on the frequency and scale of land grabs are difficult to pinpoint because official sources cite different figures[5]. However, official reports and complaints sent to human rights organisations and political committees provide an indication of the scale of land confiscation and evictions: (Giles Henley, 2014).

- The majority of the 1,700 complaints that the National Human Rights Commission received in its first six months of operation were related to land grabs;
- A commission on agriculture formed in 2012 by the National Democratic Force, a political party, received 4,000 complaints regarding land grabs and dispossession in the first few months of investigation;
- The cross-party Land Acquisition Investigation Committee has received more than 2,000 complaints about land grabs and dispossession since 2012.

Available evidence suggests that land has been acquired mainly by the former military government, principally for Myanmar business interests. In conflict areas the military has expropriated land for military bases and training. Here and elsewhere the military confiscated land to grow cash crops to raise revenue or to grow food for army rations (Chao, 2013; AAYSC et al, 2009; BEWG, 2011).

[5] For instance, the Ministry of Agriculture recently acknowledged 745 cases of land rights abuses, while the Parliamentary Land Investigatory Committee cites over 6,000 complaints (The Irrawaddy, 2014).

For example, reports from Mon State highlight widespread expropriation of existing betel nut and rubber farms as the military moved across the state between 2001 and 2007 (AAYSC et al, 2009). These expropriations have typically happened without any payment of compensation to farmers; local populations have often been forced to provide free labour, or pay rent and fines for continued use of the land.

Land acquired by the government for investment purposes. Growth of the agribusiness sector has been heavily promoted in agricultural policy. The 30-year Master Plan for the Agriculture Sector launched in 2000 aimed to convert 4 million has of what is defined as wasteland into productive land under private agribusiness (Chao, 2013). Certain parts of the country have been identified for investment: half of the total area allocated for new investment nationally is for oil palm development in Tamintharyi Division near the Thai border, and large concessions have been given to companies in Kachin and South Shan.

Besides military and government officials, the main beneficiaries of confiscations are Myanmar agribusinesses and, to a lesser extent, foreign companies. Myanmar agribusinesses with close affiliations to the government are given considerable opportunities to access land at low or no cost and are encouraged to develop plantations for exporting agriculture products (especially sugar cane and oil palm), on top of receiving generous state funding to complement an unsuccessful export quota programme[6]. According to official figures, by March 2012 1.38 million has of virgin and fallow land have been acquired by the Ministry of Agriculture and granted to 390 companies and government organisations (MoAI, 2012). In August 2013, the government announced that 6,400 companies had been granted land concessions totalling 1.6 million has (Myanmar Times, 2013).

However, land confiscated and designated for large-scale farming operations is often not put to use. In 2013, the Ministry of Agriculture and Irrigation released figures stating that less than one quarter of land concessions had been developed (The Irrawaddy, 2013). There is also anecdotal evidence that the speed and scale of land acquisitions (at least by the army and businesses) has slowed considerably in the last year, following efforts by senior political officials to clamp down on land grabs. The Land Acquisition Scrutinising Committee is one such effort (Obendorf, 2012; Landesa, 2013).

Although formal foreign management of land concessions is rare, several large concessions in Kachin and Shan are under *de facto* Chinese management. These concessions were set up by both Myanmar regional military commanders and opposition forces in areas under their control. China's policy of providing grants for agribusinesses to develop alternative economic activity to opium cultivation played an important role in financing the expansion of Chinese companies into these areas (BEWG, 2011). Major investors from Thailand, Vietnam and Malaysia are also thought to have completed or be in the process of acquiring large plantations for cash crop production (Chao, 2013).

Although reports on land acquisitions state that private land transactions are common, these are not well documented because they were illegal before the introduction of new legislation in 2012 (BEWG, 2011), (Giles Henley, 2014).

Rice accounts for 97 percent of total food grain production by weight. Through collaboration with the International Rice Research Institute (IRRI), 52 modern rice varieties were released in the

[6] The Myanmar government operates a system of export quotas to control trade and incentivise the production of certain agricultural products, such as oil palm. As these are distributed erratically and can be withdrawn arbitrarily, they do not offer much security to producers (Ash Center, 2011). In addition, export quotas for oil seeds are mainly given to large agribusinesses that have been awarded land but are not able to fulfil production targets (BEWG, 2011).

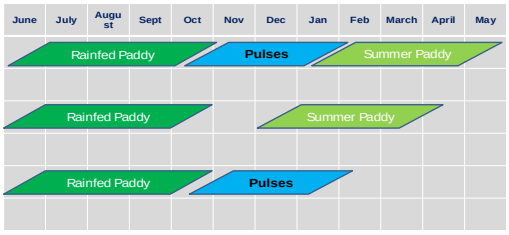
country between 1966 and 1997, helping to increase national rice production to 14 million tons in 1987 and to 19 million tons in 1996.

5.1.4.5 Cropping patterns

Rice accounts for 97 percent of total food grain production by weight. Through collaboration with the International Rice Research Institute (IRRI), 52 modern rice varieties were released in the country between 1966 and 1997, helping to increase national rice production to 14 million tons in 1987 and to 19 million tons in 1996.

In addition to rice farming, aquaculture, poultry and pig farms are being operated. Moreover, some areas (like Labutta Township) are famous for salt production. Some vegetables are grown for home consumption and the surplus as other source of income. Rice is followed by black gram as winter crops. Cash crop production like vegetables is an important income source mainly for landless farmer. For instance, some farmers in Labutta North Polder cultivate cauliflower, cucumber, water melon, pumpkin, leaf on small-scale farmland. According to the farmers, profit of vegetable production is higher than paddy production.

Livestock is an important asset and work force for farmers. Most of farmers own water buffalo, pig and/or poultry. It is reported that many villages in the Ayeyarwady Region have inadequate work force due to the loss of huge numbers of water buffalos caused by Cyclone Nargis. There exists a distinct difference in cropping patterns between the Lower, Middle and Upper Delta mainly related to the availability of fresh water during the various seasons. In fact, due to the ever saline water in the rivers in the Lower Delta only rainfed rice paddy during the monsoon season can been grown with locally some possibilities for a second crop (e.g. beans) on residual water in soil and drainage canals. In the Upper Delta, however, two or three crops can be grown, due to the fact that fresh water is available all year round.

	Present cropping patterns in Irrigated Area of the Ayeyarwady Region
	Present double cropping patterns in rainfed area of Ayeyarwady Region

	Present double cropping patterns in rainfed area of the Ayeyarwady Region

Figure 5.1 Cropping patterns of Ayeyarwady Region. Ministry of Agriculture and Irrigation (2013).

Table 5.2 Crop area in 2011-2012 and 2012-2013 for Ayeyarwady Region (MOAI, 2013).

Name of Crops	2011-2012 (hectare)		2012-2013 (hectare)	
Paddy	1,933,654		1,957,662	
Monsoon		1,473,564		1,469,498
Summer		460,090		488,163
Corn	6,280	6,280	8,683	8,683
Oil Seed Crops	96,672		77,647	
Ground nut		46,545		44,327
Sesame		10,900		9,638
Sunflower		39,227		23,682
Pulses	547,127		519,754	
Black gram		455,295		449,717
Green gram		89,910		68,208
Pigeon pea		1,922		1,829
Cotton	126	126	4	4
Sugar cane	117	117	93	93
Total	**2,583,976**	**2,583,976**	**2563843**	**2563843**

5.1.4.6 Crop Yields and Prices

Crop yields are still low. According to the Agricultural Census 1985-86 to 1995-96, average cropping yield of paddy in Ayeyarwady Region is 3,250 kg/hectare. Information obtained from the Irrigation Department in the Pyapon District during the mission indicates an average production of 55 baskets/acre (2,890 kg/hectare) for rainfed monsoon paddy and 95 baskets/acre (4,990 kg/hectare) for irrigated summer paddy. Potential cropping yield of local variety is originally low because of low response to fertilizer, etc.

Therefore, application of HYV (High Yielding Variety) to a larger extent is necessary, if drastic increase of paddy production is required. For applying HYV, constraints like i) high investment cost, ii) unstable paddy price and iii) unverified appropriateness and cropping technology of HYV in field, should be solved to reduce farmer's risk. In addition, the quality (taste) of HYV is considered low by the people compared to the local varieties. Under the above mentioned

situation, improvement of both production amount and quality is indispensable to secure stable supply of high quality rice for the country and to grow paddy as an export crop.

A minimum price for rice is guaranteed by the Government. Because of its quality the price of the local varieties is considerably higher than for HYV. The prices can triple in the course of the season. Due to low storage capacity, lack of farmer organisations, need for cash for daily life and reimbursement of credits, the farmers tend to sell their products for a low price directly after the harvest. The large variation in price during the year provides high margins for the merchants. This issue should get special attention in view of the desired improvement of the resilience of the rural communities.

Even though liberalization of rice export is functioning since 2003, the development of the rice industry has not much improved, which would be needed to make the structural adjustment along the supply chain from farm to export. This constraint may be listed among other things such as farmers' investment through sufficient credit, improvement of the quality seeds, pricing policy, land tenure system, elimination of the export tax, strengthening extension services, developing the farm inputs industries, improvement of milling facilities, infrastructures for export facilities and encouragement of private partnership.

To generate increased production of paddy, measures are also being undertaken in growing high yielding varieties, including introduction of hybrid rice varieties. According to the major tasks of the Ministry, adoption of 14 points Good Agricultural Practices in paddy cultivation and production of qualified and good high-yield seeds have been undertaken during the 2011 paddy growing season.

5.1.4.7 Irrigation development

The increase of the rice production in the Ayeyarwady Delta got an important boost in the period 1976 – 1988 with the implementation of the Paddy Land Development Projects 1 and 2 (World Bank Projects). The projects consisted mainly of the construction of polders in the lower delta provided with embankments, sluice gates and drainage systems, hence protecting the land from salt water intrusion. For instance in Pyapon District the paddy cultivation area increased by the construction of 7 polders from 12,000 hectares in 1976 to 34,500 hectares in 1985. In the Laputta District the embankment enclose an area of 42,000 hectares.

As official recorded data in 2009-2010 in Myanmar, rice harvested area reached to 8.1 million hectares and its production increased to 32.68 million tons, which is equivalent to 19.61 million tons of milled rice. The country as a whole is in surplus of rice and self-sufficiency rate is estimated to be about 168 %. However Mandalay Region, Magway Region and Chin State out of 14 states and regions are recorded as rice deficit areas, accounting self-sufficiency rate is estimated to be about 66, 98 and 69 % respectively.

Paddy I

Paddy I was proposed to protect 11[7] islands located in the southern part of the Ayeyarwady Delta from flood and tidal intrusions by building or rebuilding embankments, excavating drains and constructing sluice gates. Developing a total of 185.00 acres of farm land including the reclamation of 65,000 acres of abandoned and cultivated wasteland, providing equipment for construction, maintenance, reclamation, farming and lift irrigation, and providing also funds for

[7] *Shwelaung, Zinbaung, Letpanbin, Kyetphamwezaung, Myogon, Daw Nyein, Dedalu, Bantbwezu, Betut, Alegyum and Dauntgyi.*

strengthening extension and other agricultural supporting services. It included also a delta-wide hydrological investigation for planning future projects and a feasibility study for improving paddy storage and handling (Ministry of Agriculture and Forests, 1986).

The implementation of Paddy I project was completely finished in 1985 (Ministry of Agriculture and Forests, 1986).

Implementation areas in the Ayeyarwady Delta of Paddy I and Paddy II are presented in figure 5.2.

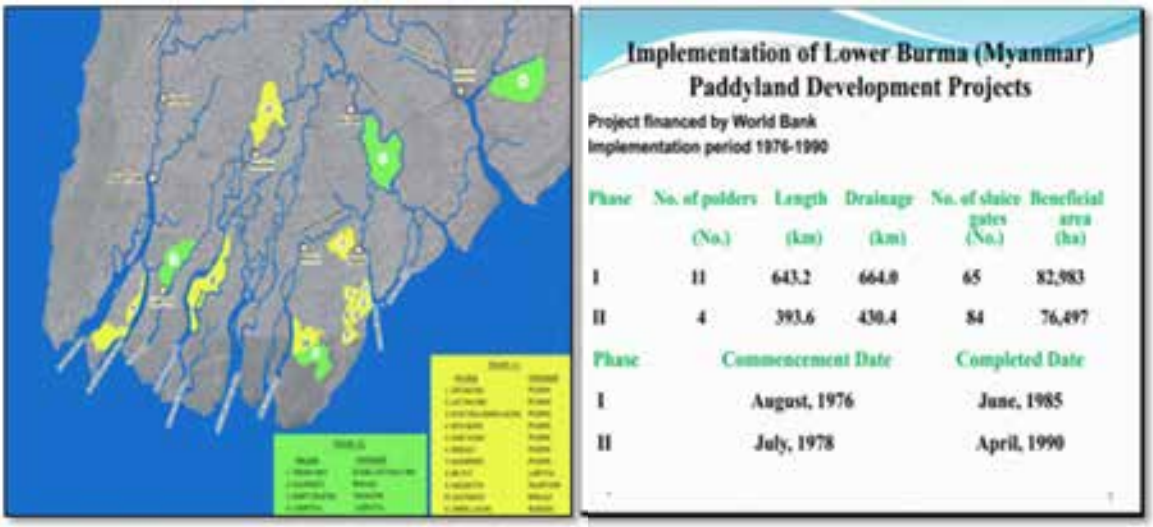


Figure 5.2 Implementation Paddy I and Paddy II (Yin Mai Wai Aung, 2014).

Paddy II

Paddy II is located in the Ayeyarwady Delta in the townships: Maubin-Polder Thongwa, Bogale-polder Daunggyi, Laputta-polder Labutta and Syriam-polder Bawchaung (Ministry of Agriculture and Forests, 1984).

Project features for Paddy II:

- Rehabilitation and construction of minor flood embankments and drains to protect 175,000 acres;
- Construction of building complex;
- Reclamation of 50,000 acres of abandoned paddy land;
- Provision of equipment and spares for construction and maintenance of embankment, drainages and structures;
- Provision of equipment and spares for land reclamation and lift irrigation;
- Construction of provision of equipment for service stations for repairing project farm machinery;
- Strengthening of agricultural extension services;
- Construction of fertilizer godowns and training centers;
- Provision of consulting services to assist in developing a medium and long-term credit programme for farmers and to assist in preparing a credit project suitable for external financing;
- Provision of survey and office equipment for the marking out of plots for land allocation by the township councils (Ministry of Agriculture and Forests, 1984).

The implementation of Paddy II project was completely finished in 1990 (Yin Mai Wai Aung, 2014).

Paddy III

The implementation of Paddy III still has to start. Paddy III is located in the Ayeyarwady delta in the Nyaungdone island (see Figure 5.3).

Figure 5.3 Map of the area for Paddy III (Yin Mai Wai Aung, 2014).

Paddy III implementation objectives are:

- Sustainable development of the Paddy III project area by means of modern day IWRM approaches leading to poverty reduction and social and environmental integrity in the project areas concerned;
- Water supply in salt intruded area of Twontay, Dela, Kawhmu and Kungyangone Townships;
- Reduction of conflicts between farmers and fishers (Yin Mai Wai Aung, 2014).

The expected project features for Paddy III are:

- Land potential of 95,000 acres of formerly deep flooded and salt intruded areas would be improved;
- Fresh water can be abstracted mainly from the Toe River located in the western part of the project area so that some areas for summer paddy and winter crops of, mainly, chickpea would be irrigated with low lift pumps following the monsoon paddy crops;
- Considerable Improvement to the environment would be attained as a result of the project by IWRM approaches to water resources development;
- Apart from the increase of paddy rice production by the project, perennial supply of fresh water for domestic use in areas with drinking water shortages would become available together with an improvement to fishing potential in the creeks;
- Land and water transportation within the project area would also be much improved by the construction of access roads and multi- purpose water supply, drainage and navigational canals by the project, with associated social environmental benefits in educational, medical,

and some other marketing sectors;

- Due to the result of the project, some agricultural employment opportunity would also be created;
- There may not be much foreseeable adverse environmental effects except for the possible proliferation of water hyacinth, which would require control during routine operations.

5.1.4.8 Agricultural Practices

Agricultural practices are generally still very low tech. Land preparation (by ploughing) is hard work for the farmer due to very hard soil dried up by strong sunshine in dry season. Usually, the water buffalo is used for ploughing at the beginning of the monsoon season. Use of hand tractor is limited because of its low availability, financial deficit and also low quality of machinery (or low durability against hard soil).

A distinction has to be made between the rainfed monsoon paddy and the irrigated summer paddy. For the monsoon paddy only local rice varieties and low input levels are applied. Data obtained from the Irrigation Department indicate that for monsoon paddy in the Ayeyarwady on average only 32.5 kg/ha of fertilizer is being used. The High Yielding Varieties (HYV) are not suitable for the rather uncontrollable water levels in the paddy fields during the monsoon season. Also the taste of the local varieties is preferred above the one of the HYV.

Due to unavailability of fresh water in the lower delta the irrigated summer paddy can only be cultivated in the middle and higher regions of the delta, unless special water conveyance canals are constructed for the transport of fresh water from upstream tidal reaches of the river. Better water control permits the use of HYV and the application of higher input levels of fertilizer and pesticides.

Fertilizers

The domestic fertilizer industry in Myanmar is concentrated around the production of urea fertilizer from the abundant sources of natural gas in the country. Phosphate and potash fertilizers are imported. The Ministry of Energy prefers to export natural gas in order to obtain foreign exchange, and thus supplies of gas to the urea plant have been decreasing. Although imports of fertilizers are liberalized to the private sector, most of farmers are unable to acquire sufficient amount of fertilizer due to financial constraints (JICA, 2013).

Table 5.3 Requirement and supply of fertilizers estimated by the JICA Survey (JICA, 2013).

Year	Paddy Sown Area (million ha)	Requirement (t)	Domestic supply of Fertilizers (t)					Surplus/Deficit (1,000 t)
			Urea	T.Super	Potash	Compound	Total	
1997-1998	5.78	2,139,000	145,524	30,916	7,704	4,816	188,960	▵1,950
1998-1999	5.76	2,131,000	215,483	11,802	5,884	547	233,716	▵,1897
1999-2000	6.28	2,324,000	100,996	3,745	5,974	0	110,715	▵2,213
2000-2001	6.36	2,353,000	219,101	11,796	6,269	0	237,166	▵2,116
2001-2002	6.45	2,387,000	56,000	34,272	6,086	0	96,358	▵2,291
2002-2003	6.49	2,401,000	10,651	48,112	10,280	0	69,043	▵2,332
2003-2004	6.55	2,424,000	464	1,306	2,867	0	4,637	▵2,419
2004-2005	6.86	2,538,000	19	162	247	0	428	▵2,538
2005-2006	7.39	2,734,000	3,100	73	47	372	3,592	▵2,730
2006-2007	8.12	3,004,000	4,494	195	7	3,152	7,848	▵2,996
2007-2008	8.09	2,993,000	4,214	10	0	806	5,030	▵2,988
2008-2009	8.09	2,993,000	4,050	0	0	3,274	7,324	▵2,986
2009-2010	8.07	2,986,000	4,101	0	0	1,032	5,133	▵2,981

Farmer's Associations

Farmers associations have been setup by MOAI[8], but they are practically not functioning and awareness of farmer's ownership is not remarkable. Myanmar Farmer Association (MFA) was setup by and under Myanmar Rice Federation (MRF) as one of societies to petition against the government in terms of building the farmer's capacity as well as improving rural living conditions. The MFA shares information related to agriculture with member farmers and negotiates with the government based on the farmers' needs. The member farmers exchange information related to agriculture though mobile phone supplied by FAO in 2008.

MFA negotiates with the government on the distribution of fertilizers and seeds based on the Agriculture Development Issues and Strategies. Moreover, MFA is going to setup the Farmer Extension Center at Kawthmu Township in Yangon Region to provide information services such as agricultural technologies and farm machinery. In future, Farmer Extension Centers will be established at every township (JICA, 2013).

5.1.4.9 Agricultural credit

The most common constraint to crop production is the lack of inputs or lack of money to buy them. Limited capital equipment (tools, daft animals, mechanical power) and land are also common constraints. Overall, constraints to crop production are generally related to low-intensity production techniques that could be addressed with increased availability of credit, technical advice and improved access to land, and related to lack of infrastructures for irrigation and water control (JICA, 2013).

Institutional credit

There are four national banks in Myanmar including Myanmar Agriculture Development Bank (MADB), Myanmar Economic Bank (MEB), Myanmar Foreign Trade Bank (MFTB), and Myanmar Investment and Commercial Bank (MICB). MADB is not under the supervision of Central Bank of Myanmar, but under the Ministry of Agriculture and Irrigation.

Moreover, 19 private banks are operated in Myanmar, which include for instance the Global Treasure Bank Public Co., Ltd., a former, Livestock and Fisheries Development Bank, Sibin Tharyar Yay Bank, Myanmar Industrial Development Bank. The current Financial Institutions Law does not allow foreign banks to formulate joint ventures for banking business. However, the government makes it clear that foreign banks can operate after domestic banks gain enough competitive power against foreign banks. Therefore, 17 foreign banks have opened a branch office in Myanmar as of January 2013.

Among domestic banks, Myanmar Agriculture Development Bank (MADB) and Global Treasure Bank Public Co., Ltd. provide financial services to agriculture sector. Most banks in Myanmar establish branch offices in urban areas, but these two banks are operating in rural area to provide services to farmers and fishermen/ women. The Fifth Five-Year Development Plan stated that agricultural credit is one of the five-target sectors to enhance. According to the plan, the government will increase the loan amount by 1.3 times from 2011-12 to 2015-16.

To improve financial accessibility of farmers, the government allows tiller's right holders to collateralize the right after putting the Farm Land Law in force on March 2012. Also, according to Myanmar Rice Federation (MRF), the Ministry of Agriculture and Irrigation increases the

[8] *The Ministry of Agriculture and Irrigation (MOAI) in the Myanmar goverment.*

maximum loan amount from 20,000 kyat/acre to 100,000 kyat/acre (49,420 kyat/ha to 247,100 kyat/ha), as a substitute for stopping the government support for fertilizer and seed procurement.

However, the loan amount is still limited and not enough for farmers since the demand for loan is increasing in the agriculture sector. The agriculture sector is the largest economic sector, which accounts for 40% of GDP, and employ 54% of economically active labours, but loan amount for the sector is only 2.5% of total loan outstanding. According to MADB, defect of loan for rice production is estimated at 170 billion kyat (173 million US$). The production costs of rice are around 250,000 - 300,000 kyat/acre (617,740 – 741,290 kyat/ha) in May 2013, but the maximum loan amount to individuals is only 100,000 kyat per acre (247,100 kyat/ha) (JICA, 2013).

Microfinance

Microfinance is one of eight priority subjects in the National Comprehensive Development Plan, and is an important financial scheme since it does not require mortgage. Microfinance is arranged by the Microfinance Law (2011), and the Microfinance Notification and Directives (2011). Before the Microfinance Law came into effect, most microfinance institutions (MFI) had operated based on a memorandum of understanding (MOU), but did not have legal status except PACT-UNDP. However, after the law, MFI can have legal status, and are not informal organizations anymore. Regulatory authorities of the MFI are the Microfinance Supervisory Committee (MSC) and the Microfinance Supervisory Enterprise (MSE).

MSE examines MFIs in terms of legal status, capital fund, lending rate and savings rate, and has a right to issue a license for lending operation. According to the MSE, 118 MFIs have obtained a license as of November 2012, including 6 international NGOs, 9 domestic NGOs, 60 cooperatives and 43 domestic firms. Among licensed MFIs, cooperatives account for more than a half, but most of them carry out business in urban areas and do not have enough experiences in rural areas. The United Nations Capital Development Fund (UNCDF) estimated that demand for microfinance is around US$ 1,000 million, but only 28% (US$ 283 million) is actually provided by MFIs (JICA, 2013).

5.1.4.10 Agricultural Damage by Cyclone Nargis

Inflow of saline water into paddy fields by Nargis decreased agricultural production instantly. According to farmers in Labutta North Polder, crop yield of local variety paddy rice of the first crop after Nargis attack was decreased to 10-20 baskets/acre, equivalent to minus 50-75 percent from 40-50 baskets of cropping yield before Nargis (JICA, 2011). However, the crop yield of the 2009 cropping season had already recovered with a yield of 40-50 baskets/acre. By puddling the soil and subsequent surface drainage the salt deposit in the soil could be removed. Main farming constraints are lack of input of farming tools, draft animal, fertilizer and access to agricultural finance. These constraints became worse after Cyclone Nargis. Especially, the number of farmers without draft animal increased from 4 percent to 35 percent.

5.1.4.11 Constraints for Farming

As far as the present farming system in the Ayeyarwady Delta is concerned, the World Bank study (August, 1999) described it concisely as follows:

‘The Ayeyarwady Delta of southern Myanmar is a fragile and intricate ecosystem of mangrove swamps and tidal estuaries. Non saline arable areas are limited and becoming scarce due to the erosion of riverbanks, saltwater intrusion, and increasing soil salinity. Poor water control and

drainage works contribute to periodic flooding and crop losses. Most poor households cultivate a single crop of traditional monsoon paddy. Better-off farmers able to grow early maturing, high-yielding varieties of paddy benefit from an additional winter crop such as groundnuts or soybeans. In the very few areas where irrigation facilities are available, summer paddy is grown. Marginal farm households cannot afford to use chemical fertilizer or manure and suffer from declining crop yields. In some townships such as Laputta, Bogalay and Mawlamyaingyun, it is estimated that more than half of the population is landless. Many marginal farmers engage in fishing and crabbing. Those who fish typically do not own fishing gear or boats and depend on fish traders for such resources. Some households raise pigs, chickens, or ducks. Others crop during the slack growing season by borrowing from more well-off farmers; loans are paid back through labour or through a portion of paddy crop. The effective interest rate charged by fish traders, rice traders and others in these loan arrangements typically amount to 10 per cent a month'.

According to JICA (2011) the major problems on farming in the Nargis affected areas can be summarized as follows:

- Poor farming techniques: Since natural soil condition of polder areas have been deteriorated, adequate farm management is essential to reduce such risk. Most of farmers in polder areas have practiced traditional farming such as "use of ordinary (low quality) seed", "inadequate use of fertilizer", "non-regular row transplanting method", etc. which have kept the productivity low.
- Lack of support on farming technique: the number of staff of the Myanmar Agriculture Service MAS (now change its name as Agriculture Department), which is the responsible agency to provide extension services to farmers, was drastically decreased during the past 10 years. Consequently it has resulted to the slowing of agricultural developments.
- Lack of farming inputs: Lack of seed, fertilizer, animal-power and agricultural finance have become serious especially after Nargis. Inputs such as seed and fertilizer are required at every cropping season on a permanent basis. Therefore, supply of these inputs should be secured to realize agricultural recovery and further development in the polder areas on medium and long term basis. Lack of adequate agricultural loans is also a serious issue and farmers have to consider private agricultural loans, which require very high interest rates. As a consequence some farmers are forced to sell their paddy immediately after harvest in order to repay their loan.

In addition, the lack of farm-to-market roads or roads in general in the southern delta should be added as a serious constraint.

During field visits it was also observed that poor water tightness of the sluice gates of the polders create too high salt concentrations of the water. This seriously affects farming in the serviced areas. In addition, inundation of farms occurs due to poor drainage caused by uncontrolled sluice gates in wet season.

5.1.5 Fisheries and aquaculture

5.1.5.1 Fisheries important for livelihood

Fisheries are the second main livelihood option after agriculture in the delta. One of the most common sources of income for the poor household is the fish, prawn, eel and crab catching (MMRD, 2013). The fishery sector maintains a high per capita consumption of about 43 kg/year according to the statistics of year 2008-2009.

Also a JICA (2011) study confirmed that fishery stands as the second important source of income

after farming in all villages located in survey areas of six townships in the delta. Fishing and processing of fishery products provide an opportunity for landless people to earn income for their livelihood. Based on information from the key informants' survey, prawn is the most important source of income in the aquaculture industry in the villages and is given first priority for earning income. Dry prawn, fried fish and prawn paste making industries are performed in most of the surveyed villages (MMRD, 2013).

The Myanmar Marketing Research & Development (MMRD) performed a Socio-economic analysis of the Delta fishery villages and small scale fishery livelihood (MMRD, 2013). Fish catching, fish paste production, dry fish production, fish paste milling, prawn and shrimps catching, dry shrimps production, dry shrimp powder production, crab catching, small and medium crab farms (captive breeding), inland small and medium fish / shrimp ponds and commercial scale aquaculture are some of the activities available as the opportunities in fisheries sector of the Delta area.

The MMRD (2013) study revealed the following conclusions:

- Poor fishery households of the Ayeyarwady Delta are struggling to meet their daily food and essential household needs. It will require many different interventions, and will take many years before these marginal poor escape from the chronic poverty and able to establish sustainable livelihoods, families, and futures.
- Evidently, chronic food insecurity is occurring in poorer fishery households; Report on Socio-economy Analysis of the Delta Fishery villages and small Scale Fishery Livelihood", only 48% of the poor households were able to meet their food needs on a daily basis. Families are adopting diverse coping strategies ranging from changing to less expensive or unusual foods to more severe measures i.e. skipping a meal (8%).
- The surveys show that (13.5%) of the fishery households in the Delta rely for 100% on food from their fish catch and hence as much as 54% of fishery households are consuming half of the fish catch. They are also depending on fish traders and/or falling into debt to provide food for their families. This majority – the landless poor - small scale fishers must have access to income earning opportunity to enable them to derive cash income to meet their food and essential non-food budget requirement.
- Clearly 'Cash' is a critical need in the delta, as most of the poor households mentioned that access to finance is the biggest challenge to establish subsistence and sustainable livelihoods.
- Fishing gears (or) Assets is mentioned as one of the major constraints for the poor fishery households, hence taken loans to acquire fishing net was one of the main reasons fishermen are caught in the vicious cycle of debt (or) more severely forced to leave the fishing livelihood.
- Moreover, fishing rights is also one of the major concerns and a burden for the poor fishery households in the Delta, especially the competitive tender system of Bogalay was mentioned as a biggest constraint for the Bogalay fishermen, on the other hand the per net per year license system in Laputta, comparing to tender system, was mentioned as favourable system for the poor fishermen.
- Socio-economy of the village and the surrounding area is also affecting the fishery households in the delta; hence one of the major constraints for education of the children of the poor fishery household was not having accessible schools in the convenient distance. Poor infrastructure such as poor access to roads, no electricity, poor conditioned slow motor boats, poor access to school, poor access to health care, etc. are also fuelling the prolonged poverty of the fishery households.
- Low fish catch is also mentioned as another one of the major concerns of the fishery households, although this study was not designed to determine the cause of the problem, observation and experiences suggests that many fishermen do not seem to have

awareness on 'sustainable fishing practices', and also poor law enforcement capability of fishery departments on the enforcing of no fish catch season orders in the rivers, are some of the possible facts causing depletion of the fish resources in the rivers. Although some respondents claimed that Cyclone Nargis was one of the main causes, assuming the Cyclone may have destroyed many of the fish habitats in the river, it was also expressed that free distribution of fishing nets and boats to almost everyone by the humanitarian organizations in the Delta after Nargis has increased the fishermen population in the delta rivers into three folds.

5.1.5.2 Fish consumption in Myanmar

Fish is a key staple food in Myanmar. Rice and fish are among the key staples in Myanmar. Although the figures are rather old, 2001 data indicated that on average 12.3% of household spending on food products was spent on fish.

Fish consumption is higher than in Europe. Based on Department of Fisheries estimations for national fish production (almost 4.5 million tonnes) and subtracting exports (400,000 tonnes) suggest a per capita consumption of 51 kg/caput/yr.

Also preserved fish has a good local market. Preserved fish (dried, salted, etc.) plays an evident role in the local diet. However, the small quantities consumed make the consumption of preserved fish products an often hidden contribution to the overall fish consumption (CBI & LEI Wageningen UR, 2013).

5.1.5.3 Zoning of fishery and aquacultural activities

The fisheries of the Ayeyarwady Delta are among the most diverse and complex found anywhere on earth. The dynamic natural environment of the delta sustains habitats and ecosystems that range from fully marine, through brackish to entirely freshwater. Much of the Delta area is influenced by tides. The productive soils and abundance of water create conditions for a highly productive and diverse fauna, although large parts of the Delta are now a simplified agro-ecosystem of rice fields, plantations and degraded mangrove areas linked by rivers and canals. These fisheries are exploited by a large number of commercial and subsistence fishers. In almost any Delta village, many people, will be involved in fishing related activities to an extent. The gears and boats used for fishing are also diverse, ranging from traditional low-cost, hand-held or fixed gears used in rice fields and wetlands to large river boats with drift nets, to modern trawlers ploughing the high seas. (Gregory, Rick & Saw La Paw Wah, 2009).

Gregory & Saw La Paw Wah (2009) describe in their report on a Participatory Rural Assessment of Delta Livelihoods and the Value of Fishing Assets in areas affected by Cyclone Nargis that these fishery practices take place in three main ecological zones in the delta which are related to the distance to the sea and to the salinity level:

- a floodplain zone characterized by freshwater or a very low salinity maximum, the presence of freshwater fish species, large scale fencing for fishing and an unknown percentage of migratory species;
  These inland freshwater zones are located in the labyrinth of small rivers and creeks. These creeks are still influenced by tides, even in some completely freshwater areas. Water turbidity levels appear to be lower in this zone. The area has fewer Nipa palms but more Betel palms and more varied natural vegetation. In northern parts of the delta, water supplies are fresh all year and here two crops of paddy are possible, as are a range of other crops such as pulses,

vegetable and fruit. Small-scale irrigation from pumped river water is commonly practiced. Large numbers of ducks and other livestock are raised in this zone. In rice fields and freshwater areas, snakehead, eels, crabs and shrimp are collected during the wet season and

Figure 5.4 Ecological zones (MyFish, 2012)

early dry season for subsistence purposes. Large areas are allocated as concession areas and in these areas access is restricted. The farming of carp and freshwater shrimp in large ponds occurs in some part of this zone. Large fishponds for the culture of Macrobrachium prawns and Indian Carps were noted in the inland freshwater site. Throughout the Delta, very few small backyard ponds were noted. Overall, the cyclone affected parts of the Delta appear to have little small-scale aquaculture. The FAO 2008 survey of 4656 households suggests that 99.2% do not have a fishpond. Villages are better connected to each other and local markets, with traders being regular travelers through the inland canal system. There is also better road access in these areas but small boats are still used extensively through the canal networks and along roadside borrow pits.

- an estuarine zone characterized by multiple waterways, temporary brackish water, typically estuarine species, degraded mangroves along waterways and a patchwork of rice fields, trees and villages. This riverine zone is characterised by wide river reaches, smaller creeks and canal networks. The tidal range is significant and water turbidity levels appear to be high. Numerous Nipa palms grow along the river edges, especially in the sheltered, smaller creeks and scattered betel palms can also be found. Processing nipa palms into roof panels is one of the few income generating household based activities that poor households, including women can engage in. The tarpaulin sheets distributed for roofing and wall construction following the Cyclone, are considered very hot and are slowly being replaced by traditional Nipa made panels. Other poor households engage in petty trading and transportation work, for which a small boat is an essential asset. Agriculture in large parts of this zone is characterised by

single crop paddy production as irrigated rice and crop diversification remains constrained by the saline conditions that develop during the dry season. The most important commercial river species caught are hilsa, nibea, pangasius, macro-brachium & penaid shrimp and mud crabs. Smaller mystus catfish are also caught in large quantities from river sites. In the smaller creeks, sea bass and snakehead are also targeted. Villages and markets tend to be better connected, although intra-village travel is still exclusively by boat. Siltation of the main rivers and small creeks is occurring and boat travel during low tide becomes difficult in many areas.

- a coastal front characterized by a very flat land, quasi permanent brackish water, salty soils, almost no vegetation and fishing activities targeting the coastal and marine zones. The coastal zone is an exposed area with few trees, except for scattered coconut palms and it is in this region, where the infrastructure of many villages was completely destroyed by the Cyclone. Mangroves are present in this zone but those observed appear to be in a seriously degraded condition with trees being small in size, and restricted to the river edges. The tidal amplitude ranges from 2 – 5 m. River and estuarine water turbidity was very high during the field visits. The most important commercial river species caught are hilsa, nibea, pangasius, macrobrachium & penaid shrimp and mud crabs. Villages are scattered and isolated and communications are exclusively through boats and waterways. Fishers depend on collectors to purchase their catches and arrange for their transportation to Yangon. Agriculture is characterised by single crop paddy production and small livestock production, mainly pigs. Options for irrigated rice, vegetable and fruit production are limited due to low freshwater availability outside of the wet season. Extensive salt and shrimp farms exist in this zone and offer labour opportunities to poor households that live locally. ‘Tambak’ system relying on the free entry of prawn and sea bass seed are also found. In many coastal villages, freshwater ponds which are dedicated as a source of potable water, have been contaminated by sea water during the cyclone and, despite the efforts of the villagers, the water remains too salty to drink. Freshwater supplies during the dry season are a concern to many villagers. Firewood is collected from mangrove areas or from trees which came down during the cyclone or have subsequently died. Villagers did not list firewood supplies as a particular concern, although this may well emerge as a chronic problem in future years. Other sources of fuel for cooking include dried Nipa palm sheaths and dried coconut husks.

5.1.5.4 *Impact of cyclone Nargis*

Cyclone Nargis, which swept through the area on 2nd-3rd May 2008 claimed the lives of an estimated 138,000 people and destroyed the livelihoods of hundreds of thousands of fisher and farming families, (PONJA 2008). Subsistence fishing in the immediate aftermath of the cyclone was extremely important for many people’s early survival before relief supplies reached them. Recovery efforts in the fisheries sector to date appear to have focused on the more commercial fishers, to enable the businesses that focus on exports to Yangon and beyond, to become re-established within about one month. The replacement of lost assets to those involved in small-scale fishing is progressing but for many, they have not yet been able to return to their pre cyclone livelihood activities and are still handicapped by the loss of fishing assets and boats (Gregory, Rick & Saw La Paw Wah, 2009).

5.1.5.5 *Fishing practices and developments*

The main fishery resources in Myanmar include:

- Freshwater through:

  - Fish culture
  - Leasable resource
  - Open fisheries
- Marine fishery through:
  - In-shore fisheries
  - Off-shore fisheries

The FAO report (2003) on Myanmar Aquaculture and Inland Fisheries gives the best overview of current fishing practices and developments. The MYFISH report (2012) on 'Delta draft scoping report 'Improving Research and Development of Myanmar's Inland and Coastal Fishery' provided a recent update.

In MYFish report 'Improving Research and Development of Myanmar's Inland and Coastal Fishery' (2012) it is concluded that there is an increasing loss of connectivity in floodplains due to the extension of rice farming. Like in the Mekong, there is a trade-off between rice production development and sustainability of the capture fish resource.

The report mentions that all people interviewed had observed in the past years a reduction in the diversity of catches and in biomass; the main species characterized by a strong reduction are snakeheads and catfishes. It seemed that the fish species composition looks richer in the floodplain zone than further downstream, which is surprising (the biodiversity of estuarine zones is generally much higher than that of rivers since they combine representatives of the freshwater, brackish and estuarine faunas). Similarly the contribution of migratory species to the biodiversity and to fish yields in this ecological zone is not clear. This zone is characterised by substantial collective efforts in the past to restock water bodies in order to sustain the productivity (lease holders must invest into restocking, and hatcheries provide fingerlings). However water bodies are stocked with mainly aquaculture farmed species (rohu, tilapia, catla and silver barb), and there is no assessment of: (i) the efficiency of the restocking efforts, or (ii) their impact on the natural biodiversity.

The MYFish report concludes also that from a national perspective the fisheries economics of the estuarine zone are clearly more influenced by coastal and marine fisheries than by local catches, however local fisheries and the lease system play an important role for small shareholders and local communities. The respective role of changes in policies, in competition and in the resource base are not clear and deserve clarification; from that perspective research in biology could focus on medium to long term trends in species composition, catches and dominance.

Dwellers of the coastal zone are clearly among the poorest of the delta; they suffer from harsh natural conditions and from a social and economic disintegration following Nargis.

The MYFish report observes also clearly an opportunity for research on the effect on natural productivity of current restocking efforts and on possible improved options in terms of stocking densities, stocking periods, species stocked, water bodies to be stocked, etc. However, there is also a risk that this research ultimately demonstrates that either the former efforts were not effective, which would not be politically welcome, or that they were actually effective, which would not be very useful in terms of applied research.

5.1.5.6 Capture Fisheries

The Dutch Centre for the Promotion of the Import from Developing Countries (CBI) and LEI Wageningen UR have conducted a quick scan to analyse the EU market potential of the seafood

sector ion Myanmar. This information in this section is directly derived from that study (CBI & LEI Wageningen UR, 2012) with a focus on the Ayeyarwady Delta.

The capture fisheries sector in Myanmar can be divided into inland and marine capture fisheries. In 2011 inland capture fisheries contributed 1.15m (27%) tonnes and marine capture fisheries 2.15m (52%) tonnes to the total seafood production[9].

***Inland capture fisheries*[10]**

Inland capture fisheries in Myanmar can be divided into leasable and open fisheries. Leasable fisheries are floodplain fishing grounds which are leased on a yearly basis to individuals (or groups). The lessee has the right to exploit all the fish resources and is allowed to choose to stock species of his choice when the flooding occurs. Leasable fisheries are mainly controlled by large commercial operators or institutions, but depending on the management these lessees can support large numbers of sub-lessees and fish sellers. Open fisheries informally use water bodies, streams, lakes, reservoirs and rice. Even though officially all fishing activities need to be approved and monitored by the DoF, this activity is widespread as these activities are difficult to monitor. The DoF generally accepts that fishing for subsistence purposes cannot be regulated. In 2011 the total production of leasable fisheries was estimated at 250,000 tonnes while the production of the open fisheries is estimated at 910,000 tonnes.

Marine capture fisheries

Although landings are currently declining, the marine fisheries resources potential is high and a wide variety of commercially interesting species including white pomfret, ribbonfish, pink shrimp, sea eel, Hilsa and Croaker are captured by small-scale and commercial fishing boats and vessels.

Marine capture fisheries in Myanmar can be divided in small-scale inshore and offshore marine fisheries. In 2011 there were 28,350 small-scale fisheries boats registered by the DoF of which 15,100 (53%) were non-motorised. In addition, there were 2,450 offshore vessels of which 400 (16%) were owned by foreigners. The off-shore vessels mainly use the following fishing catching methods: trawling (41%), driftnet (32%) and purse seine (7%)[11]. Interestingly, while other countries try to diversify their trawling fleets with longline vessels which are more suitable and more sustainable for catching yellow fin tuna, Myanmar currently has only one vessel that is equipped with longline technology. Although there are a few pursein vessels, tuna catches are limited.

A main constraint to the development of marine capture fisheries is that the DoF does not permit deep-sea fishing for Myanmar vessels, but restricts fishing activities to inshore waters. Deep-sea fishing grounds are allocated to foreign vessels that have been granted a permit by the DoF. As a result, valuable seafood products like yellow fin and skipjack tuna are landed in Thailand instead of Myanmar. Moreover, although foreign vessels are only allowed to fish in allocated fishing grounds, this is often not enforced by the coast guard and the DoF. Local fishermen complain that foreign vessels do not comply with the regulations and illegally capture large volumes of fish in inshore waters that are formally allocated to Myanmar vessels.

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[9] *Department of Fisheries, Fishery Statistics 2012. Ministry of Livestock and Fisheries, Nay Pyi Taw. 2012.*

[10] *FAO, Myanmar Aquaculture and Inland Fisheries. RAP publication 2003/18. Food and Agricultural Organisation, Bangkok. 2003.*

[11] Department of Fisheries, Fishery Statistics 2012. Ministry of Livestock and Fisheries, Nay Pyi Taw. 2012.

Fish Landings

Fish landings in Myanmar are well organised compared with other countries in the region like Bangladesh and India. Each boat has a registration number from the DoF and is allocated to one specific fish landing site (or jetty). These landing sites are located throughout the country where fresh water and marine fish are landed. Capture fish are sold through an auction system at the jetty.

Currently only three landing sites have been approved by the EU, two for marine capture fisheries and one for inland capture fisheries. These landing sites are located close to Yangon and organise the landing and marketing system according to EU food safety standards. The fish landed here is auctioned per product per boat. The Yangon office of the DoF issues Product Movement Documents (PMDs) that include the species, fishing vessel, fishing ground, landing site, etcetera. With a PMD, exporters can comply with traceability and Illegal, Unreported and Unregulated fishing (IUU fishing) regulations.

5.1.5.7 Fishing Gears in the Delta.

The FAO (2008) asset distribution data suggest that 28.9% of households had either fishing nets or traps before the cyclone. The main fishing gears used in the Delta region are described below. For convenience, data have been disaggregated into licensed gear, (which is generally used for commercial purposes) and gear that does not require a license, (the catches from which are generally used for home consumption).

Licensed Fishing Gear

- Stow net/Tiger Mouth (Kyar Pasat). A conical shaped net with or without wings, depending on the local practice. The mouth of the net is fastened to two fixed poles and held open against the current. The current carries fish through the net and they are collected at the cod end, which is lifted by fishers in boats at the turn of the tide. These nets are operated year round, (but less so in the wet season) day or at night usually from after high tide to the lowest tide. The fine mesh used at the cod end results in the capture of large numbers of small fish and shrimp suitable for processing.
- Trammel net (Thone Htat). This net consists of three layers with the inner layer being of smaller mesh than the outer layers. When a fish enters the first layer, it passes through the outer layer, eventually hitting the inner layer where the fish becomes entangled. The net is set across the tide and allowed to drift downstream for one or two hours before hauling, (see plate). Two persons are needed to operate this gear. There are three types of trammel nets; Nga Tha Lauk Pike, which catches Hilsa from close to the surface of the water; Nga Dan Pike which catches striped cat fish; and Nga Poke Thin Pike, which catches Croaker from the middle layer of water Different type of floats are used for different species and different sizes of nets.
- Net Fence Pike (Ba Winn). The net fence is a fishing method that uses tidal fluctuations for fish accumulation and harvesting. A series of bamboo poles is driven into the river bottom facing the shore at low tide and a small mesh net is placed at the base of the poles. The nets can be as long as 500 m in length. At high tide the net is lifted from the bottom and hung above the surface, on to the poles. When the water begins to recede, fish from the inundated areas are caught as they attempt to return to the main river and are collected from the bottom of the net, at low tide. Net fences catch a wide range of fish and shrimp including products suitable for fish processing.

- Stake Net (Tar Pite/Htaung Pite). These gill nets nets are fixed to the bottom or at a certain distance above it by means of bamboo poles. These nets are generally operated in shallow water areas where the depth ranges between 1 - 5 meters. They target larger fish species.
- Beach Seine (Thaung Swle Pike) The beach seine consists of two long wings made of netting and hung to a weighted foot rope and kept in position by a float line. A bunt or a bag is attached to the wings. The seine is dragged into shallow water and the catch sorted. Small mesh allows for the indiscriminate capture of a range of fish and shrimp sizes (Rick Gregory & Saw la Paw Wah, 2009).

Fishing Gears which do not require a License

- Prawn Trap (Pa Zun Hymone). These bamboo traps are shaped like a funnel and are operated in flooded areas, rivers and lakes where there is some current. Harvesting takes place once a day. The trap is baited.
- Crab Trap (Ka Nam Hymone). A rectangular shaped baited trap made of wire or rattans are used for mangrove crab capture. Often a float is attached to allow the trap to be retrieved. Crab traps are set in the river edges, in small creeks or in mangrove areas. Small pieces of fish are used as a bait.
- Small Lift Net (Dine wonn) is used for the small-scale collection of crabs in southern areas and fish in the northern delta.
- Long Line (Nga Hmyar Tann). This consists of a main line and a number of branch lines or hook lines. The long line is set at mid water or bottom of the river or flooded area. Usually small boats are used for long line fishing and the length of the long line varies between 50 m and 1,000 meters. Local preferences in terms of hook size and twine used, vary considerably in different areas of the Delta.
- Small (portable) cast net (Let Pyit Con). This weighted net is thrown by the fisher. At the bottom of the net are small pockets where the fish become trapped. The top of the net has a line for hauling. Two people are usually required for operation from a boat. This is an important fishing gear used by individual fishers in the wet season rice field fishery.
- Giant Cast Net (Mat-Kun). These nets can be up to 40m long and are not cast, but dragged though the water like a seine net; the fish collecting in pockets as with the more conventional cast nets. A boat and two people are needed for the operation of this gear.
- Push net (Yin Tun). The push net consists of two components namely a net and a scissors shaped 2 to 3 meter bamboo frame. The mouth of the net is linked to the bamboo frame to keep it open and the fishermen wade into the water pushing the net forward, (see cover picture). It is lifted periodically and the catch sorted. Although this gear is used by a wading fisher, they often tow a small boat behind them for travel to fishing grounds and equipment transportation.
- Fish Trap (Hymone). These traps vary according to the type of fish to be caught. They are generally made from split bamboo. Fish traos are commonly used in rice fields and adjacent wetland areas and catch a range of small fish and shrimp.
- Eel Trap (Nga Shint Hymone). This is a vertically positioned bamboo trap with an entrance cone on the side near the base. It is operated in the flood plains and rice fields during the rainy season.
- Rice field fish traps (Hsare). These traps are used between paddy fields and catch fish as waters recede at the end of the wet season, or with the tide. They operate on a 'V' slot principle, with the fish entering a chamber through the V slot, from which are difficult to escape.
- Hook and stick. This fishing gear is using a small thin bamboo and connect with hook by line for fishing, usually overnight. The bamboo is pushed into the rice bund and checked each morning. They are used for catching snakehead and other rice field fish.
- Plunge basket (Saung). This is a conical bamboo basket with a hole on the top for catching large fish in shallow waters. The basket is plunged into the water and when a fish

is trapped, the fisher extracts the fish from the hole at the top, with his hand. It can use for fishing inside wetland, creek and paddy field.

- Brush Park. This fishing method uses tree branches or bamboo to aggregate fish. periodically, a net is set around the area and the branches removed. A small seine net then collects the fish (Rick Gregory & Saw la Paw Wah, 2009).

5.1.5.8 Aquaculture

The information in this section is directly derived from the CBI & LEI Wageningen UR (*2012)* study.

In Myanmar the total area under aquaculture production is about 181,000 ha (450.000 acres). The total area under shrimp culture is over 92,000 ha while the total area under fish culture is approximately 89,000 ha. Shrimp ponds are mainly located in the following regions: Rhakine (75%), Ayeyarwady (20%) and Yangon (5%). Fish ponds are mainly located in Bago (11%), Ayeyarwady (50%) and Yangon (28%). The estimated total shrimp production for 2011 is 20,000 tonnes while fish accounts for more than 800,000 tonnes[12]. The DoF has increased efforts to further develop the aquaculture sector because it recognises its potential for Myanmar. This section discusses the main characteristics of shrimp, fish and other aquaculture activities in Myanmar.

Shrimp farming

The shrimp farming sector in Myanmar is concentrated in three regions: 1) Rakhine in the Northwest, close to the border with Bangladesh and 2) Ayeyarwady and Yangon in the delta region in the central part of the country.

The total shrimp farming area in the Ayeyarwady and Yangon region covers approximately 28,000 ha (24,000 ha in Ayeyarwady, 4,000 ha in Yangon). Currently two main species are cultured: 1) Pacific white shrimp 2) Giant freshwater prawn *(Macrobrachium rosenbergii).*

In 2000 the government instituted the Shrimp Aquaculture Development Committee, which formulated and implemented a three-year project plan for the intensification of the shrimp production in Myanmar. The project focused on transforming extensive ponds into improved extensive systems in the Rhakine region and the Ayeyarwady region and on introducing semi-intensive and intensive production systems in Yangon and Ayeyarwady. To manage the shrimp farming sector, the committee appointed specific areas for shrimp farming where families and commercial enterprises could lease land to construct shrimp farms.

When the project was finished in 2003, 2,100 ha of semi-intensive or intensive shrimp ponds were built in Ayeyarwady and Yangon. By the time the three-year project plan was implemented, many private companies emerged that got involved in the shrimp industry. The rapid expansion of shrimp production resulted in a shortage of post-larvae due to a limited number of local hatcheries. To secure the supply of post-larvae, shrimp farmers bought post-larvae from hatcheries in Thailand and Bangladesh. Purchases of bad quality post-larvae are expected to be the source of the outbreaks of the White Spot Disease. In 2004-2005 this disease hit the semi-intensive and intensive shrimp farms in Ayeyarwady and Yangon.

As a response to the White Spot Disease, shrimp farmers requested the DoF to allow the import of Pacific white shrimp. Although the government hesitated, after a couple of trial projects and a

[12] *Department of Fisheries, Fishery Statistics 2012. Ministry of Livestock and Fisheries, Nay Pyi Taw. 2012.*

temporary ban that was implemented to prevent disease outbreaks, the DoF approved to import SPF Pacific white shrimp post-larvae from Hawaii. Although initially the culture of Pacific white shrimp was relatively successful, production has now collapsed. This collapse was caused by:

- natural disasters in 2008 and 2010;
- high fuel prices for the use of paddlewheels and pumps;
- low market prices.

Currently most of the intensive and semi-intensive shrimp farms and companies have ceased production or changed to extensive production systems and fish instead of shrimp culture. Farms that continue intensive and semi-intensive shrimp production currently only produce for the local market. Local market demand is mainly small size (100 headless shrimps per 450 grams) Pacific white shrimp of which the local market can absorb approximately 6 tonnes per day. Farmers in Ayeyarwady and Yangon emphasise that they need government assistance to revitalise production and to reduce production costs to be able to produce a competitive product that can be marketed internationally.

Besides the production of Pacific white shrimp, this region is also known for the production of Giant freshwater prawn. Giant freshwater prawn is mostly produced in polyculture systems where the culture of Giant freshwater prawn is combined with carp and other freshwater fish species. Exporters in Yangon purchase the prawns from local collectors who consolidate supply and process the material at their factories. At the moment Giant freshwater prawn is mainly exported to Japan, but there is also an increasing local demand for what is considered a luxury product *(CBI &LEI Wageningen UR, 2012).*

Other coastal and marine aquaculture

Besides shrimp, coastal and marine aquaculture consists mainly of the culture of groupers, seabass, mud crab and relatively small volumes of e.g. cockles and lobster[13]. These activities are concentrated in the Ayeyarwady and Yangon regions, but also take place at a smaller scale in other coastal regions.

Mud crab (*Scylla spp.*) farming is also important in Myanmar. Mud crab culture in mangroves or on tidal flats is practiced mainly in the Ayeyarwady delta area, in
Rakhine and southern parts of Myanmar. Most crab fattening is practiced in ponds, pens (bamboo enclosures) or cages located in river and canal systems. Trade in mud crab appears to be thriving in the Ayeyarwady delta region. A large part of the production is for export to Singapore and China, including significant quantities transported to China by road. Since crabs must arrive live at their final destination, the trading network is well organised.

Groupers (*Epinephelus* sp.), locally known as 'Kyauk Nga' or 'Nga Tauk Tu', are important marine fishes. Groupers are exported live, and in chilled or frozen form. The export of live groupers is intended primarily for the live reef fish trade in Hong Kong. Marine and brackish water fish farming is mainly found in the Ayeyarwady delta area, Rakhine and southern parts of Myanmar. There is also some extensive pond culture of sea bass in these areas. Sea bass is sometimes also a by-product in extensive shrimp ponds. Sea bass is mostly consumed locally but small volumes are also exported to Australia.

Although there have been efforts to culture seaweed, oysters, cockles, lobsters and other products, until now these efforts have not yet shown significant results. The DoF invests in trials and experiments but until now the extent of upscaling to commercial operations has been limited.

[13] *FAO, Myanmar Aquaculture and Inland Fisheries. RAP publication 2003/18. Food and Agricultural Organisation, Bangkok. 2003.*

Without foreign expertise and capital it will be difficult to further develop coastal and marine aquaculture.

Inland fresh water aquaculture

Freshwater aquaculture takes place mostly in the Ayeryawady, Yangon and Bago regions. Freshwater fish producers can be divided into small-scale producers that cater mainly to the local market and large-scale vertically integrated farms that cater mostly to the export markets. Small-scale producers contribute directly to local food security, while the larger producers contribute indirectly through creating employment and foreign exchange earnings. The most important export market for freshwater fish is the fast developing intraregional market in Southeast Asia. It essentially consists of indigenous freshwater species such as Indian carp (*Labeo rohita)*, Catla (*Catla catla)*, Mrigal (*Cirrhinus mrigal),* Pangasius and tilapia[14].

The culture of Indian carp (locally referred to as Rohu) developed into a lucrative industry during the late 1990s and 21st century[15]. The vertically integrated enterprises normally have their own hatchery, farm and processing establishment. In some cases these enterprises even have their own feed production units. The integrated farms initially focused on an export market for Indian carp in Bangladesh. Particularly in the last 10 or 11 years, this focus on Bangladesh has expanded to other regions where there are considerable expatriate communities of Indian and Bangladeshi origin, including the Middle East and the EU. This sector flourished until 2007-2008, but as a result of overproduction, market prices collapsed and the business went down. Currently the sector is relatively stable. (CBI &LEI Wageningen UR, 2012)

5.1.5.9 Production and fisheries values chains

Production

Aquaculture production in Myanmar has grown in the past decade, see also table 5.4. Commercial fish farming, including some large scale fish farms, have grown successfully in Myanmar in recent years, but now appear to be facing considerable difficulties in sustaining commercial operations.

Table 5.4 Inland and marine fisheries production (in thousand metric ton). Source: DoF.

Year	Inland	Marine	Aquaculture	Total
2001 - 2002	131	298	87	516
2002 - 2003	145	306	132	583
2003 - 2004	195	308	158	660
2004 - 2005	220	330	219	769
2005 - 2006	121	267	276	664
2006 - 2007	320	395	302	1017
2007 - 2008	368	441	348	1157
2008 - 2009	406	532	404	1342
2009 - 2010	306	316	202	824

Large scale aquaculture production in Myanmar is characterized by low productivity and low diversity. The main focus of the production system is on the slow growing, low value commercial

species. Ponds are typically large (often 20 hectares by pond) with slow grow-out periods of between 18 to 24 months. Pond resources are not efficiently used. Farms provide seasonal low levels of employment. The low productivity of the aquaculture system is compounded by increasing input costs (feed, labour and electricity) and low outputs benefits raising concerns about the long term sustainability of the model, the species economics and markets. Large scale export oriented enterprises have reverted to selling on domestic markets, practices in themselves which may be influencing competitiveness of smaller scale commercial producers. Commercial aquaculture enterprises could provide employment, food security and extension and inputs that can support a small scale household oriented aquaculture development. Hatcheries appear to be underperforming, and carp breeding and hatchery programs need revitalisation.

Production systems for fish are dominated by extensive and semi-intensive ponds, with some marine and cage culture and rice-fish farming. Scale of production varies, but particularly in the Ayeyarwady delta region, large ponds and more commercially oriented enterprises appear to make most significant contributions to fish supply.

Employment opportunities in fisheries and aquaculture are seasonal in nature. Small scale household level aquaculture is surprisingly absent; it can be found with mixed success. Institutional, policy and services appear not yet to be favourable to development of this part of the sector, and it is uncertain whether the present investments will sustain and are able to move to a scale where they can make significant differences to the income and nutrition of the many poor and vulnerable households in the Ayeyarwady delta, or elsewhere in the country (which remains to be investigated).

The CBI Import Intelligence (2013) gives the following analysis of the production in Myanmar:

- Overall Production: In 2012, fisheries and aquaculture production in Myanmar is higher than the production in Bangladesh (3.1 million tonnes) and Thailand (2.9 million tonnes) According to the official figures of the department of fisheries production increased from 1.6 million tonnes in 2002 to 4.5 million tonnes in 2012. This increase is partly accounted for by an actual increase in production of mainly aquaculture and partly by an adjustment of capture fisheries statistics because previously illegal and unreported fisheries were not included.
- Fish landings: Although production is dispersed, fish landings both from aquaculture and from fisheries are concentrated in Yangon in the central of the country and Myeik in the South of the country close to the Thai border.
- Deep-sea fisheries: Although currently deep-sea fisheries rights have been given to foreign vessels landing fish outside Myanmar, this situation will change early 2014. The deep-sea fishing rights are terminated in the first half of 2014 and it has been announced that the fishing rights will not be given to foreign vessels in the future. This will have considerable implications for the volume of marine fish and other seafood landed in Myanmar. Increased landings will contribute to increased domestic processing and exports of marine fishery products from Myanmar.
- Aquaculture production: Between 2002 and 2012 aquaculture production increased from 0.25 million tonnes to almost 1 million tonnes. The total production area in 2012 amounts 450.000 acres of which 200.000 are used for fishponds and 250.000 for shrimp ponds. Especially the area for fishponds increased drastically while the area for shrimp ponds remained relatively stable. Fishponds are concentrated in Bago, Yangon and Ayeyarwady. Shrimp ponds are concentrated in Ayeyarwady, Yangon and Rhakine.
- Shrimp production: Shrimp is sourced both from aquaculture and fisheries sources. M. rosenbergi, P. Monodon and P. Vannamei are produced in extensive and semi-intensive

aquaculture production systems. Total production from aquaculture accounts approximately 10,000 tonnes per year. As a result of intensification programs, shrimp production increased steadily between 2000 and 2008. However, since several cyclones hit major production areas in 2008 and 2010, production stagnated and has not yet revived. Now the political climate is improving, it is expected that international support will contribute to an increased production in the coming years. In addition to aquaculture, from fisheries there is sourced 43,000 tonnes of wild shrimp. This is mainly larger size tiger shrimp destined for export markets. Catches from fisheries are not expected to increase in the future.

- Fresh water fish production: freshwater fish is mainly produced from aquaculture sources (carps 700,000 tonnes, tilapias 40,000 tonnes). Myanmar had a flourishing Indian carp sector with several integrated producers. However, production crashed as a result of an oversupply in the regional and local market and a lack of competitiveness of exporters from Myanmar. However, freshwater fish remains an important source of animal protein and production is expected to increase further in the coming years as support for further development is provided. While currently most products are supplied to the local market, there might be an export potential for species like tilapia and pangasius.
- Marine fish production: According to FAO data, more than 2 million tonnes of marine fish is captured in marine waters. Unfortunately there is no specification of the captured species but they include barramundi, and various pomfret species. Marine fish landed in Myanmar is limited to the fish captured in the coastal areas because the fish rights for the deep see areas are given to foreign vessels. As a result, high value species like tuna are almost not landed in Myanmar. Marine aquaculture (e.g. barramundi) is currently limited but developing and production is expected to increase in the future.
- Mud crab: Besides the above-mentioned products there is also produced a significant volume of mud crab destined for export markets. Mud crab is mainly produced in commercial farms managed by small and medium sized entrepreneurs. Although mud crab farming is a lucrative business because of its good market prices, its sustainability is questionable. The main reason is that the seeds are coming from wild sources and not from hatcheries. So far, there are no proper hatcheries that can produce seeds and reduce the pressure on wild stocks.

Fisheries value chains

The fisheries value chains in the Delta are well established and are based on strong social networks and trust-based relationships. Fishers sell mainly to the same traders who often provide loans and maintain buyer-seller dependency. Many of the poor are engaging as a wage labour in different parts of the value chain and whilst this provides people with regular although seasonal employment and contributes to their livelihoods, they are caught in a poverty trap.

Fish traders in the townships will provide loans (in some case boats and nets) to the trusted fishermen and in return the fisherman will sell their captured fish only to the same traders.
However by taking loans, poor fishermen will be exploited in three ways(1) The price offered to capture fish/prawn will be lower than from other traders.(2) The weighing of the buying fish/prawn will be not accurate but in fact will favour the trader.(3) The quality assessment of the captured fish/prawn will also favour the trader Moreover in the event that the fishermen could not capture enough fish to pay instalment for boat and net, the trader would take back all fishing gears, hence the fisherman without fishing gears would become casual labour.

- Fish trader's network: The traders in the townships are well organized and have formed a Township Myanmar Fishery Federations, and hence are strongly influenced on the fishery

affairs and also on the township authority as the fish trader are also contributing to township social and religious affairs. Moreover fish traders in the Laputta township have formed their own fish transportation network consists of boats and motorcars, and transporting fishery products to Yangon, to make the transportation cost effective and also because it is difficult to hire boats and cars to transport fish in the rainy season.

- Logistics: The transportation fees between Laputta, Bogalay and Yangon were about Ks 8,000 (8$) to Ks 8,500 (8.5$) for the 220 liters box (or 50 viss) of fishery product, including the loading charge. In average, one fish trader is transporting all kinds of fish from delta to Yangon, from minimum 20 viss per day to maximum 300 viss per day. Wage labours are use in the logistic chain, depending on the size of the business, the traders hired 3 workers or more and the wages for the workers are starting from Ks. 2,500 (2.5$) to over Ks 10,000 (10$) per day depends on their work.
- Fish traders in the value chain: The traders buy all kinds of fish and prawns from the fisherman, normally fishermen will come and sell at the fish market in the town, and traders also have their purchasers going around to the villages and, or have representatives to buy fish and prawns at the village level.

An average price of the fish in the village is from 600 Ks (0.6$) to 800 Ks (0.8 $) per viss, and hence the price is higher in the township as ranging from 800 Ks. (0.8 $) to 1400 Ks. (1.4$) per viss. And therefore most of the fish are transported to the Yangon Sanpya Fish wholesale market and are selling at much higher prices. There are some loss and damage in transporting fishery products because of the mud and rubbish mixed with the fishes, and hence the weights are lost after cleaning.

Fishery businessmen in the township level are financially supported by the fish wholesalers from Yangon normally, and some parts are finance by the banks (by collateralizing the land and house in the bank), reportedly no interest was charged to the loan taken from Yangon wholesale dealers. However many traders in the townships expressed that they need more investment to expand their business, and are also conveyed that they need technologies and trainings for marketing, fish and prawn culture technologies, and fish and prawn storing methods (MMRD, 2013).

5.1.5.10 *Constraints for the fishery and aquaculture sector*

According to WorldFish, the Ayeyarwady Delta has the potential to be as productive as the Mekong Delta. However, pressures (such as overfishing, destructive fishing practices, reduced fish migration routes due to dams) exploitation mangroves, limited research and development and monitoring, increasing water pollution) are now being exerted on fish stocks and the natural resources that support production in the Delta and there are concerns that current fish production, consumption and export earnings levels may become difficult to maintain. Anecdotal information from fishery communities also suggests that fish catches have yet to return to pre-Cyclone Nargis levels.

Delta Alliance farmer- fishermen workshops

Delta Alliance conducted jointly with MYFISH in July 2014 three workshops in fishermen communities. The workshops had a total duration of 3 days and it were attended by 58 men and women (residing from the sectors of farmers, fishermen and daily labours related to fisheries) in 3 different areas in the Ayeyarwady Delta: Maubin, Pyapon and Dedaye.

Figure 5.5 Delta Alliance survey with farmers-fishermen in different locations in the Ayeyarwady Delta (July 2014).

In the survey the participants were asked which are the main threats to their activity and the possible solutions to these threats. Which are summarized in Table 5.5.

Table 5.5 Results of the Delta Alliance survey with farmers-fishermen in the Ayeyarwady Delta.

Location	Profession	Main threats	Solutions and measures
Daedaye	**Daily-labours related to the fishery sector**	Debt in local market No regular income Rare work in rainy season Cash	Cash down selling system Lower interest Job opportunity
Maubin	**Farmer-Fishermen**	Investment during rainy season Scarce labour Need of fishing tools	Lower interest Cooperation with farmers
	Fishermen	Need of fishing tools and boat Investment for tools	Making dry fish and fish paste in rainy season Lower interest Good road Cash advance for labour
Pyapon	**Farmers**	High interest Scarce labour Weather (rainy season) Investment	Lower interest Loan from organizations or from the government Own livestock
	Farmers-fishermen	Scarce labour Weather (rainy season)	Machinery tools Assistance from the village Committee Need of investment

Constraints at the production level in aquaculture (CBI &LEI Wageningen UR, 2012)

The Pacific white shrimp but also to a lesser extent the Black tiger prawn farm sector have been in crisis since the 21st century. There are a number of issues at the primary production level that need to be solved before the sector can revive and reach its full potential. The most important issues are discussed below:

- Lack of access to capital to build infrastructure for intensive and semi-intensive farms. As a result of cyclones in 2008 and 2010 many shrimp farms have been damaged. Shrimp farmers lack the capital and as interest rates for loans reach 60% they also lack the market incentives to repair their farms. As a result they request the government and exporters with processing establishments to invest in the shrimp farming sector. However, until now financial support has been limited. The exporters argue that they do not have the financial capacity to invest outside the factory boundaries. It is likely that there will only be investments in shrimp farm infrastructure when the farms are able to produce a competitive product. However, farmers will not start to invest in production as long as there is no market for their products.

- High cost for shrimp production for intensive and semi-intensive farms. Electricity supply is a crucial issue in Myanmar. While even factories in the cities are not continuously supplied with electricity, shrimp farms in rural areas have no electricity supply at all. Therefore especially semi-intensive and intensive farms that depend on power supply for water exchange and paddlewheels are confronted with extremely high costs. According to farmers, diesel costs amount to approximately 25% of total production costs and make local production uncompetitive compared with the shrimp produced in other countries where farmers operate tidal systems or have an electricity supply on the farm. This is stipulated by the fact that it already has been reported that Thai shrimp were sold in the local markets below the local prices. Semi-intensive shrimp farms will be unable to produce a competitive product if they do not have access to electricity.

- Lack of cooperation between farmers and exporters in the Ayeyarwady and Yangon regions. Exporters are reluctant to work with farmers as there is no product that can compete in the international market. They do not invest outside their factory boundaries and do not provide inputs such as feed, post-larvae and working capital. Moreover, farmers are not supported during harvest and post-harvest activities. This contributes to the high production costs of shrimp farms. In other countries it has been proven that cooperation between farmers and exporters is a crucial issue to improve farm productivity and ensure food safety issues in the supply chain. However, as long as the locally produced shrimp is not competitive in the international market, exporters have no incentive to increase cooperation.

5.1.5.11 Research on fisheries and aquaculture: MYFish project

The Australian Government through the Australian Centre for International Agricultural Research (ACIAR) is funding a $AUD 10 million multi-disciplinary Research, Development & Extension program in Myanmar that is focussed on improving food security and livelihoods for small holders in the Central Dry Zone and Ayeyarwady Delta. WorldFish is the implementing agency for the AUS$ 2 million fishery component of the program and has developed a project for “Improving research and development of Myanmar’s inland and coastal fishery” over the next 4 years, which is called MYFish (Myanmar WorldFish). The project has been developed together with a number of local partners and in particular the Department of Fisheries (DoF) and the NGO association the Food Security Working Group (FSWG). MYFish aims to improve the capacity for management of Myanmar’s inland capture and culture fisheries and facilitate the emergence of co management of fisheries and small-scale aquaculture as cornerstones of rural food security and livelihoods.

Three project objectives have been identified to achieve this aim:

1 To characterise the fisheries sector in the Ayeyarwady Delta and to assess the scope for fisheries development in the Central Dry Zone;
2 To identify, test and then demonstrate new approaches to increase productivity, efficiency, sustainability and equity in fisheries production systems in the Ayeyarwady Delta and the Central Dry Zone;
3 To strengthen the capacity of Government, private sector and non-government organisations to carry out appropriate research & development for the fisheries sector.

The project has carried out a scoping mission in November 2012 in the Ayeyarwady Delta, with the objective to undertake a rapid assessment of the fishery sector, to develop a framework for researchable projects and to contribute to a characterisation study of the Delta in 2013.

5.1.6 Industry

Since the development of the delta has been launched only from early 20th century, industries apart from those related to farming (e.g. rice mills) and fishery (e.g. ice factories) are not found yet.

The opening up of the country to the outside world and the accompanying liberalisation of the economy will attract more industry to Myanmar. This industry will mainly concentrate in the economic free zones, of which Thilawa, near Yangon, is located within the Ayeyarwady Delta.

Micro and Small Enterprises (MSE) such as tailoring, carpentry, smiths' works, small repair shops, boat engine mechanic, masons, welding, repairing fishing nets, barber, beauty salons, battery repairing and charging, animal health workers, traditional healers, umbrella and torch repair and so on, are some of the Skilled based MSE commonly found in the Delta region. Resource based MSE such as rice trading, small rice mills, agri-produces trading, fish paste processing, dry fish processing, fish trading, forestry products producing and trading are also commonly found in the Delta.

Moreover, other Service based MSE such as food and soft drink shops, traditional snack food making, coconut noodle soup and traditional kid's snack making, tea shops, groceries, road and river transport services, video CD and book rentals, karaoke, and pool halls, money lending services, snack food makers, meat shops, cloth stores, edible oil stores, water fetching, gas and diesel stores, cigarette and betel leaves shacks, electronic and cosmetic stores, salt production and fishing materials stores, and so forth are also feasible business opportunities in the Delta (MMRD Research services, 2014).

Industry is mostly responsible for their own water supply and there is no system yet to control the use by means of permits or other regulation. The industrial development has wider side effects than just related to water (Deltares and TUDelft, 2013).

Land is evicted to support investments and the air pollution levels are increasing. Myanmar has a moderate level of air pollution and urban air quality is observed to be rapidly deteriorating (OECD 2013). Enabling Low Carbon development and Clean Development Market Mechanism initiatives are upcoming (IGES, 2012; IGES, 2013 and Deltares and TUDelft, 2013).

5.2 Drivers of change

Summary of drivers of change Occupation Layer

Demographic trends

Population of the country was estimated at 58.38 million during the census of 2008-2009. Taking into account a growth rate of 1.52 percent the actual population will be approximately 62 million. Ayeyarwady Region, covering a large part of the Ayeyarwady Delta has a population of 8,041,084 on an area of 35,032 km^2, hence a population density of 230 inhabitants/km^2. With 250 inhabitants/km^2 the delta is one of the most densely populated regions in Myanmar. This population density in Ayeyarwady Region is e.g. relatively low compared to the one of the Mekong Delta (approx. 500 inhabitants/km^2, excluding Ho Chi Minh City) and the Ganges-Brahmaputra-Meghna Delta (more than 1200 inhabitants/km^2), (Driel and Nauta, 2013).

Economic developments

The country is one of the poorest nations in Southeast Asia, 37% of the population is unemployed and 26% live in poverty. Myanmar's economy is one of the least developed in the world. In the past, GDP growth has been relatively slow averaging ~2.9% annually. A change of government in 2011, however, induced a number of policy reforms that increased GDP growth to 7.8% per annum. In 2011, agriculture contributed ~43% to GDP, services ~36.6% and industry ~20.5% (CIA, 2011). Agriculture, forestry, and fisheries constitute the largest contribution to the economy. Approximately 75% of the rural population rely on the agriculture, livestock and fisheries sectors for their livelihoods. Other major livelihood activities in Myanmar utilise the following major products: i) wood and wood products (amongst others through destructive mangrove exploitation for charcoal); ii) copper; iii) tin; iv) tungsten; v) iron; vi) cement; vii) construction materials; viii) pharmaceuticals; ix) fertilizer; x) natural gas; xi) garments; xii) jade; and xiii) gems (Hadden, R. L. 2008). The GDP growth will be around 6.8% (2013) being the GDP per capita $1,700 (CIA, 2013; Ministry of Transport - NAPA, 2012).

According to the Asian Development Bank (ADB), "many more people" in Southeast Asia died as a result of natural disasters between 2001 and 2010 than during the previous decade, primarily due to the 2004 India Ocean tsunami and 2008's Cyclone Nargis, whose aftermath showcased the Myanmar government's inability to respond to extreme weather. Although not directly to be related to climate change, the devastating Cyclone Nargis hit Myanmar with resulting waves of more than 6 meters in May 2008, the strongest ever (U Nyan Win, 2010) killing 138,373 people and leaving about 2.4 million affected. Total damage and loss was estimated at approximately 11.7 trillion Kyats, i.e. 4.1 billion US$ (Ministry of Social Welfare, Relief and Resettlement, 2012).

Political changes and foreign investments

Recently, Myanmar has opened up to the outside world and is going through a political transformation. In March 2012, a draft foreign investment law emerged, the first in more than 2 decades. This law creates unprecedented liberalization of the economy. The draft includes a proposal to transform the Myanmar Investment Commission from a government-appointed body into an independent board. This will bring greater transparency to the process of issuing investment licenses. This will lead to more foreign investments in all sectors: in industrial developments, but certainly also to investments and economic developments in the agricultural and fisheries/aquacultural sector.

Technological developments

Myanmar´s science and technology infrastructure is mainly focussing on agriculture research, due to the importance of the agriculture sector for the national development. It includes the development of agricultural products and methods as well as sustainable forestry. Many dams have been built in the mountainous areas around the Upper Delta and more upstream in the Ayeyarwady basin, mainly for irrigation purposes. It is expected that the existing irrigation systems and the polders (to protect the agricultural land from salt water intrusion) will be upgraded and extended. The annual rice production of Ayeyarwady Region of about 6 million tons accounts for 30 percent of the total production in Myanmar of about 22 million tons annually (FAO, 2001/2002). This situation is mainly due to the increase of farmland area, with a rapid 25 percent increase between 1990 and 1994. Other research focuses are set on biotechnology, renewable energy, health, internet technology and marine science and technology.16 The recent political changes are likely to give a boost to these technological activities.

Research gaps

Apart from statistical data on for instance agricultural production there is not much recent information available on the Ayeyarwady delta, mainly due to the fact that in the last 20 years not much research has been done and most of the monitoring programs have been halted. Therefore research gaps exist for all drivers of change.

The recently performed census 2013 will give new data on the population in the Delta: population number, density, composition, growth rates, etc.

It is expected (and the first signs are clearly visible) that the recent opening of the country will also create new rapid economic developments, although information on these expected developments is not easily available. To stimulate economic development and foreign investments so-called ‘special economic zones’ are and will be created in the neighbourhood in Yangon, however outside the Ayeyarwady Delta. The special economic zones and other business developments will likely on the urban infrastructure and the availability of fresh water.

Moreover, investments in research and development are needed in the agricultural sector, being the most important contributors to the GDP (World Bank, 2005). During three Delta Alliance workshops held in respectively Pathein, Hinthada and Yangon in June 2014 the key issue ‘knowledge development and innovation’ scored among the participants second highest (after flooding) out of 8 key issues for the delta.

5.3 Pressures

Summary of pressures Occupation Layer

Pressure on space

The delta is one of the most densely populated regions in Myanmar. Ayeyarwady Region, covering a large part of the Ayeyarwady Delta has a population of approximately 8 million on an area of 35,032 km^2, hence a population density of 230 inhabitants/km^2, which is three to four times as high as the country’s average.

16 Facts on Science, Technology and Innovation. South Asia and European Union (SEA-EU-NET) http://www.sea-eu.net/facts/sea/myanmar

Vulnerability to flooding and erosion

Most of the delta is still active with unstable river branches and the delta is prone to tropical cyclones with high storm surges. Many people are yearly affected by bank and coastal erosion and also floods are a permanent threat. Floods can be of different nature: floods from the rivers (mainly in the Upper Delta), floods caused by storm surges (mainly in the Lower Delta) and flash floods from the surrounding hilly and mountainous regions.

Agriculture under pressure by climate change, flooding and salinity intrusion

Agricultural production is facing challenges due to increasing risks of flooding and salinity intrusion.

Pressures on the fisheries sector: overfishing

The fishery in the Ayeyarwady Delta encounters the pressure of overexploitation, which has been impacting already the livelihood of rural poor (MYFish, 2013).

Bad performance shrimp farming

The shrimp farming sector was well established in Myanmar, but suffers now from technical problems, such as diseases, low productivity and vulnerability to market demand and price fluctuations. For more sustainable production, better environmental management of the farming system is a priority.

Lack of access to capital and/or credit

As well as in the agricultural as the aquacultural sector investments are hampered by a lack of access to credit or capital.

Degradation of mangrove forests

Especially the mangrove forests are highly valuable but also under high pressure from encroachment and exploitation and are largely in a degraded state due to human activities. This pressure will increase due to population growth and economic development. Herewith important functions of the mangroves are in danger.

Shift in land use upstream

The effects of the dams are producing a reduction of the sediment supply and therefore erosion of the delta.

Water demand / freshwater shortage

Due to upstream developments, climate change and sea level rise, critical low flow conditions of the Ayeyarwady River tributaries are likely to increase. Increase of salinity intrusion in the coastal areas is making existing water supply sources (domestic and agricultural) and freshwater ecosystem vulnerable.

Need for more livelihood opportunities

For a sustainable development of the (rural) Ayeyarwady Delta there is an urgent need for improvement of the livelihood opportunities for the local population. The majority of the people in

the Delta is landless and are therefore placed in a non-voluntary dependent position. Lack of or limited access to credit hampers also the economic development of the rural population. Multi-sectorial development is needed to increase the livelihood of the rural population (MMRD Research Services, 2014).

Impact of climate change on public health (directly derived from the NAPA)

Effects of increasing temperatures and erratic precipitation patterns are the spread of infectious diseases, heat stress, heat exhaustion and dehydration. The greatest concern at present is however related to freshwater resources (Lian and Bhullar, 2010).

Research/knowledge gaps

During the Delta Alliance missions in July 2013 (Driel and Nauta, 2013) and June 2014 the following research and knowledge gaps have been observed:

- Data on population: density, growth rate, current unemployment, projections and current situation;
- Migration both into the delta and out of the delta, due to loss of livelihoods, needs to be considered;
- More insight needed in fishing rights, not aquaculture alone, but captures fisheries in river, estuary and those on delta dependent on marine fisheries as well;
- Inventory of existing (development) plans needed;
- There is need of socio-economic and livelihood profiling of the population to understand the actual vulnerability.

Pressure in available space

Population of the country was estimated at 58.38 million during the census of 2008-2009. Taking into account a growth rate of 1.52 percent the actual population will be approximately 62 million. Ayeyarwady Region, covering a large part of the Ayeyarwady Delta has a population of 8,041,084 on an area of 35,032 km^2, hence a population density of 230 inhabitants/km^2, which is three to four times as high as the country's average. However compared to other deltas in the region the population density is relative low: Mekong delta (excluding Ho Chi Minh City) counts approx. 500 inhabitants/km^2 and the Ganges-Brahmaputra-Meghna delta more than 1200 inhabitants/km^2.

Vulnerability to flooding and erosion

Most of the delta is still active with unstable river branches and the delta is prone to tropical cyclones with high storm surges. Many people are yearly affected by bank and coastal erosion and also floods are a permanent threat. There is no regulation on spatial planning nor law enforcement to avoid that people are living in areas that are prone to flooding and erosion. Floods can be of different nature: floods from the rivers (mainly in the Upper Delta), floods caused by storm surges (mainly in the Lower Delta) and flash floods from the surrounding hilly and mountainous regions. The risks of flooding: floods are expected to increase due to the probability of more extreme events, sea level rise and increasing rainfall quantities and intensities. For further details on flooding (hazard) see also description is the Base Layer (Section 3.1.6).

Agriculture under pressure by climate change, flooding and salinity intrusion (partly derived from the NAPA)

Agriculture in Myanmar is extremely vulnerable to climate change. The predicted rise in temperature in Myanmar is expected to have major negative impacts on agricultural production and food security (Wassmann et al., 2009). Higher temperatures will reduce yields of desirable crops (e.g. rice, wheat, maize, soybean and groundnut) and encourage weed and pest proliferation. Changes in precipitation patterns will increase the likelihood of short-term crop failures as well as long-term production declines. According to the IPCC 4th Assessment Report, climate change is expected to affect agriculture in South East Asia in several ways: i) irrigation systems will be affected by changes in rainfall and runoff, and subsequently, water quality and supply; ii) temperature increases of ~2°C -4°C will threaten agricultural productivity, stressing crops and reducing yields; iii) changes in temperature, moisture and carbon dioxide concentrations will negatively affect major cereal (e.g. rice, wheat, maize and millet) and tree crops; and iv) increases in rice and wheat production associated with CO_2 fertilization will be offset by reductions in yields resulting from temperature and/or moisture changes. In particular, the increases in occurrence of droughts will result in crop failure in rain-fed agricultural areas and will increase the demand for irrigation. Conversely, increases in the occurrence of intense rains and resulting extreme floods will result in higher yield losses from crop damage (Swe, K. L.). A rise of 1 °C -2°C combined with lower solar radiation has the potential to cause rice spikelet sterility (i.e. infertile rice seeds). Rice becomes sterile if exposed to temperatures above 35°C for more than one hour during flowering and consequently produces no grain. This will limit rice production (Karim, 1994). Furthermore, higher temperatures will increase the incidence of crop diseases, insect pests and rodents (Karim, 1996; Singleton et al, 2010).

The highly productive deltaic and low-lying coastal rice/local crop cultivation areas in Myanmar will not only be exposed to increased temperatures, erratic rainfall, droughts, floods and intense rains, but will also be exposed to increased salinity, coastal erosion, and inundation as a result of sea-level rise (World Vision, 2008). The extensive, low-lying Ayeyarwady/Yangon Deltaic regions are particularly vulnerable to sea-level rise. By 2100, global sea level could rise by >0.2 m-0.6 m. A 0.5 m sea level rise would result in the shoreline along the Ayeyarwady Delta advancing by 10 km. This would have a significant impact on local communities and the agricultural sector.

Conversely, increases in drought events will increase utilisation pressures on ground water for expanding irrigated agriculture. Rising sea levels will lead to salt-water intrusion into groundwater supplies particularly as existing water levels decrease. Ground water supplies will be particularly vulnerable to saline intrusion during the dry season as a result of low water volumes in river systems.

Increasing risks of flooding and salinity intrusion will put a stress on agricultural production. The risk of increasing salinity intrusion is largest in the Middle Delta: the area for and time period during which fresh water is available will likely decrease. More extreme floods with saline water (mainly in Lower Delta) have direct impact on agricultural production. Inflow of saline water into paddy fields by Nargis decreased agricultural production instantly. According to farmers in Labutta North Polder, cropping yield of paddy of immediate crop after Nargis attack was decreased to 10-20 baskets/acre equivalent to minus 50-75 percent from 40-50 baskets of cropping yield before Nargis (local variety), (JICA, 2011).

Increased river and flash floods (mainly in the Middle and Upper Delta) will damage the crops and therefor the income of the farmers. During an increase of the discharges and water levels in the water level, in combination with the increase in development of the area along the rivers and coastal areas, the probability of flooding increases if no proper flood control and protection measures in place. With the help of retention reservoirs in the hilly region and constructions like

weirs and good embankments (dikes) can prevent the high discharges from cause damage and possible loss of life in the vulnerable areas (Hassman, 2013).

Agricultural impacts will particularly affect low-income rural populations that depend on traditional agricultural systems or on marginal lands. According to detailed modelling of crop growth under climate change using global agriculture models (Nelson, 2009), climate change will result in the following impacts for South Asian countries: i) severe declines in important crops including rice, wheat, maize, soybeans and groundnuts; and ii) large declines for irrigated crops. This will result in: i) additional price increases for important agricultural crops (rice, wheat, maize, soybeans and groundnut); ii) higher livestock feed prices which will result in higher meat prices; iii) a reduction in meat consumption; iv) a substantial fall in cereal consumption; and v) a decline in calorie availability which will increase child malnutrition by 20%.

Construction of new infrastructural works for irrigation (such as the Paddy III project) might partly mitigate the impacts of these pressures on agriculture.

Pressures on the fisheries sector: overfishing

After agriculture fisheries are the second main livelihood option in the delta. Any pressure on the fishery sector affects the local population. In the current situation the fishery (and aquaculture) sector in the Ayeyarwady Delta encounters the following pressures: a decline catch of natural fish, smaller individual fish sizes, uncontrolled fishing, lack of empowerment in preventing illegal fishing (using smaller mesh in fish nets, less awareness on fisheries closure season and increase using of fishing methods that may destroy natural habitat and environment) which has been impacting the livelihood of rural poor (MYFish, 2013).

Bad performance shrimp farming

The shrimp farming sector was well established in Myanmar, but suffers now from technical problems, such as diseases, low productivity and vulnerability to market demand, high fuel prices and price fluctuations. For more sustainable production, better environmental management of the farming system is a priority.

As a response to the outbreaks of White Spot Disease (2004-2005), shrimp farmers requested the DoF to allow the import of Pacific white shrimp. Although initially the culture of Pacific white shrimp was relatively successful, production has now collapsed. This collapse was caused by:

- natural disasters in 2008 and 2010;
- high fuel prices for the use of paddlewheels and pumps;
- low market prices.

Currently most of the intensive and semi-intensive shrimp farms and companies have ceased production or changed to extensive production systems and fish instead of shrimp culture. Farms that continue intensive and semi-intensive shrimp production currently only produce for the local market. Farmers in Ayeyarwady and Yangon emphasise that they need government assistance to revitalise production and to reduce production costs to be able to produce a competitive product that can be marketed internationally.

Lack of access to capital and/or credit

As well as in the agricultural as the aquacultural sector investments are hampered by a lack of access to credit or capital. As a result of cyclones in 2008 and 2010 many shrimp farms have been damaged. Shrimp farmers lack the capital and as interest rates for loans reach 60% they also lack the market incentives to repair their farms.

Constraints to agricultural are generally related to low-intensity farming techniques, that could be addressed with increased availability of credit as well as by technical advice and improved access to land.

Degradation of mangrove forests

Especially the mangrove forests are highly valuable but also under high pressure from encroachment and exploitation and are largely in a degraded state due to human activities. such as wood harvesting (mainly for the production of charcoal) and coastal development (paddy fields and shrimp/fish ponds). Important prawning grounds for the coastal fish species are being lost. Further clearance needs to be stopped if coastal fisheries are to be maintained at high production levels. Integrated production systems should be encouraged. There is some evidence to suggest that production from extensive, integrated mangrove-shrimp-fish, shrimp-rice-salt pan systems is higher than is shrimp monoculture systems (MYFish, 2013).

Shift in land use upstream

The effects of the dams are producing a reduction of the sediment supply and therefore erosion of the delta. Losses of sediment will also affect the fertility of the agricultural land.

Water demand / freshwater shortage

Due to upstream developments, climate change and sea level rise, critical low flow conditions of the Ayeyarwady River tributaries are likely to increase. Increase of salinity intrusion in the coastal areas is making existing water supply sources (domestic and agricultural) and freshwater ecosystem vulnerable. Also the urban and industrial development in and around Yangon will put extra pressure on water availability. The local existence of arsenic contamination of the ground water often hampers the use of shallow tube wells (around 30 m depth).

Need for more livelihood opportunities

For a sustainable development of the (rural) Ayeyarwady Delta there is an urgent need for improvement of the livelihood opportunities for the local population. The majority of the people in the Delta is landless and are therefore placed in a non-voluntary dependent position. Lack of or limited access to credit hampers also the economic development of the rural population. Multi-sectorial development is needed to increase the livelihood of the rural population (MMRD Research Services, 2014).

Impact of climate change on public health (directly derived from the NAPA)

Increasing temperatures and erratic precipitation patterns will create favourable conditions for the spread of infectious diseases. Additional effects of increasing temperatures on human health, including inter alia heat stress, heat exhaustion and dehydration. The greatest concern at present regarding climate change impacts on human health is related to freshwater resources (Lian and Bhullar, 2010). Increases in intense rain events and tropical storms will lead to increases in flooding events and storm surges. This will affect freshwater sources as they become contaminated by rising flood water levels. Furthermore, rising sea-levels will result in fresh groundwater resources being displaced with salt water.

6 Governance

Summary of governance issues

Cooperation between (scale) Levels and Sectors of Government

Myanmar counts many ministries which are often working in quite a sectorial way. Efforts are underway to improve core governance systems. In Myanmar land and water are managed by many ministries, agencies and departments. Several departments, under their respective ministries, remain for instance responsible for the supply and management of water for agriculture, industrial, domestic and sanitation purposes. Different departments have different acts, proclamations and laws, but most of them need to be strengthened in order to overcome problems caused by the lack of regulations on land and water. There is also a lack of coordination and collaboration between the different institutions, including a lack of sharing of data and information.

Cooperation between Government and Private Sector

Economic sanctions on Maynamr prevented western investments and trade for most of the last twenty years). The recent relaxation of sanctions and political change have led to both the Myanmar government and foreign investors seeking to significantly increase investment across economic sectors (Henley, 2014). Although the private sector is looking into opportunities in Myanmar with great interest, it should be noted that only 30 percent of the transactions is successful according to McKinsey (2013). This is mainly due to the lack of knowledge and legislation in Myanmar, e.g. in the specific field of Public Private Partnerships. The privatization of public sector industries need to be further developed.

Involvement of Stakeholders and Citizens

Stakeholder consultation at planning and implementation phase of a project in different parts of the country needs to be further encouraged.

Approaches for dealing with Risks and Uncertainties

To reduce loss of lives and property, Myanmar needs to focus on the development of flood forecasting and warning systems. Coastal area has already been practiced the early warning system for cyclonic storm surge and got the benefit. Disaster Reduction Plans have been developed for all districts.

Research gaps

- Lack of knowledge and legislation in Myanmar, e.g. in the specific field of Public Private Partnerships.
- Improved land administration by increasing dialogue on land issues with political leaders, by funding technical expertise to assist land administration functions and land governance processes. (Henley, 2014).

6.1 Administrative system

The Republic of the Union of Myanmar comprises seven states and seven regions named in the 2008 Constitution, six self-administered zones or divisions, and one union territory containing the capital Nay Pyi Taw and surrounding townships[17]. The smallest formal administrative unit is the village, with several grouped together into village tracts. Urban wards, towns and village tracts are grouped into townships, where the lowest levels of government offices are generally located. Collections of townships are organized as districts, which in turn form the region or state. There are 325 townships and 67 districts in Myanmar's states and regions[18] (H. Nixon, C. Joelene, Kyi Pyar Chit Saw, Thet Aung Lynn & M. Arnold, 2013). The creation of a level of state and region government is the most significant change to the structures of subnational governance brought about by Myanmar's new constitution with two important issues for the future: the relationship between the evolution of state/region government and both the peace process and the overall process of democratization (H. Nixon, C. Joelene, Kyi Pyar Chit Saw, Thet Aung Lynn & M. Arnold, 2013).

6.1.1 Land and water management

In Myanmar land and water are managed by many ministries, agencies and departments. Several departments, under their respective ministries, remain for instance responsible for the supply and management of water for agriculture, industrial, domestic and sanitation purposes. Different departments have different acts, proclamations and laws, but most of them need to be strengthened in order to overcome problems caused by the lack of regulations on land and water. There is also a lack of coordination and collaboration between the different institutions, including a lack of sharing of data and information.

Table 6.1 includes an overview of duties and functions for some of the most important Agency / Department.

Table 6.1 Overview of duties and functions for some of the most important Agency / Department (especially related to water).

Agency / Department	Ministry/City/Other	Duty and function
Irrigation Department	Agriculture & Irrigation	Provision of irrigation water to farmlands
Water Resources Utilization Department	Agriculture & Irrigation	Pumped irrigation and rural water supply
Directorate of Water Resources and Improvements of River Systems	Transport	River training and navigation
Department of Meteorology and Hydrology	Transport	Water assessment of main rivers
Ministerial factories	Industry (1), Industry (2)	Industrial use

[17] The six self-administered territories are the zones of Naga in Sagaing Region, Danu, Pa-O, Palaung, Kokaung, and the Self-Administered Division of Wa (all in Shan State).

[18] Statistical Yearbook 2011, Central Statistical Organization, Ministry of National Planning and Economic Development Nay Pyi Taw, Myanmar (2012): 20. There are two districts contained within the self-administered zones.

Department of Fisheries	Livestock, Breeding and Fisheries	Fishery activities
City Development Committee	Yangon, Mandalay and Naypyitaw	City water supply and sanitation
Department of Rural Development –	Ministry of Livestock and Fisheries and Rural Development	Domestic water and rural supply, and sanitation
Private Users	private entrepreneurs	Domestic water supply, navigation, irrigation and fisheries
Forest & Environment Department	Ministry of Environmental Conservation and Forestry	Reforestation, conservation of (mangrove) forests and environment
Public Works	Construction	Domestic and industrial water supply and sanitation
Department of Human Settlement and Housing Development	Construction	Domestic water supply
Department of Health	Health	Environmental health, water quality assessment and control
Department of Health Planning	Health	Social mobilization, health, etc.
Yangon Technological Universities	Science and technology	Training and research
Myanma Port Authority	Transport	Port development in Yangon
Special Economic Zone Department	Planning	Planning of SEZ's - Thilawa
Myanmar Development Resource Institute	President's Office	Think tank for governance, socio-economic development and legal affairs

Figure 6.1 gives the overview of the administrative system at the level of the Ayeyarwady region.

Figure 6.1 Government organisation of the Ayeyarwady Region.

6.2 Governance

Myanmar is still a fragile state undergoing a period of profound economic and political reform following a period of conflict and isolation (Henley, 2014). As the poorest country in South Asia, land is the main asset for many people, especially in rural areas such as the Ayeyarwady Delta.
The recent political changes have profound implications for security of land tenure. Land legislation passed in 2012 is meant to strengthen the formal land administration and provide more rights for landholders, including the right to lease and sell land. At the same time the , the government's policy to open up to foreign investments for large scale agriculture, mining and industrial zones threatens to place further pressure on land (Henley, 2014).
Apart from a lack of spatial planning processes and procedures, there is a lack of legislation, regulation and enforcement to avoid the settlement of (mainly fishermen communities on the erosion (and flooding) sensitive coasts and river banks.

6.2.1 Key trends in governance.

Since the first version of the Situation Analysis of the Democratic Governance in Myanmar was completed in 2012, the country's transition has progressed considerably along the Government's framework of the Four Waves of Reforms[19] (UNDP, 2013):

- Political and democratic reforms;
- Socio-economic reforms;
- Governance and administrative reforms;
- Private sector development.

While the transition toward participatory democracy and rule of law is building on the strong reform momentum which became apparent in 2012, it also reflects several new trends discussed in this analysis. These trends present both opportunities and challenges for the continued transition, and are likely to shape the reform context and agenda up to 2015 and beyond. The following analysis presents first the most significant societal and governance trends likely to have a considerable influence on the transition, followed by the institutional and operational trends that will affect how reforms can be managed (UNDP, 2013).

- evolving peace process;
- intensified communal violence;
- federalism on the agenda;
- devolution of power;
- new momentum for constitutional reform;
- expanded democratic space;
- guaranteeing fundamental rights;
- strong parliament;
- changing leadership landscape;
- planning challenges;
- data and Analysis;
- increased exposure and accumulated experience;
- absorption crunch;
- election countdown.

[19] President U Thein Sein, Speech to Union ministers, Region/State chief ministers, and deputy ministers (delivered at Naypyitaw, 9 August 2013): www.president-office.gov.mm/en/?q=briefing-room/speeches-and-remarks/2013/08/11/id-2536.

6.2.2 Implications of the trends for policy and for developments cooperation

The steps taken now should be part of a sustainable plan that sees democratic governance continue to evolve in a way that ensures Myanmar's steady development over following decades. The analysis that follows is intended to encourage dialogue about building democratic governance in Myanmar through a long-term vision shared between government and civil society that also incorporates attainable short-term goals (UNDP, 2013).

The implications of the trends for policy and development cooperation are:

- Conflict and stability
  - Ethnic conflict, power-sharing and the federalism debate
  - Communal violence
- Constitution and constitutional reform
  - Support and long-term planning
- Executive governance and decentralization
  - Devolution of executive power
  - Accountability for administrative decisions
- Planning and information
  - Development planning
  - Data collection and analysis
- Political representation and the legislative process
  - Electoral system and representation
  - Party politics
  - Constituent engagement
  - Law-making
  - Staffs support
- Legal sector and access to justice
  - Union Attorney-General's Office
  - Courts and the judiciary
  - Access to justice
  - Police
  - Legal awareness
  - Legal professionals
  - Legal education
- Human rights
  - Implementation of international human rights law
  - Mechanisms for safeguarding human rights
- Civil society participation in governance
  - Information sharing
  - Media
  - Civil society
- Gender equality

Although the government continues its course of political liberalization, several constitutional changes are still necessary to introduce full democracy. The country's ethnic division and sectarian conflicts (especially in the border regions) also pose serious threats to stability in the country. The administration continues to promote an ambitious economic reform agenda, however, the business environment is expected to improve only gradually. Key industries, which have long been controlled by the military, are highly inefficient and corruption is rife. Due to these circumstances, Myanmar ranks relatively low on its competiveness (CBI & LEI Wageningen UR, 2013).

The influence and role of the academic sector is negligible. Also the role of NGO's is still limited.

Although the private sector (mainly Myanmar people living abroad and interested to start investing in their home country) is looking into opportunities in Myanmar with great interest, it should be noted that only 30 percent of the transactions is successful according to McKinsey (2013). This is mainly due to the lack of knowledge and legislation in Myanmar, e.g. in the specific field of Public Private Partnerships.

7 Results from the stakeholders participation and multi-criteria analyses

Following the preliminary assessment as carried out in 2013 and a large workshop in Nay Pyi Taw (June, 2014), see Figure 7.2, eight more or less independent issues of concern were agreed upon, see Table 7.1.

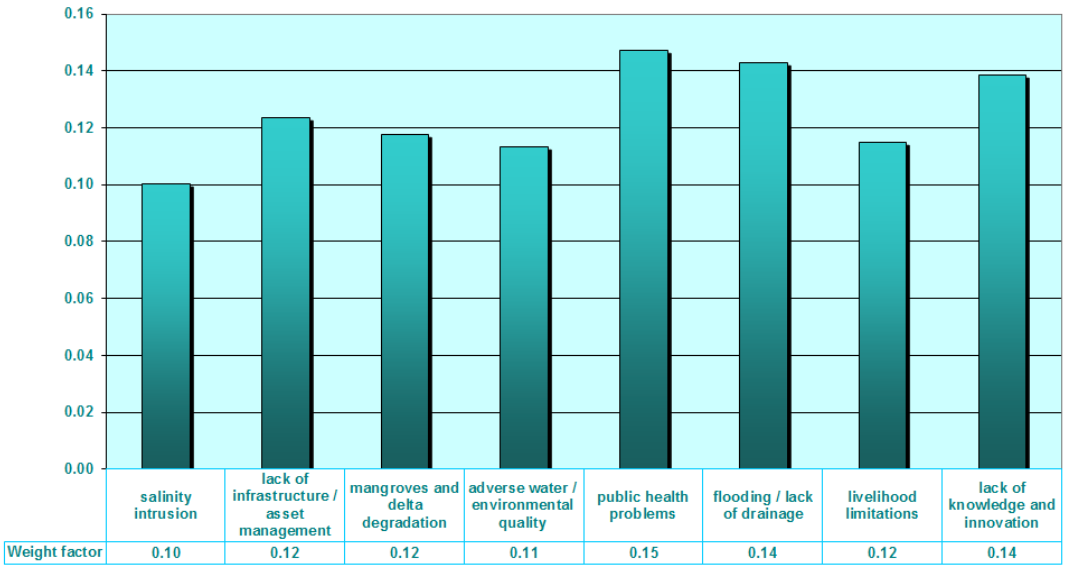
Table 7.1 Issues of concern and explanation on how to interpret them.

Key Issue of Concern	Explanation
Salinity intrusion	Seasonal, cyclone and climate induced salinity intrusion affecting agriculture / irrigation, fisheries/aquaculture, nature and water supply
Lack of infrastructure and asset management	Inadequate and aged infrastructure (irrigation structures, roads, embankments and dikes, water supply and waste water treatment plants, etc.) and lack of proper maintenance.
Mangroves and delta degradation	Mangrove deforestation / degradation, coastal and river bank erosion,, subsidence, etc.
Adverse water / environmental quality	Increased water pollution due to upstream mining, agricultural practices (fertilizers and pesticides) , industry and domestic pollution, solid waste disposal, etc.
Public health problems	Arsenic pollution (groundwater abstractions), waterborne diseases (malaria, dengue), flood related health issues, access to doctors / health centres, affordability of health care, etc.
Flooding / lack of drainage	Coastal, fluvial and pluvial induced flooding and limited drainage capacity in the delta, disaster risk management, climate change / SLR
Livelihood limitations	Low incomes farmers and fishermen, restrictions in irrigation, no/limited access to credit, dependency on input suppliers and traders, overfishing, land grabbing, etc.
Lack of knowledge, adaptive capacity and innovation	Inadequate understanding of the functioning of and threats to the delta, lack of introductions to new techniques and expertise, etc.

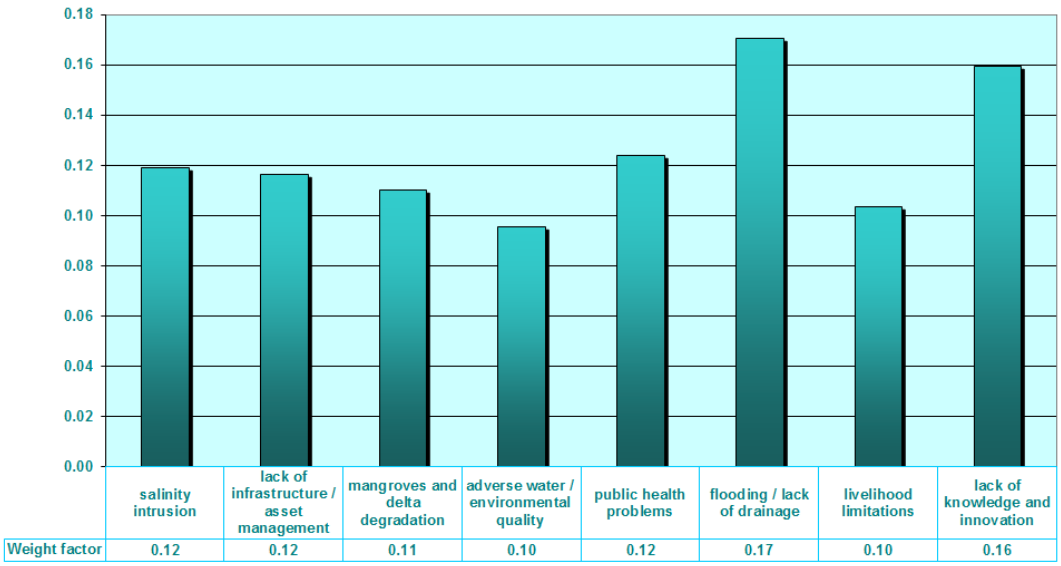
Figure 7.2 Impressions from the workshops in 2013 (Yangon) and 2014 (Nay Pyi Taw).

During the three workshops the issues of concern were explained and during all workshops the relevance of these selected issues were confirmed by all participants.

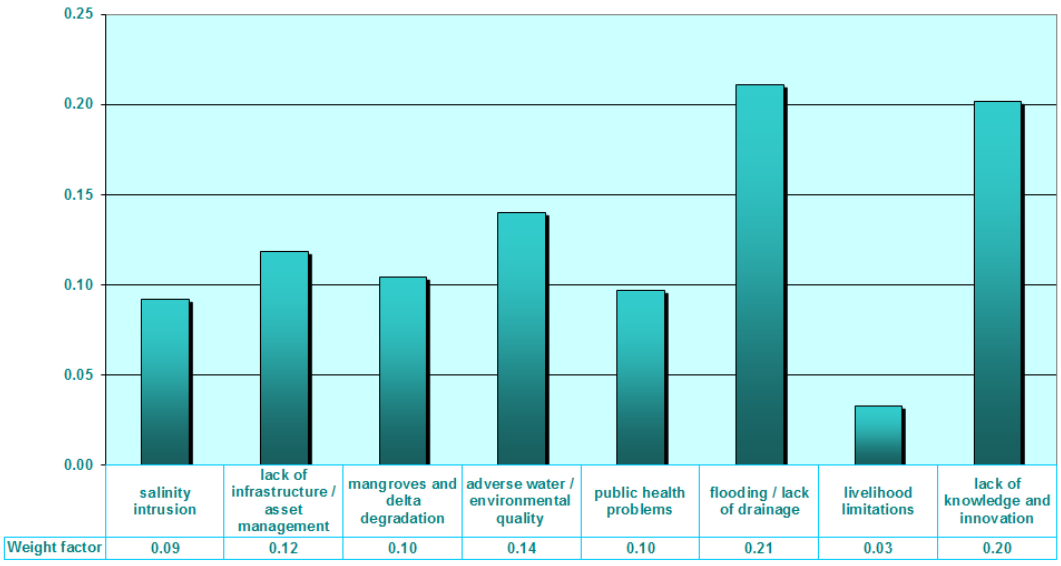
The stakeholders analysis was carried out during three different workshops in Pathein, Hinthada and Yangon in June 2014. Hereafter, some additional consultations were carried out, all together leading to a data set of 101 participants. Unfortunately, it appeared impossible to have the workshops be attended by representatives from the industrial sector (which was absent in Pathein and Hinthada anyway). Likewise, the contribution from the fisheries sector was limited to 3 participants only and the agricultural representatives (22) appeared all from one township (Kyaunggon). Most of the input therefore was provided by the various government representatives (69) and from people residing in Yangon (53). Some 7 NGO's and academe were consulted.



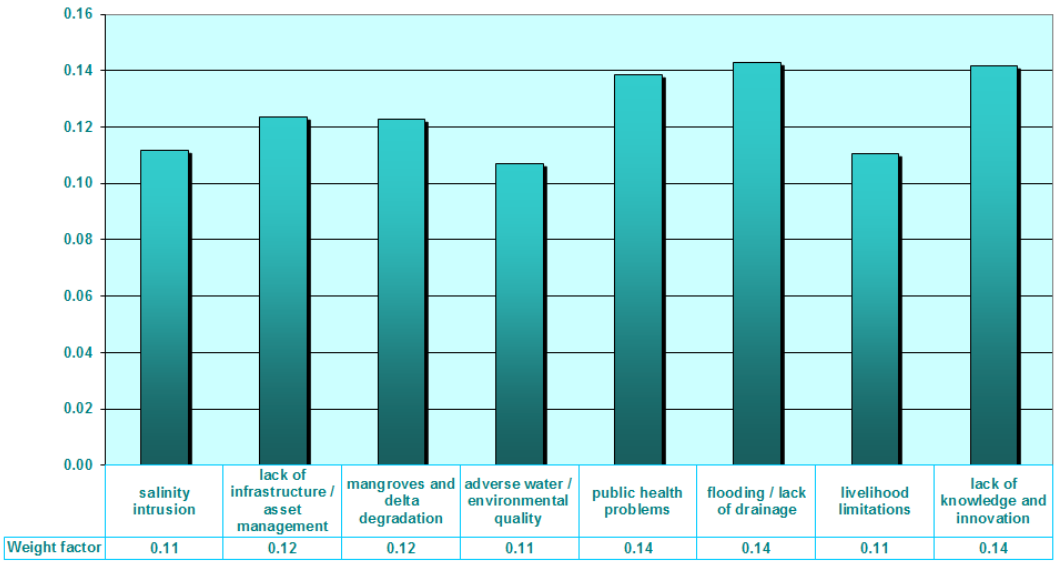
Average of all stakeholders



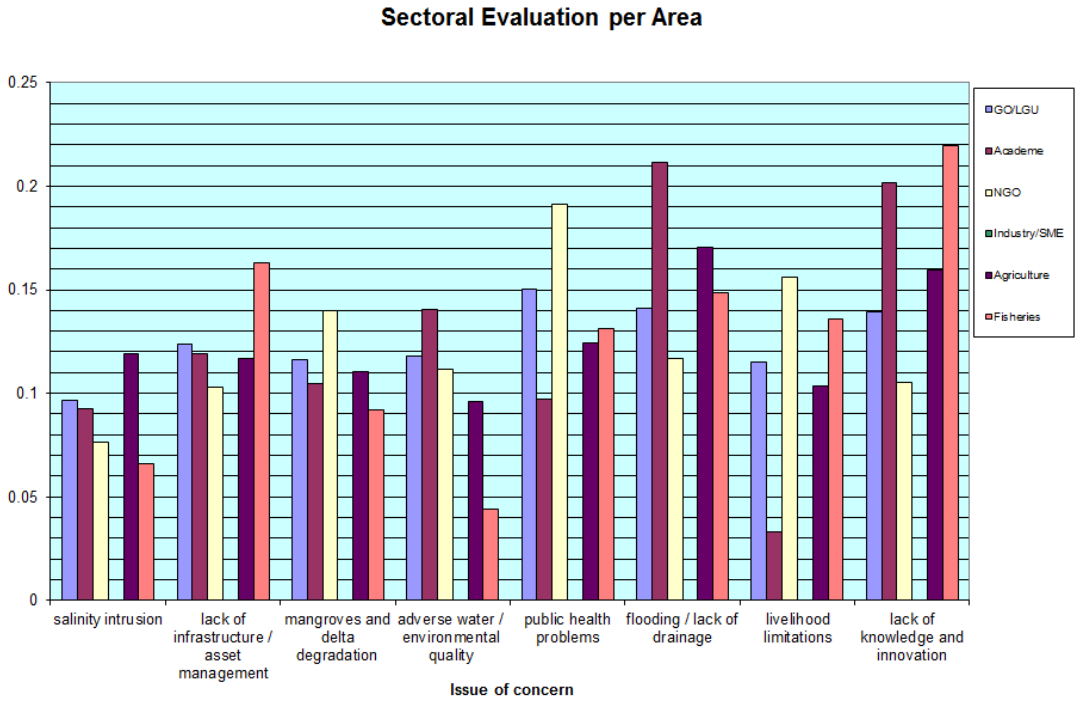
Average of agricultural participants only



Average of academic participants only



Average of participants from Yangon



Sectoral evaluation, representing averages per sector

Figure 7.3 Examples of some results of the stakeholders analysis.

The results of the stakeholders analysis (Figure 7.3) can briefly be described as follows:

- When considering the average of all stakeholders the relative importance, i.e. weight factor for the MCA, is highest for public health problems (1), flooding / lack of drainage (2) and lack of knowledge and innovation (3);
- The relative low score for salinity intrusion, which is an issue in only part of the delta anyway, can be explained by the relative high numbers of participants from the Government and Yangon and the absence in the data set of farmers from the Lower Delta;
- The academe has scored livelihood limitations lowest; reason for this may be related to their secured income situation and lack of responsibility to address the issues in the delta (like the Government representatives);
- Surprisingly, the few fishery representatives scored lack of infrastructure / asset management and lack of knowledge highest;
- Both fishery and agricultural sector feel that new knowledge and innovation can help improve their situation;
- Flooding / lack of drainage scored highest for Yangon, partly explained by the flooding situation in Yangon at the time of the workshop.

To illustrate the working of the MCA a number of possible measures were presented and discussed, see Table 7.4. In assessing the costs of measures it is important to take into account the economies of scale. This has been considered in the assumed costs per measure.

Table 7.4 Set up of the MCA as developed during and after the workshops.

	Possible measure	Possible impact (% problem solving)	Possible proponent	Assumed costs (million USD)	Expected benefits / impacts
1a	Mangrove rehabilitation	10	Ministry of Forestry and Environmental Conservation	10	Coastal protection, nurseries, livelihood
1b	Mangrove rehabilitation	25	Ministry of Forestry and Environmental Conservation	25	Coastal protection, nurseries, livelihood
2a	Dredging of water ways	10	Ministry of Transport - DWIR	100	Navigation improvements, livelihood
2b	Dredging of water ways	25	Ministry of Transport - DWIR	200	Navigation improvements, livelihood
3a	Solid waste awareness campaign	10	Ministry of Public Health	2	Aesthetics, public health, flooding
3b	Solid waste awareness campaign	25	Ministry of Public Health	10	Aesthetics, public health, flooding
4a	Crop change: more salt resistant	10	Ministry of Irrigation	10	Livelihood
4b	Crop change: more salt resistant	25	Ministry of Irrigation	20	Livelihood
5a	Development / enhancing of embankments	10	Ministry of Transport / Ministry of Irrigation	50	Asset management, livelihood and flood management
5b	Development / enhancing of embankments	25	Ministry of Transport/ Ministry of Irrigation	125	Asset management, livelihood and flood management
6a	Improve water supply	10	YCDC, townships	100	Public health
6b	Improve water supply	25	YCDC, townships	250	public health
7a	Improve the drainage system	10	YCDC, townships	100	Flooding
7b	Improve the drainage system	25	YCDC, townships	250	Flooding
8	Development of monitoring and modelling program / transfer of knowledge	10	Various (universities	5	Capacity building

Table 7.5 Results of the MCA as developed during and after the workshops.

	Possible measure	Total effectivity	Total corrected effectivity	Cost effectivity	Financial capability	Institutional capacity	Social acceptability
1a	Mangrove rehabilitation	3	6	5	+	++	++
1b	Mangrove rehabilitation	2	1	4	+	++	++
2a	Dredging of water ways	15	15	15	-	+	+-
2b	Dredging of water ways	14	11	14	-	+	+-
3a	Solid waste awareness campaign	4	8	1	++	++	++
3b	Solid waste awareness campaign	5	2	3	++	++	++
4a	Crop change: more salt resistant	13	14	7	+	++	-
4b	Crop change: more salt resistant	12	10	6	+	++	-
5a	Development / enhancing of embankments	6	9	8	+-	+-	+
5b	Development / enhancing of embankments	7	3	9	+-	+-	+
6a	Improve water supply	10	13	12	__	++	++
6b	Improve water supply	11	7	13		++	++
7a	Improve the drainage system	9	12	11	__	+-	++
7b	Improve the drainage system	8	4	10	__	+-	++
8	Development of monitoring and modelling program / transfer of knowledge	1	5	2	++	++	++

++ very good -- problematic

The ranking of measures was done using expert judgement, assessing the way each measure was addressing the issue of concern, and using three different ranking criteria: total effectivity (technical ranking), total corrected effectivity (technical ranking corrected for the spatial impact coverage of the measure) and cost-effectivity (technical result per capital investment). Hereto, different weight factors have been used: from the pair-wise comparison the weights per sector or per area were included in the analysis.

The total effectivity is calculated as: $\sum^{8} ai * wi$, in which 8 is the total number of issues of concern, *ai* is the assessment of how the measures addresses each issues of concern and *wi* is the weight factor per issue of concern. The sum of all weight factors equals 1.

For *ai* the following ranges apply:

-3 significant negative impact
-2 moderate negative impact
-1 negligible negative impact
0 no impact
1 negligible positive impact
2 moderate positive impact
3 significant positive impact

The total effectivity is calculated as: $\sum^{8} ci * ai * wi$, in which ci is an assessment of the spatial coverage of the measure (i.e. %problem solving). The cost-effectivity is calculated as: $(\sum^{8} ci * ai * wi)$/ CI, in which CI is the assumed total capital investment of the measure considered.

The assessment of the ai numbers was carried out within the workshops. It was observed that this assessment was relatively easy, not leading to significant differences in scores per individual. The results of the workshops were cross-checked with most participants. Once again, no significant changes were made indicating the lack of variation in interpretation of the impacts per measure.

In Table 7.5 the results of the rankings are presented. The following observations were made:

- Regarding the total effectivity ranking the knowledge development and mangrove projects perform good. However, in the ranking of the total corrected effectivity only the larger mangrove project scores good. Apparently these projects are well-designed, but need to be up-scaled.
- In terms of cost-effectivity the solid waste and knowledge development score best. These are relatively low cost projects with sufficiently large coverage.
- The results per sector and per area are quite consistent. This stems with the observation that the sectors show little variation in judging the different issues of concern.
- The financial capability in Myanmar for implementation of large structural measures (water supply, dredging and drainage is considered limited. As most measures considered fall under the responsibility of one ministry or local government the institutional capacity for implementation is considered rather high. Likewise, the social acceptability of these measures is considered high. Only the change of agricultural practices may have significant consequences for the income of the farmers.

The measures can also be evaluated with the following characteristics of no regret (see Figure 7.5):

- Proven technique or approach which has been used successfully in similar conditions;
- No irreversible consequences;
- Sufficient data is available to support implementation;
- The expenditures do not substantially limit the implementation of other measures;
- The action is low risk.

In Figure 7.5 the measures considered are presented.

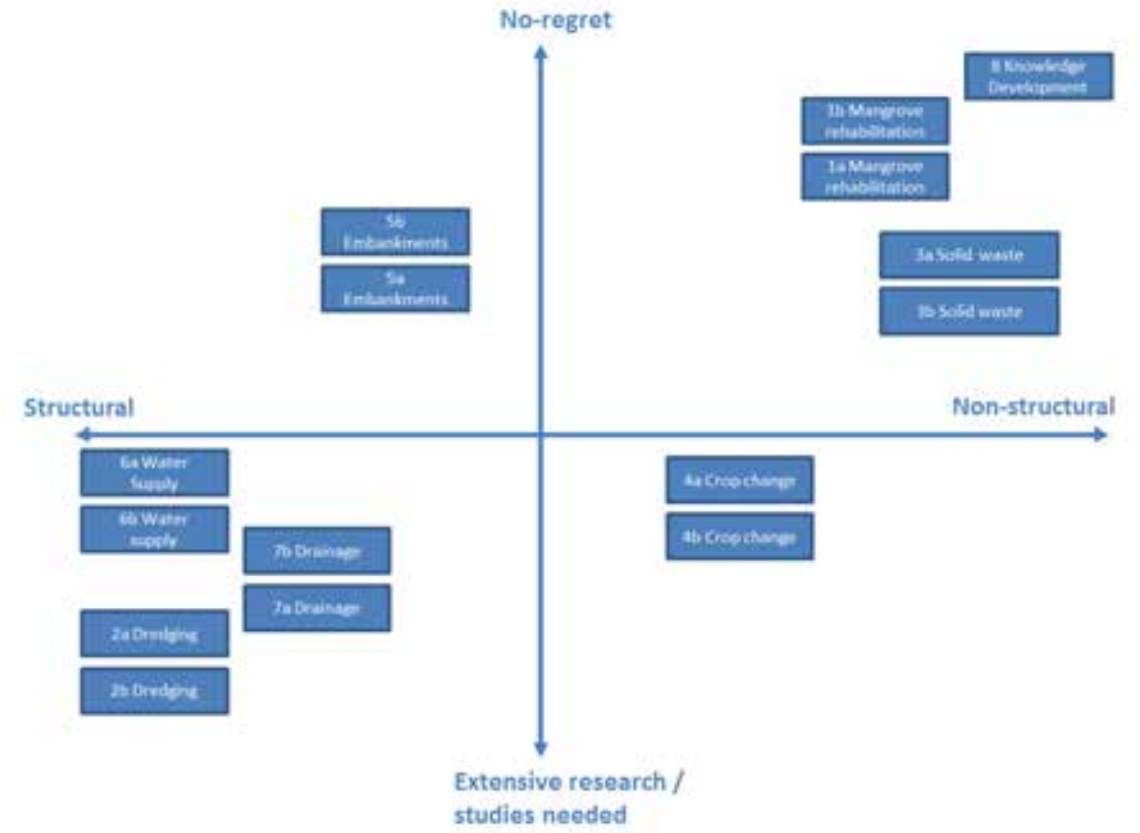


Figure 7.5 Measures considered during the MCA.

Discussion and recommendations

The reasons behind the differences found within one stakeholder group may be related to:

- type of respondents;
- differences in presentation of survey methodology and type of interviewers;
- timing and location of the survey.

Recommendations for future follow up on the stakeholders analysis would be:

- Improve survey (methodology) such that a proper representation of respondents could be attained;
- Use only the translated survey forms (in Burmese);
- Regularly update the stakeholders analysis to capture the latest ideas and to keep the stakeholders involved in the decision-making process.

Finally, the MCA approach also has some limitations, which are mainly related to

- Selection of (independent) criteria / issues of concern;
- Grouping of stakeholders;
- Use of judgement scales;

- Available expert knowledge (in the future the computational tools may come in to make the assessment more objective and consistent);
- Local vs. regional interests;
- Long list of measures to be considered;
- Use of capital investment costs and operational costs (the measure may be implementable and at the same time hard to sustain due to high operation and maintenance costs). In the future the operational costs need to be considered as well. It is recommended to include the results of a Cost-benefit Analysis for determining the cost-effectivity (/ financial capability) of the measures.

However, by being aware of these limitations and by assuring that the prioritization process is open and shared, a very useful and relatively simple tool / methodology has become available. During the workshops this methodology / tools was much appreciated and may be very helpful to guide the process from vision to action in the delta. The stepwise approach also proved to be very useful in streamlining the workshops.

8 Vulnerability assessment and score card assessment

During the several workshops the combined DPSIR and Layer model was discussed. The results of the group discussions and additional analyses on the basis of literature review are depicted in Table 8.1. Besides the (potential) pressures and impacts, some responses in order to cope with these pressures and impacts and the existing gaps in knowledge are identified in this table. In addition, for each of the 4 regions (Lower Delta, Middle Delta, Upper Delta and Urban Delta) an indication of the vulnerability to these pressures has been given.

Table 8.1 Combined DPSIR and Layer Model for the Ayeyarwady Delta.

Drivers	Pressures		Impact	Response	Gaps in Knowledge	Vulnerability per issue and per region			
						Lower	Middle	Upper	Urban
Population growth in delta and upstream **Migration**	Base layer	Exploitation of coastal resources	Wetland degradation Reduced safety and loss of habitats	Mangrove reforestation, regulations and enforcement	Size of loss of wetlands	+++	+	-	-
	Network layer	More demand for transportation (roads, ports and waterways)	Need for corridors / interconnectivity	Spatial planning and modern transport systems, PPP legislation	Present status + future plans (Ministry of Public Works)	+++	++	++	+
		More demand for coastal and river defence system	Inadequate sea dikes / river embankments Altered delta functioning, no room for the river	River training (DWIR + Irrigation Department) L+W Management plan, blocking of waterways (roads).	Current programs, plans, etc.	+++	++	+++	+
		Lack of water supply and sanitation	Affected public health and ecosystem health Domestic water supply needs, water quality	Need for supply and treatment plants / use of PPP's	What is currently in place. Township development (Min. of Border Affairs, DRD)	+++	++	+	+
	Occupation layer	Demand for space Need for more livelihood opportunities	Altered land use	Spatial planning, increased agricultural and aqua-cultural production, multi-sectoral development	Population / density, current unemployment, projections. More insight in fishing rights, not aquaculture alone, but capture fisheries in river, estuary and those on delta dependent on marine fisheries as well.	+++	++	++	++
		Urbanisation	Pressure on space in the delta Increased traffic More congestion	Spatial planning	Existing plans	++	++	++	+++
		Freshwater shortage due to increased water demand	Increased groundwater abstraction Arsenic pollution Use of brackish water	Implementation of treatment facilities, Water allocation	The reduction in water flow, risking the minimum environment flow requirement should also be looked into and mitigation measures recommended. Current situation UNICEF study / Water	+++	++	++	+++

Drivers	Pressures		Impact	Response	Gaps in Knowledge	Vulnerability per issue and per region			
						Lower	Middle	Upper	Urban
					utilization department				
			Subsidence (by increased groundwater extraction)	Regulations and enforcement	What is known about anthropogenic subsidence Ministry of Public Works / city development / DID (Domestic Water supply). construction (permitting) - recommendation	+	+	+	++
		Overfishing	Resource depletion Ecosystem functioning (with impacts on e.g. fisheries), loss of biodiversity, livelihood	Regulations and enforcement	Records, measures -> research	++	++	++	-
Economic development Sectoral developments Upstream developments	Base layer	Sectoral developments / altered rural and urban development	Loss of nature Economic losses	Introduction of livelihood alternatives	Township planning, planning of sectoral developments	+	+	+	+++
		Shift in land use upstream (deforestation, more intense or wrong land use)	Reduced sediment supply to the delta (due to dams) Erosion of the delta	Alternative safety measures (dikes, Building with Nature concepts, etc.)	Long year trends in sediment load, aerial photo's on retreat of delta (30% reduction, aggregation rate from 2 to 1.4 mm/yr ,Sivitski). Information on Ayeyarwady tributary behaviour and characteristics.	++	+	+	-
			Reduced nutrient supply to the delta	Enhanced use of fertilizers (Irrigation Department)	Leading to water quality problems. Any information on trends. Baseline conditions.	++	++	++	-
			Enhanced sediment supply Navigation problems, clogging of irrigation drainage systems	Dredging	Trends, programs	++	++	+++	-
			Water pollution (mining, industry,	Legislation/enforcement Spatial planning	Trends, need for baseline (Env. Cons.	++	++	++	+++

Drivers	Pressures		Impact	Response	Gaps in Knowledge	Vulnerability per issue and per region			
						Lower	Middle	Upper	Urban
			agriculture, domestic wastewater) Public health, aesthetics and ecosystem functioning	Clean technologies / best practices Need of responsible Ministry / Department for WQ monitoring.	and Forestry) EIA legislation) / Fisheries Department. Search for carrying capacity.				
	Network layer	Aging of infrastructure	Inefficient operation and malfunctioning	Asset management program	Current state (before / after Nargis)	+++	++	+	++
	Occupation layer	More mechanization	Less labour needed Unemployment	Alternative employment schemes, Multi-sectoral development plans	Records	++	++	++	-
		Decrease of value chain agricultural production	Bad storage conditions, low product prices, Reduced income farmers	Better transport, better credit system, Better storage facilities Farmers organisations	Present status	++	++	++	-
		Migration to urban centres	More landless and young people to urban centres Lack of labour for agriculture	Mechanization	Opportunities, records	+	+	+	+
			Overpopulation urban centres Lack of employment	Create more economic activities		-	-	+	+++
Natural developments **Climate change and extreme events** Natural subsidence	Base layer	Flooding	Enhanced flood risks (consequences) Increased unsafety and occupancy requirements	Evacuation plans (road network, drills) / more shelters Insurances Flood early warning systems / communication systems. Embankments strengthening	Overview of all hazards and consequences. Socioeconomic and livelihood profiling of the population to understand the actual vulnerability. Migration both into the delta and out of the delta, due to loss of livelihoods, needs to be considered.	+++	+	++	+
		Sea level rise	Increased vulnerability, reduced safety	Enhanced coastal protection (soft and hard measures) Spatial planning Emergency management	. Any studies Relative change 3.4 – 6 mm relative SLR (Syvitsky ref's)	+++	++	+	+
			Increased salinity intrusion	Monitoring and modelling Awareness raising	Monitoring plans in place	+++	++	+	+

Drivers	Pressures		Impact	Response	Gaps in Knowledge	Vulnerability per issue and per region			
						Lower	Middle	Upper	Urban
	Network layer	Infrastructure not climate change proof	Flooding, salinity intrusion	Upgrade of infrastructure	Downscaling of climate models, hydrological scenario studies	++	++	++	++
	Occupation layer	Change of temperature, storms, precipitation	Impact on functioning of delta, agriculture, fisheries, aquaculture, nature	Adaptive measures Mitigation measures	Downscaling of climate models, impact analyses	++	++	++	++

+++ high vulnerability **++ medium vulnerability** **+ low vulnerability** **0 no vulnerability**

The vulnerability scores in Table 8.1 have been used to develop the resilience scorecards for each of the four regions. Each item is scored on a 5-points scale, related to resilience and sustainability. They should be considered as a qualitative and indicative expert judgment.

The following two development scenarios are recognized:

- Scenario1, moderate perspective 2050: medium economic growth and related medium technological developments, combined with medium climate change and sea level rise (to be determined by expert);
- Scenario2, extreme perspective 2050: high economic growth and related high technological developments, combined with high climate change and sea level rise (to be determined by expert).

Table 8.2 Score cards delta resilience.

Current situation 2014	Land and water use occupation layer	Infrastructure network layer	Natural resources base layer	Governance	Overall resilience & sustainability indicator
Lower Delta	-	--	--	-	--
Middle Delta	-	--	--	-	--
Upper Delta	-	-	--	-	-
Urban Delta	-	-	-	-	-
Overall Delta	-	--	--	-	-

Scenario 1 Moderate 2050	Land and water use occupation layer	Infrastructure network layer	Natural resources base layer	Governance	Overall resilience & sustainability indicator
Lower Delta	-	0	--	0	-
Middle Delta	0	+	-	0	0
Upper Delta	+	+	-	0	+
Urban Delta	0	+	-	0	0
Overall Delta	0	+	-	0	0

Scenario 2 Extreme 2050	Land and water use occupation layer	Infrastructure network layer	Natural resources base layer	Governance	Overall resilience & sustainability indicator
Lower Delta	--	--	--	0	--
Middle Delta	-	-	--	0	-
Upper Delta	0	-	-	0	0
Urban Delta	0	-	--	0	-
Overall Delta	-	-	--	0	-

Ayeyarwady Delta	Land and water use occupation layer	Infrastructure network layer	Natural resources base layer	Governance	Overall resilience & sustainability indicator
Current situation 2014	-	--	--	-	-
Scenario 1 moderate 2050	0	+	-	0	0
Scenario 2 extreme 2050	-	-	--	0	-

resilience/sustainability: ++ (very good), + (good), 0 (medium), - (low), -- (very low)

Concluding remarks on scorecards:

The population density is relatively low compared to the one of the Mekong or the Ganges-Brahmaputra-Meghna Deltas, but yet 3 to 4 times as high as the country's average. The pressure on space is not that high. The demand for water and flood vulnerability score high. It is expected that through economic development the livelihood conditions might improve under the moderate scenario. It can be discussed however, whether the economic development will be important enough to cope satisfactory with a more extreme scenario.

The current infrastructure concerning transport is badly developed. Many works have been done with regard to river embankments, construction of polders and irrigation systems, of which the maintenance could be improved. In the moderate scenario it is expected that important investments will be done to upgrade the road and other infrastructure. It is expected that the area of irrigated agriculture will increase.

The delta is and will always be very vulnerable in view of the risk of (increasing) extreme events such as storm surges, cyclones and extreme rainfall, especially under the extreme scenario.. Also salinization will be threat for mainly the Lower and Middle Delta.

The governance of the delta is currently at a rather low level. It is expected that considerable progress can be made in view of the current political change. There are ample opportunities for the application of more integrated and participatory approaches.

9 Overview of adaptive measures in the Ayeyarwady Delta

9.1 Flood management at national level

In the past two decades, the duration of monsoon in Myanmar is getting shorter but much more intense and the country has experienced heavier rainfall. For instance, in 2008, the annual rainfall surpassed yearly averages amount significantly in Kachin, upper Sagaing, Mon, Yangon, Ayeyarwady, Kayah, Kayin, Tanintharyi, Bago and Rakhine. Accordingly, the country is likely to suffer more severe floodings in the future. Unless effective mitigation and preparedness measures are adopted, floods will give serious negative repercussions, including loss of life and damage to property, critical infrastructure, crops and livestock. Thus, the potential harm to the economy and social fabric of the country as a whole could be catastrophic (UN-HABITAT).

The national level Natural Disaster Preparedness Central Committee (NDPCC), chaired by the Prime Minister, formulates policy and provides guidance on disaster preparedness. Similarly, the Chairmen of the State/Division/Township Peace and Development Councils also lead the Disaster Preparedness Committees at various levels and sub committees were formed to work in close cooperation. These committees have following duties:

1) News and Information;
2) Emergency Communication;
3) Search and Rescue;
4) Assessment and Emergency Relief;
5) Confirmation of Loss and Damage;
6) Transportation and Route Clearance;
7) Natural Disaster Reduction and Emergency Shelter Provision;
8) Healthcare;
9) Rehabilitation and Re-construction and
10) Security.

As a policy, governing flood emergency management, Relief and Resettlement Department is preparing Myanmar Action Plan on Disaster Risk Reduction (MAPDRR) is set out.

9.2 Disaster Risk Reduction and flood mitigation in Myanmar

Myanmar is exposed to multiple natural hazards which include Cyclone, Storm surge, Floods, Landslide, Earthquake, Tsunami, Drought, Fire and Forest Fire. Its coastal regions are exposed to cyclones, storm surges and tsunamis while major parts of the country are at risk from earthquakes and fires. The rainfall-induced flooding is a recurring phenomenon across the country, while some parts of the country are exposed to landslide and drought risks. As per the data from 2000-2001 to 2009-20102, fires constituted about 73% of reported disaster events, followed by floods (11%), storms (12%) and others (4%) including earthquakes, tsunami and landslides. The Cyclone Nargis (2008) was the worst natural disaster in the living memory of Myanmar.

Hazards in Myanmar (Lay Shwe Zin Oo, 2014):

- Fire (especially in Dry zone);
- Floods (Along the Ayeyarwady, Chindwin, Sittaung and Thanlwin Rivers);
- Storm;
- Cyclone (Rakhine, Ayeyarwady, Yangon, Mon and Tanintharyi regions);
- Earthquake (All round the country except Tanintharyi);
- Landslide (Kachin, Chin and Shan States and Tanintharyi region);

- Tsunami (Rakhine, Ayeyarwady , Yangon, Mon and Tanintharyi regions);
- Drought (Mandalay, Magway and Sagaing regions);
- Lightning.

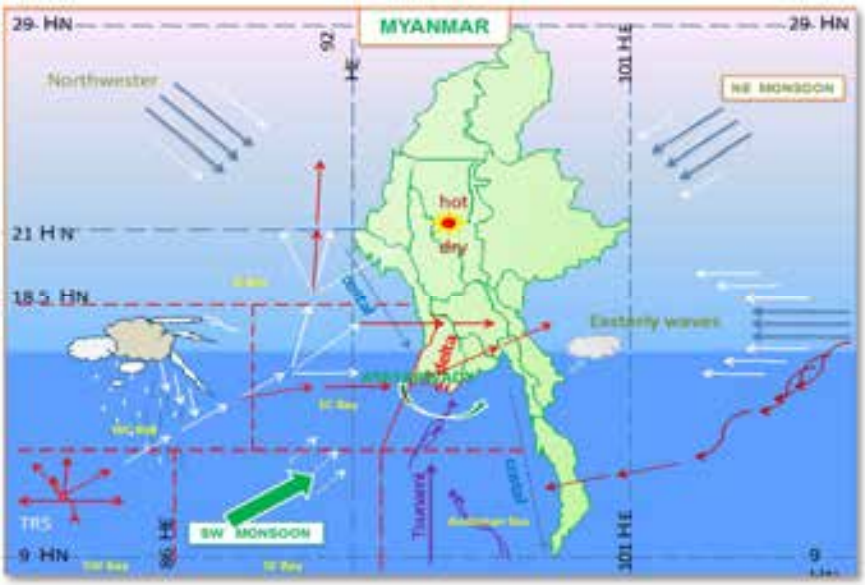


Figure 9.1 Risk map of Myanmar (Ministry of Transport, 2014).

Recent natural disasters in Ayeyarwady region (Ministry of Transport, 2014):

- 2006 Apr Cyclone Mala
- 2008 May Cyclone Nargis
- 2010 Oct Cyclone GIRI
- 2011 Mar Earthquake Tarlay
- 2011 Heavy Rain & Floods
- 2011 Oct Flash Flood Pakokku

The elements of vulnerability of the Ayeyarwady Delta: (Kyaw Zayer Tint, 2014):

- Low lying area;
- Most populated area;
- Many tributaries with high tidal range;
- Few shelters;
- No hazard maps and risk assessments;
- Hard to learn from past events;
- Hard to convince local people;
- Low knowledge on risk;
- Poor mobility;
- Poor education.

In order to reduce the impact of flood hazards the following policies and regulations are proposed (Zaw Lwin Tun & Hla Oo Nwe, 2010):

- long-term sustainable measures;
- structural and non-structural measures;
- measures that need government intervention and support with community participation;

- some of the processes, especially legislation and policy frameworks, cannot be initiated by the community alone and require the government's initiative and intervention;
- develop the flood hazard map for downstream area of the Ayeyarwady River and flood inundation map for middle reach of the Ayeyarwady River should be carried out.

The preparedness and mitigation should be an integral part of the development plans and programmes. It is also important to make prior arrangement for relief, rehabilitation and reconstruction activities, in case a natural disaster strikes. The Republic of the Union of Myanmar is committed to disaster risk reduction and it has systems and procedures at National, State/Region, District, Township, Wards and Village Tracts levels for Disaster Management.

Furthermore, the Myanmar Disaster Preparedness Agency was constituted on 20 April, 2011 to take the systematic preparedness measures for the disasters, which can occur, from time to time in the country and to undertake the quick and effective activities on relief and support during the disaster. And to coordinate effectively among the countries in south east Asia and the Pacific region on search and rescue, and to lay down and implement the national search and rescue measures, the Myanmar National Search and Rescue Committee was also constituted on 20 April, 2011 (Ministry of Social Welfare, Relief and Resettlement, 2012).

In order to make Myanmar disaster resilient the Myanmar Action Plan on Disaster Risk Reduction MAPDRR has been prepared with a consultative and partnership approach. The goal of MAPDRR is 'to make Myanmar Safer and more Resilient against Natural Hazards, thus Protecting Lives, Livelihood and Developmental Gains'. In order to achieve the Goal, the objectives of MAPDRR are as follows:

- To build a more resilient and safer community through conceptualization, development and implementation of appropriate disaster risk reduction programs and culture of safety;
- To provide a framework for implementing Myanmar's DRR commitments at the global and regional levels, under HFA and AADMER[20];
- To provide a mechanism where the disaster risk reduction initiatives of all Government Ministries and Departments, supported by UN organizations and other stakeholders, can be coordinated and monitored;
- To provide a conducive environment for mainstreaming DRR into development plans, and programs at the National, State, Division, Township, and Village Tract levels, and
- To support mutually beneficial partnerships between the Myanmar Government and their development cooperation partners in DRR programs.

9.3 Disaster Risk Reduction in the ASEAN region

The ASEAN Agreement on Disaster Management and Emergency Response (AADMER) was signed by member countries in 2005 and provides mechanisms to achieve a substantial reduction of disaster losses in the lives and social, economic and environmental assets of member countries. AADMER also provides for cooperation and collaboration among ASEAN Member States in areas of common concern along the priorities of action. The ASEAN Regional Programme on Disaster Management (ARPDM) being implemented by the ASEAN Committee on Disaster Management (ACDM) also provides a frame work for promoting regional cooperation and outlines ASEAN's regional strategy, priority areas and activities for DRR for the 2004-2010 periods (Zaw Lwin Tun & Hla Oo Nwe, 2010).

[20] *Agreement on Disaster Management and Emergency Response.*

9.4 Forest conservation and restoration

The development strategies of the Myanmar government are sustainable development, sustainable utilisation of recourses and forest conservation. The Forest Department has developed a 30-year Master Plan (2001/02 to 2030/31), aimed at undertaking forest conservation and restoration. By the end of the 30-year plan, the following work will have been completed:

- The formulation of land-use plans for all states and divisions of the country with three revisions;
- The establishment of 199,355 ha of watershed plantations in the whole country;
- The establishment of 295,431 ha of community forest in the whole country.

9.5 Early Forecasting, Warning Systems and Mitigation Measures

For flood warning, the Department of Meteorology and Hydrology (Ministry of Transport) issues the weather condition, flood forecasts and warnings. A multiple regression model is used for flood forecasting, sometimes in combination with more conceptual models such as the Sacramento model, the Tank model, the SSARR model, the HBV model and APIC-hydrologic model. If during the monsoon season the water level of any station along the rivers is going to reach or exceed its local danger levels, the flood warning is timely issued and sent to the higher authorities, concerned ministries, Myanmar radio and television stations, newspapers and local authorities where flood are going to strike. In case of severe floods the department has to request a radio station to broadcast it frequently (every 3 hours). In this way the preparation for flood protection can be done in advance (Zaw Lwin Tun & Hla Oo Nwe, 2010).

There are eight river basins in Myanmar equipped with early forecasting and warning systems:

1) Ayeyarwaddy river basin (12 stations);
2) Chindwin river basin (5 stations);
3) Dokehtawaddy river basin (2 stations);
4) Sittoung river basin (2 stations);
5) Shwegyin river basin (1 station);
6) Bago river basin (1 station);
7) Thanlwin river basin (1 station);
8) Ngawun river basin (1 station).

Figure 9.2 Flood forecasting stations.

Flood mitigation

The key agency for flood risk mitigation is the Irrigation Department under the Ministry of Agriculture and Irrigation. Conservation and reforestation activities in important watersheds are undertaken jointly by the Irrigation Department and the Forest Department. Many dams along tributaries of major rivers, implemented by the Irrigation Department, are multi-purpose: water storage for agriculture, reduction of river floods and droughts and/or hydropower. In Myanmar, flood protection and drainage problems in the delta area are increasing due to sedimentation in the river beds (Zaw Lwin Tun & Hla Oo Nwe, 2010).

The Ayeyarwady Delta supplies 65 percent of the total rice production of the country. Most of the rice production areas are protected by embankments and sluices from floods and saline water intrusion. Under the responsibility of the Irrigation Department, 163,899 ha area were protected by 41 polders and 1024 km of embankments, which often serve at the same time as rural roads. The embankments are the vital means for daily life of 3.2 million people who live in that rural area. During floods, the embankments function also as a shelter and evacuation place for saving people's life from high flood and surge.

Figure 9.3 illustrates the type of floods that occur in the Lower, Middle and Upper Delta and the control measures that are taken.

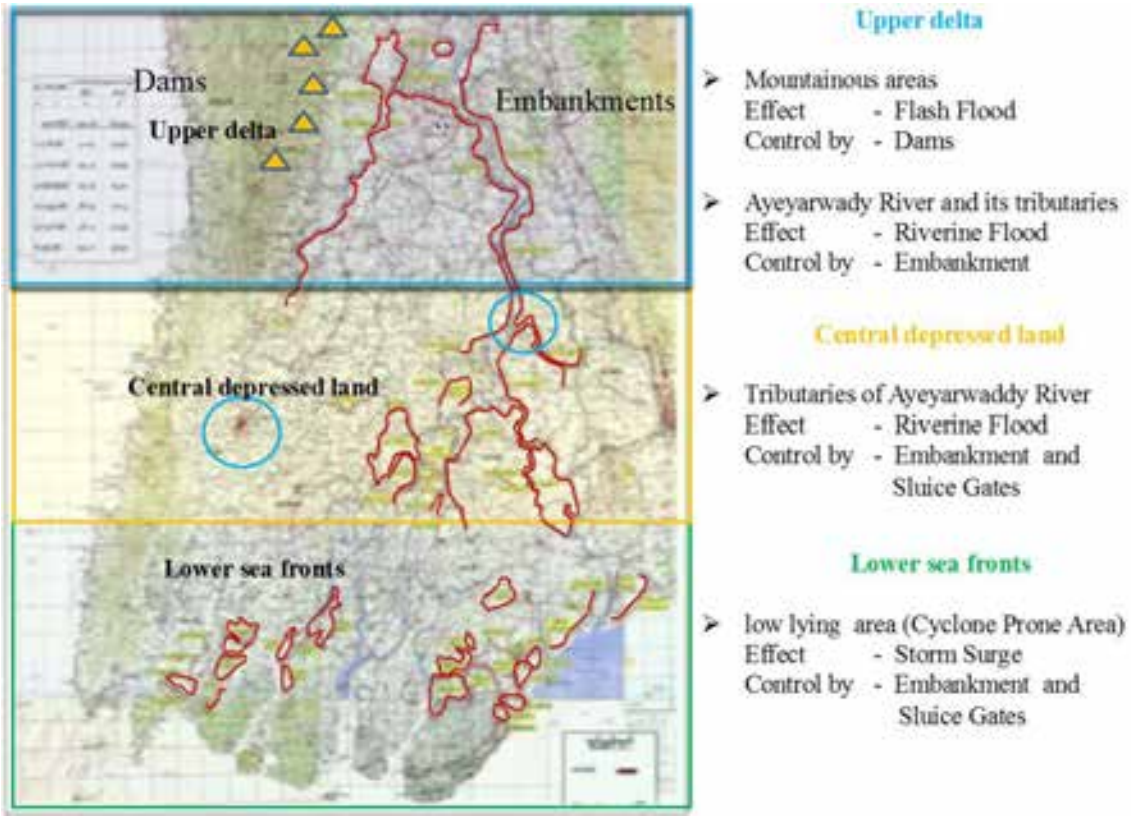


Figure 9.3 Control of flooding in different areas in Ayeyarwady Delta (U Htwe Myint, 2014).

Figure 9.4 Multi-purpose Nan Kathu Dam in Ingapu Township of Hinthada District (Arantza Pi Gonzalez, 2014).

Better disaster response preparedness such as stock piling of relief goods and contingency planning are needed. Community participation is essential to upgrade coordination and cooperation among related agencies. Under the guideline of Ministry of Social Welfare, Relief and Resettlement, the Department of Relief and Resettlement, being Focal Point of disaster risk management, is conducting a capacity building program for disaster management implementers and community awareness programmes. Environmental disaster health management plays also an important role to mitigate the impact (Zaw Lwin Tun & Hla Oo Nwe, 2010).

9.6 Adaptive measures mentioned in the NAPA

In the Nation Adaptation Programme of Action - NAPA (Ministry of Transport, 2012) most relevant adaptive measures are briefly described:

Improve agricultural productivity and food security

- The Government implemented 129 irrigation projects between 1988 and 2002 in the whole country. This includes the Thaphanseik dam, which is the largest dam in Southeast Asia.
- The International Development Enterprise (IDE) project: i) developed small-plot water technologies e.g. micro-irrigation facilities (treadle pumps and engines); and ii) created linkages between local farmers and fruit and vegetable markets. This has enabled certain farmers in Myanmar to move from subsistence rain-fed farming to small-scale commercial (and thus income-generating) farming.
- In the Ayeyarwady Delta, a range of rice varieties have been introduced for cultivation including traditional quality, salt-tolerant, deep-water, waterlogged and submerged rice varieties e.g. Pawsan Hmway, Pawsan Baygyar and Phyarpon Pawsan rice varieties are highly valued and cover ~20% of the Delta region.

Early Warning Systems

The following measures have been implemented in Myanmar to ensure effective early warning for severe weather events:

- The Department of Meteorology and Hydrology (DMH) collects analyses and archives meteorological, hydrological and seismological related data to inform early warnings for extreme weather events. This is achieved using 161 manual meteorological observation

stations across the country in combination with satellite-based estimation techniques and forecast information received from Global Producing Centres. Early warnings and weather related bulletins are disseminated using television and radio.
- The Relief and Resettlement Department (RRD) conduct disaster response and recovery activities including training and awareness raising campaigns at grass-root, regional and national levels.
- The RRD and DMH collaborate to disseminate early warnings to local authorities that transfer warnings to district and grass-root levels.

Regional Integrated Multi-hazard Early Warning Systems (RIMES) are conducting community-based pilot programmes for training local communities to prepare for and respond to early warnings received from DMH and RRD. The United Nations Development Programme developed multi-hazard risk assessments for Ayeyarwady, Bago, Yangon and Rakhine Regions/States in 2011**.**

Sustainable and community-based forestry

- A Thirty year Forest Action Plan has been developed on disaster risk reduction, sustainable forest management including natural, plantation and community forests.
- A people centred Community Forestry approach (Community Forestry Instruction 1995) is being used in several regions including the Ayeyarwady Delta, Yangon Deltaic region and Central Dry Zone. This approach aims to promote sustainable management of natural forests through decentralisation to established Forest User Groups (~30-year lease).
- Reforestation efforts are being undertaken in the Ayeyarwady Delta and Yangon Deltaic region. This includes the establishment of ~65,108 ha of plantation forests comprising mangrove and other forestry species.
- The Integrated Mangrove Rehabilitation and Management Project (Japan International Cooperation Agency [JICA] 2007-2013) is being implemented to ensure sustainable management of mangrove ecosystems and poverty alleviation in the Ayeyarwady Delta.
- Awareness rising is being conducted using pamphlets and posters distributed throughout the Ayeyarwady Delta and Yangon Deltaic regions.

Reduce health risk

The following measures have been implemented in Myanmar to reduce health risks to local communities associated with climate variability:

- The Department of Health raises awareness using newspapers, TV Spot and posters on the necessary precautions (appropriate behaviour changes) vulnerable communities should take to prevent climate-related health risks such as heat-related disorders and the spread of water-borne diseases.
- Twenty national hospitals and 32 state and regional hospitals exist in Myanmar. These hospitals have been supported by the World Health Organisation (WHO) since 2006.

The Department of Health (DoH) provides local communities with pan and pipe sanitation systems for reducing outbreaks of water-borne diseases.
'National Sanitation Week' is held annually to highlight the importance of personal hygiene and sanitation for decreasing health risks.

Water Resources

Considerable investments have been made to ensure water security across Myanmar. The Government initiated a number of irrigation schemes from 1988 to 2010 to maintain agriculture productivity during dry periods. Additional measures to assist water security in Myanmar include:

The Yangon City Development Committee (YCDC) has been implementing tube-wells to supplement piped water supply from reservoirs. The Water Resources Utilization Department (WRUD) is using artesian tube-wells in the Sagaing Region and shallow/deep tube-wells in the Mandalay Region to utilise ground water for irrigation. The Electric-powered Water Pumping Project and the Meiktila-Thazi Groundwater Irrigation Project were recently implemented in the Meiktila plain. A range of local and international NGOs provides treadle pumps for assisting communities to obtain drinking water in rural areas. The Irrigation Department in collaboration with the Italian Government and Food and Agriculture Organisation (FAO) installed a number of small-scale water impoundments during 2010 and 2011 in the whole country.

Sustainable and community-based coastal management

The Government of Myanmar is currently involved in the Bay of Bengal Large Marine Ecosystem (BOBLME) Programme, which promotes sustainable marine ecosystem management and sustainable coastal livelihood development. The programme aims to improve the lives of coastal populations through effective regional management of marine biodiversity and fisheries.

Four Marine Protected Areas (MPAs) have been established along Myanmar's coast, including i) Moscos Island; ii) Thamihla Kyuun; iii) Mainmahla Kyuun; and iv) Lampi.

The Department of Fisheries in collaboration with Biodiversity And Nature Conservation Association (BANCA) and Fauna and Flora International (FFI) are planning to establish an MPA Network System that will incorporate existing MPAs, for example, the Shark Reserves in the Myeik archipelago (Lampi MPA).

A number of different agencies and organisations, including JICA (Japan International Cooperation Agency), FREDA (Forest Resource Environment Development and Conservation Association), and UNDP/MERN (Mangrove Environmental Rehabilitation Network) are undertaking mangrove and coastal forest restoration efforts following damage from recent cyclones in Myanmar's coastal areas. The Department of Marine Science within the University of Mawlamyine has established an aquaculture research centre.

Energy and Industry

Many industries and economic sectors in Myanmar have limited capacity or financing to use modern technologies for harnessing efficient and renewable energy sources. The Water Resources Sector, for example, has limited access to energy efficient water purification technologies. Therefore, many communities suffer from scarcity of safe water supplies. Despite this, efforts are currently being made to support/promote the utilisation of efficient and renewable energy sources in the country.

Projects have been implemented for harnessing Myanmar's solar energy, including: i) Photovoltaic Power Systems are being installed in remote villages under the Technical Cooperation among the Developing Countries Programme; ii) a number of pilot projects are being undertaken by Solar Photovoltaic Battery Charging Community Enterprise; and iii) the Myanmar Scientific and Technological Research Department (MSTRD) in collaboration with the Department of Physics (Yangon University) are implementing the Solar Power Village Electrification Scheme.

Research on solar energy is being conducted, including the development of prototypes of solar equipment and the potential use of solar energy in: i) cooking and other household purposes; ii) water pumps; iii) solar drying for grain and fish products; and iv) salt extraction from seawater. Research/implementation of pilot projects using 'biogas' is being conducted to capture cheap and efficient energy from methane gas produced from animal waste, particularly cow dung. Approximately 400 biogas stations have been constructed in the rural areas throughout Myanmar to provide cooking gas and light energy.

Myanmar's fourth short-term five-year plan (2006/2007 to 2010/2011) of the National 30-year Energy Development Plan indicated that the country will invest in measures to improve energy supply, particularly within rural areas.

Biodiversity

Myanmar has made concerted efforts to protect biodiversity within the country including:

- An extensive Protected Area (PA) system comprising 43 PAs (35 designated and 8 proposed) covering 49,500 km^2 (7.3% of total land area). This surpasses the 5% target set by the Myanmar's Forest Policy but is still under the 10% set by the National Forest Master Plan (2001).
- Protection and restoration of the spawning and feeding habitats for fish and other marine species as well as conservation of sea turtles through extension services and education activities.
- Sustainable utilisation of aquatic resources through closed seasons, licensing, surveillance and enforcement of existing Fishery Law e.g. closed fishing season during June-August (spawning and feeding season of juvenile fish and shrimp species).
- Restrictions on removal and trade of restricted species e.g. Asian elephant (*Elephas maximus*), Bengal tiger (*Panthera tigris tigris*), Saing/Banteng/wild cow (*Bos javanicus*), Ayeyarwady- Iinpaing/Irrawaddy Dolphin (*Orcaella brevirostris*), Golden deer/Brow antlered deer(*Rucervus eldi eldi*) and Spotted deer (*Axis axis*) through the Protection of Wildlife and Conservation of Natural Areas Law, International Union for Conservation of Nature and Natural Resources (IUCN) red data list as well as Convention on International Trade in Endangered Species (CITIES).
- Community based approaches for site based conservation by Biodiversity And Nature Conservation Association BANCA including identifying Important Bird Areas in Myanmar and promoting biodiversity through research, partnerships, environmental education and improvement of rural livelihoods. BANCA has identified more than 1000 bird species in Myanmar, including a rediscovery of the critically endangered Gurney's pitta (*Pitta gurneyi)* in 2003 within the Ngawun Reserved Forests.
- Wildlife conservation training courses and small research grant programs are being undertaken by Wildlife Conservation Society (WCS) for Hkakaborazi National Park, Hukaung Tiger Reserve, and Hponkanrazi Wildlife Sanctuary. WCS is currently exploring additional areas for potential PAs and environmental education programmes.

The table below gives a summarized overview of (possible) adaptive measures in the three spatial layers based on potential adaptation projects as identified by the NAPA (Ministry of Transport, 2012). The measures are classified in types of measures (technical, ecological, economic and institutional/organizational), related strategy (protect, adapt, relocate) and involved layer (occupation layer, network layer, base layer).

Table 9.1 Overview of adaptive measures mentioned in the NAPA.

Name of measure	**Type of measure** 1. Technical 2. Ecological 3. Economic 4. Institutional	**Brief description**	**Strategy** 1. Protect 2. Adapt 3. Relocate	**Layer** 1. Occupation. 2. Network 3. Base
Improve agricultural productivity and food security agriculture	1,2,3	• Developed small-plot water technologies. • Linkages between farmers and fruit and vegetable markets. • Rice varieties have been introduced.	2	1
Early Warning Systems	1,4	• 161 manual meteorological observation stations across the country. • Training and awareness raising campaigns at grass-root, regional and national levels. • Early warnings to local authorities that transfer warnings to district and grass-root levels. Community-based pilot programmes for training local communities in respond to early warnings. Multi-hazard risk assessments**.**	1	1
Sustainable and community-based forestry	1,2,4	• Sustainable forest management Plan including natural, plantation and community forests. • A people centred Community Forestry approach promotes sustainable management of natural forests. • Reforestation ~65,108 ha of plantation forests comprising mangrove and other forestry species. • Management Project implemented to ensure sustainable management of mangrove ecosystems. • Awareness conducted using pamphlets and posters.	1,2	1,3
Reduce health risk	1,4	• Using newspapers, TV and posters to prevent climate-related health risks. • Twenty national hospitals and 32 state and regional hospitals exist in Myanmar supported by the World Health Organisation since 2006. Pan and pipe sanitation systems for reducing outbreaks of water-borne diseases. 'National Sanitation Week' annually, to highlight the importance of personal hygiene and sanitation for decreasing health risks.	1	1,2
Water	1	Implementation tube-wells to supplement	1,2	1,3

resources		piped water supply from reservoirs. Using artesian tube-well to utilise ground water for irrigation. The Electric-powered Water Pumping Project and the Meiktila-Thazi Groundwater Irrigation Project were recently implemented. Local and international NGOs provide pumps for assisting communities to obtain drinking water in rural areas. Small-scale water impoundments during 2010 and 2011 in the whole country.		
Sustainable and community-based coastal management	1,2,3,4	Programme promotes sustainable marine ecosystem management and sustainable coastal livelihood development to improve the lives of coastal populations with effective regional management of marine biodiversity and fisheries. Four Marine Protected Areas (MPAs) have been established along Myanmar's coast. Plan to establish a Marine Planning Areas Network System. A number of different agencies are undertaking mangrove and coastal forest restoration efforts following damage from recent cyclones in Myanmar's coastal areas. Established an aquaculture research centre.	1,2	1,3
Energy and Industry	1,2,3,4	Projects have been implemented for harnessing Myanmar's solar energy. Has been implemented Solar Power Village Electrification Scheme. Research on solar energy is being conducted, including the development of prototypes of solar equipment and the potential use of solar energy. Research/implementation of pilot projects using 'biogas' is being conducted to capture cheap and efficient energy from methane gas produced from animal waste, particularly cow dung. National 30-year Energy Development Plan invests in measures to improve energy supply particularly in rural areas.	1,2	1,2
Biodiversity	2,3,4	• An extensive Protected Area system comprising this surpasses the 5% target set by the Myanmar's Forest Policy but is under the 10% set by the National Forest Master Plan. • Protection and restoration of the spawning and feeding habitats for fish and other marine species. • Sustainable utilisation of aquatic resources through closed seasons,	1,2	1,3

		licensing, surveillance and enforcement of existing Fishery Law. • Restrictions on removal and trade of restricted species. • Community based approaches for site based conservation by Biodiversity And Nature Conservation Association BANCA including identifying Important Bird Areas in Myanmar. • Wildlife conservation training courses and small research grant programs are being undertaken by Wildlife Conservation Society.		

10 Overview of technical methods and tools to support delta management and development in the Ayeyarwady Delta

Overview of methods and tools for assessments, planning and decision making on delta management and development issues.

Table 10.1 Overview of modelling tools for the Ayeyarwady River & Delta.

Name of tool	Brief description	Organisation/ institute	Available at
Delft3D	Delft3D is a flexible integrated modelling suite, which simulates two-dimensional (in either the horizontal or a vertical plane) and three-dimensional flow, sediment transport and morphology, waves, water quality and ecology and is capable of handling the interactions between these processes. For the Ayeyarwady Delta and adjacent coastal waters a 2D hydrodynamic model has been developed for water circulation and salinity intrusion.	Directorate of Water Resources & Improvement of River Systems (Ministry of Transport, Myanmar) and Deltares	Deltares (open source) http://www.deltaressystems.com/hydro/product/621497/delft3d-suite
SOBEK	SOBEK is a powerful modelling suite for flood forecasting, optimisation of drainage systems, control of irrigation systems, sewer overflow design, river morphology, salt intrusion and surface water quality. The current application is a hydraulic and morphodynamic 1D Ayeyarwady River model.	D Directorate of Water Resources & Improvement of River Systems (Ministry of Transport, Myanmar) and Deltares	Deltares (open source) www.deltaressystems.com/hydro/product/108282/sobek-suite
WFlow	Wflow is a distributed hydrological modelling platform generating rainfall-runoff for all major river basins and serves as input for RIBASIM and SOBEK	Deltares	Deltares (OpenStreams providing the building blocks that make up integrated hydrological models) publicwiki.deltares.nl/display/OpenS/wflow+-+PCRaster-Python+based+distributed+hydrological+models
RIBASIM	RIBASIM is a generic model package for simulating the behaviour of river basins under various hydrological conditions. The model package is a comprehensive and flexible tool which links the hydrological water inputs at various locations with the specific water-users in the basin.	Irrigation Department (Ministry of Agriculture and Irrigation, Myanmar) and Deltares	Deltares www.deltares.nl/nl/software/101928/ribasim

11 Knowledge gaps

Drivers of change

Apart from statistical data on for instance agricultural production there is not much recent information available on the Ayeyarwady delta, mainly due to the fact that in the last 20 years not much research has been done and most of the monitoring programs have been halted. Therefore research gaps exist for all drivers of change. Moreover:

- The recently performed census 2014 will give new data on the population in the Delta: population number, density, composition, growth rates, etc.;
- Not much information has been found on the expected economic developments and their impacts on land pressure, urban infrastructure and availability of fresh water;
- Climate change brings a new kind of uncertainty: dry areas get much drier, wetter areas get much wetter, and there is greater unpredictability of rainfall. More knowledge has to be developed on how e.g. hydrological systems will change. New infrastructure needs to be planned accordingly.
- Investments in research and development are needed in the agricultural sector, being the most important contributors to the GDP (World Bank, 2005);
- During three Delta Alliance workshops held in respectively Pathein, Hinthada and Yangon in June 2014 the key issue 'knowledge development and innovation' scored among the participants second highest (after flooding) out of 8 key issues for the delta (see Chapter 7).

Pressures – potential problems / Challenges – opportunities

Occupation layer

- Data on population: density, growth rate, current unemployment, projections and current situation;
- Migration both into the delta and out of the delta, due to loss of livelihoods, needs to be considered;
- More insight needed in fishing rights, not aquaculture alone, but captures fisheries in river, estuary and those on delta dependent on marine fisheries as well;
- Inventory of existing (development) plans needed;
- There is need of socio-economic and livelihood profiling of the population to understand the actual vulnerability.

Network layer

- Present status and future plans of the transportation sector (Ministry of Public Works);
- Current programs and plans, for drinking water supply and sanitation facilities, etc.;
- Plans for township development (Min. of Border Affairs, DRD);
- Cost-efficient and innovative infrastructure;
- Innovation in agricultural engineering (irrigation, etc).

Base layer

- Need for overview of all hazards and consequences;
- Hydrological and monitoring data;
- Water balances and allocation studies are necessary to address future water resources problems;
- Information on Ayeyarwady tributary behaviour and characteristics;
- Trends, programs, leading to water quality problems. Baseline conditions;.
- Knowledge on arsenic contamination of groundwater;
- Monitoring system needed for anthropogenic subsidence and groundwater exploitation;
- Size of loss of wetlands;
- Potential impacts of climate change and sea level rise on mangroves and biodiversity conservation.

12 Comparative assessment of 14 deltas including Ayeyarwady

12.1 The 14 deltas assessed

This chapter summarizes the comparative assessment of 14 other deltas worldwide, including the Ayeyarwady Delta, for which a similar approach was applied as described in this document. Annex A (Bucx et al, 2014) presents the complete synthesis report of this comparative assessment of these 14 deltas. The first 10 deltas have been assessed in 2010 (Bucx et al, 2010). The assessment of 3 other deltas have taken place in 2014 simultaneously with the assessment of the Ayeyarwady Delta. The 14 deltas that have been assessed are mentioned in Table 12.1.

Table 12.1 Overview of the deltas assessed in 2010 (in black) and in 2014 (in green).

Continent	Country	Delta	No
Africa	Egypt	Nile	1
	Kenya	Tana	11
	Mozambique	Incomati	2
	Mozambique	Zambezi	12
Asia	Bangladesh	Ganges-Brahmaputra-Meghna	3
	China	Yangtze	4
	Indonesia	Cilliwung	5
	Myanmar	Ayeyarwady	13
	Vietnam	Mekoog	6
Europe	The Netherlands	Rhine-Meuse	7
	Roomania	Dannbe	8
N-America	United States of America	California Bay-Delta	9
	United States of America	Mississippi River Delta	10
Z-America	Argentina	Parana	14

The sections below are abstracts from the synthesis report (Annex A).The assessments and qualifications should be regarded as an expert judgment at a fairly aggregated level. It enables to draw some general conclusions that are formulated below.

12.2 Drivers of change

Based on the delta descriptions an inventory of the drivers of change impacting delta areas has been prepared. Table 12.2 shows an overview of this inventory.

Table 12.2 Overview of drivers of change in the studied deltas.

Continent	Country	Delta	Demographic trends	Economic developments	Technological developments	Climate change	Subsidence
Africa	Egypt	Nile	***	**	**	***	**
	Kenya	Tana	***	**	*	**	unknown
	Mozambique	Incomati	*	****	**	***	*
	Mozambique	Zambezi	*	***	**	***	unknown
Asia	Bangladesh	Ganges-Brahmaputra-Meghna delta	**	***	**	****	**
	China	Yangtze	***	****	**	**	**
	Indonesia	Citarum	****	***	**	***	****
	Myanmar	Ayeyarwady	**	***	**	****	***
	Vietnam	Mekong	**	****	**	***	**
Europe	Netherlands	Rhine-Meuse	*	**	***	**	**
	Romania	Danube	*	*	*	**	*
N-America	USA	California Bay-Delta	**	**	**	***	****
	USA	Mississippi River Delta	*	**	***	***	***
Z-America	Argentina	Parana	**	***	**	**	***

* *minimal impacts, now and in the near future (around 10 years)*
** *small impacts*
*** *medium impacts*
**** *severe impacts*

12.3 Pressures

12.3.1 Base layer (Natural resources)

Pressures on the base layer of deltas can be subdivided into geological, hydrological and ecological/environmental pressures. Geological pressures are coastal erosion and river morpho-dynamics, which may lead to loss of land and infrastructure. Hydrological pressures include flooding, salinisation, and freshwater shortage, of which the latter two are strongly related, and therefore taken together in this study. The category of ecological/environmental pressures includes water and soil pollution, and wetland and biodiversity loss.

Based on the delta descriptions an inventory of the base-layer pressures has been prepared. Table 12.3 shows an overview of this inventory. Note that the scores mainly indicate whether the pressure presently is a problem, which partly depends also on land use and population density.

Table 12.3 Overview of base-layer pressures in the studied deltas.

	Coastal erosion	River morpho-dynamics	Flooding	Salinisation/ freshwater shortage	Water and soil pollution	Wetland and biodiversity loss	Overall Score
Nile	••	•	•	•••	•••	••	–
Tana	•	••	••	••	••	••	0
Incomati	••	••	••	••	••	•••	–
Zambezi	•	•	•	•	•	••	+
Ganges-Brahmaputra-Meghna delta	••	•••	•••	•••	•••	•••	– –
Yangtze	•	•	••	••	•••	•••	–
Citiwung	••	•	•••	••	•••	•••	– –
Ayeyarwady	•••	•••	•••	•••	••	•••	– –
Mekong	•	••	••	••	•••	••	–
Rhine-Meuse	•	•	•	••	•	••	0
Danube	••	•	•	•	•	•	+
California Bay-Delta	•	•	•	•••	••	••	–
Mississippi River Delta	•••	•	••	•	•••	•••	–
Parana	••	••	••	••	••	••	–

• = minor and/or well controlled
•• = intermediate and/or partly controlled
••• = major and largely uncontrolled

resilience/sustainability:
++(very good), + (good), 0 (medium), – (low), – – (very low)

12.3.2 Network layer (Infrastructure)

Living in deltas has always required human intervention. Infrastructure was and is developed to adapt the natural systems to create more favourable conditions for living and working in deltas. Historically, the infrastructure network used the natural patterns of river channels for transportation and levees on which dikes and roads were built. Evidence can still be seen in the road/railway network in Bangladesh that often runs parallel to major river branches. Ferries are used to cross the many open watercourses. Construction of new roads and bridges requires considerable investment, but can greatly contribute to the economic development of delta areas.

Based on the delta descriptions an inventory of the present condition and problems regarding the major infrastructure categories has been prepared. Table 12.3 shows an overview of this inventory. Note that ‘Adequate’ does not mean that everything is in order, but that there are relatively minor problems within the network layer

Table 12.4 Overview of status of major infrastructure in the studied deltas.

	Flood protection	Irrigation & drainage	Water supply & sanitation	Roads, railways, ports & navigation channels	Overall Score
Nile	**	*	****	***	0
Tana	***	***	****	***	–
Incomati	****	***	***	***	–
Zambezi	***	***	****	***	–
Ganges-Brahmaputra-Meghna delta	****	***	****	****	– –
Yangtze	*	**	*	*	+
Ciliwung	****	****	****	***	– –
Ayeyarwady	****	***	****	****	– –
Mekong	**	**	***	***	0
Rhine-Meuse	**	**	*	*	+ +
Danube	*	*	**	*	+
California Bay-Delta	****	**	***	*	–
Mississippi River Delta	****	**	*	*	0
Parana	***	**	**	**	0

* *Adequate, now and in the near future (around 10 years)*
** *Adequate, but adaptation needed in view of climate change (long term)*
*** *Improvements are desirable in view of economic development (medium term)*
**** *Rehabilitation or upgrading urgently needed*

resilience/sustainability:
+ +(very good), + (good), 0 (medium), – (low), – – (very low)

12.3.3 Occupation layer (land and water use)

Based on the delta descriptions an inventory of the present condition and problems regarding the land and water use has been prepared. Table 12.5 shows an overview of this inventory.

Table 12.5 Overview of status of land and water use in the studied deltas.

	Pressure on space (including urbanization)	Water demand/Fresh water shortage	Flood vulnerability	Overall Score
Nile	***	***	***	– –
Tana	**	***	***	–
Incomati	**	***	****	0
Zambezi	*	*	**	+
Ganges-Brahmaputra-Meghna delta	***	**	****	– –
Yangtze	***	****	**	–
Ciliwung	****	****	****	– –
Ayeyarwady	**	****	****	–
Mekong	**	**	***	0
Rhine-Meuse	**	**	**	+
Danube	*	*	*	+
California Bay-Delta	**	***	****	0
Mississippi River Delta	*	*	***	0
Parana	***	**	**	+

* *no (additional) pressure, now and in the near future (around 10 years)*
** *some pressure*
*** *moderate pressure*
**** *severe pressure*

resilience/sustainability:
+ +(very good), + (good), 0 (medium), – (low), – – (very low)

12.4 Governance

Based on the delta descriptions an inventory of the present condition and problems regarding governance issues has been prepared. Table 12.6 shows an overview of this inventory. The qualifications should be regarded as an expert judgment at a fairly aggregated level.

Table 12.6 Overview of status of governance in the studied deltas.

	Cooperation between levels and sectors of government	Cooperation between government and private sector	Involvement of stakeholders and citizens	Approaches for dealing with risks and uncertainties	Overall Score
Nile	••	••	••	••	0
Tana	••	••	••	•	–
Incomati	••	••	••	•	–
Zambezi	••	•	••	••	–
Ganges-Brahmaputra-Meghna delta	••	••	••	•••	0
Yangtze	••	•••	••	••	0
Ciliwung	••	•	••	••	–
Ayeyarwady	••	•	•	••	–
Mekong	••	••	•••	••	0
Rhine-Meuse	•••	•••	•••	•••	+
Danube	•••	•	••	••	0
California Bay-Delta	••	•••	•••	••	0
Mississippi River Delta	••	••	••	••	0
Parana	••	••	•••	•	0

• *Practically non-existent, unknown*
•• *First initiatives*
••• *Developing, mixed results*
•••• *Fully developed, satisfactory results*

resilience/sustainability:
++(very good), + (good), 0 (medium), – (low), –– (very low)

12.5 Adaptive measures

Various types of adaptive measures can be proposed to improve resilience and sustainability of deltas. The types distinguished in this study are: technical, ecological, economic and institutional measures. Technical measures comprise all 'hard' adaptations of the physical environment and infrastructure in the delta. Ecological measures are 'soft' adaptations, designed to support, restore or strengthen the natural delta processes that lead to resilience. Economic measures include financial or legal arrangements that can be made to support and promote activities that contribute to delta resilience and sustainability, and, on the other hand, to restrict activities that counteract sustainable delta development. Institutional measures involve adaptations at the level of governance and society.

Based on the delta descriptions an inventory of adaptive measures has been prepared. Table 12.7 shows an overview of this inventory. The table shows that adaptive measures in general tend to be technical and ecological, rather than economic or institutional.

Table 12.7 Overview of the types of adaptive measures proposed for the studied deltas.

	Technical	Ecological	Economic	Institutional
Nile	**	*	*	*
Tana	**	*	*	**
Ioconati	*	**	*	**
Zambezi	***	*	**	**
Ganges-Brahmaputra-Meghna delta	***	*	*	*
Yangtze	*	***	*	*
Ciliwung	**	**	*	**
Ayeyarwady	**	**	**	**
Mekong	**	**	*	**
Rhine-Meuse	***	***	**	**
Danube	*	*	*	*
California Bay-Delta	*	***	*	*
Mississippi River Delta	**	**	*	*
Parana	**	**	**	**

* none or few
** some
*** many

12.6 Comparison of delta score cards

Comparing the score cards of the deltas produces a broad picture regarding the problems and sustainability of the major deltas in the world (Table 12.8). It also has the advantage that it identifies in what way deltas resemble or differ from each other. Scores for each of the deltas are based on indicators as well as interpretation of the extended descriptions, which can be found in a separate working documents (http://www.delta-alliance.org/publications). For some indicators quantitative data are available. For other indicators these data are lacking, incomplete or only available in qualitative format. The combined scorecard, below, should therefore be used with care. It will certainly lead to discussions and questions why a certain delta has a higher score than another delta. But this should not be seen as a weakness, but as an intended spin-off of this scorecard: only by such discussions better insight can be gained regarding the interpretation of concepts such as resilience and sustainability, which are difficult to define and quantify. And they may eventually lead to an update of the scorecard altogether.

Comparison of the scorecards for the different deltas clearly shows that current overall sustainability is not satisfactory for most of them. Many are in the danger zone (orange), which means that they are very vulnerable to adverse drivers of change. The GBM and the Ciliwung deltas are in a critical state and score lowest (red), because they have major problems for all layers and also governance has not yet been capable to improve this situation.

For the deltas that are in or beyond the danger zone the reasons for this position differ. The Ciliwung delta, GBM delta and Nile delta are examples of deltas that have to cope with very high land and water demands due to high population pressures, which combined with a moderate (Nile) to inadequate (Ciliwung and GBM) infrastructure lead to significant problems. The California Bay-Delta and Mississippi River delta have moderate land and water pressures, but their major problem lies in the rapid declining nature values (e.g. ongoing wetland loss in Louisiana). Furthermore, their current flood vulnerability in combination with the weak flood protection system results in relatively high flood risks. The Ayeyarwady delta faces a similar situation with underdeveloped infrastructure and high vulnerability to extreme events such as

cyclones, storm surges and extreme rainfall. Although the governance is still rather weak it is expected that considerable progress can be made in view of the current political change. Also the Incomati and the Tana delta combine a moderate land and water pressure with degrading natural resources and an insufficient infrastructure.

Positive exceptions are the Yangtze, Mekong, Rhine-Meuse, Danube, Zambezi and Parana deltas. The Rhine-Meuse delta can currently be considered to have a relatively good sustainability, mainly because of the high score for infrastructure, moderate land and water use and relatively good governance. The Danube delta scores positive on the status of all three layers, which is not a surprise considering the very low population density of around 5 inhabitants per km^2. The Yangtze delta (and maybe the Mekong delta) seems to be in a transition zone: currently the demands on land and water use can be balanced by the infrastructure. But the natural resources are in decline and land and water use are on the rise, which in due time could affect sustainability negatively.

In the Zambezi delta the pressure on land and water use is considered low due to low population density and the delta has good and sufficient natural resources. However, the flow regime and ecosystem has changed considerably due to the construction of upstream dams. The average land and water use in the Parana delta is still estimated to be sustainable but in the lower delta the pressure is increasing because of the growth of the Buenos Aires Metropolitan Area with expected negative impacts.

Table 12.8 Comparative overview of the score cards of 14 deltas studied.

Current situation	Land and water use (occupation layer)	Infra-structure (network layer)	Natural Resources (base layer)	Governance	Resilience & Sustainability Indicator		
					Current	Moderate Scenario	Extreme scenario
Nile delta	---	0	-	0	-	-	---
Tana	-	-	0	-	-	-	---
Incomati delta	0	-	-	-	-	-	---
Zambezi	+	-	+	-	0	0	-
Ganges-Brahmaputra-Meghna delta	---	---	---	0	---	-	---
Yangtze delta	-	+	-	0	0	0	---
Citiwung delta	---	---	---	-	---	---	-
Ayeyarwady	-	---	---	-	-	0	-
Mekong delta	0	0	-	0	0	+	0
Rhine-Meuse delta	+	++	0	+	+	0	-
Danube delta	+	+	+	0	+	0	0
California Bay-Delta	0	-	-	0	-	0	-
Mississippi River Delta	0	0	-	0	-	0	-
Parana	+	0	-	0	+	0	-

With regard to the developments on the medium term (2050), we can distinguish two counteracting drivers of change: on the one hand there is the expectation that with economic growth, technological improvements and improved governance, the current problems stemming from inadequate infrastructure and poverty can be ameliorated. On the other hand we find also negative impacts of growth by increased pressure on land use and natural resources, and climate change (including extreme events) impacting the natural systems and their resources (base

layer), which reduces the enabling conditions for continuing working and living in a delta. The challenge is to have a socio-economic development that will be sustainable, also contributing to improved resilience of deltas.

For several deltas (e.g. the GBM, Mekong, California Bay-Delta, Mississippi River and Ayeyarwady deltas) there is slight optimism that with a moderate economic and climate change scenario the improvements in infrastructure will outweigh the adverse effects of climate change, resulting in better sustainability. However, in a more extreme scenario it is expected that the balance will tilt to the negative side, leading to an overall reduction of sustainability.

For all the other deltas it is expected that both scenarios make it a lot more difficult to maintain the present resilience and sustainability status, leading to lower scores in 2050 for most of them.

12.7 Research gaps and opportunities for knowledge exchange and collaboration

An inventory of research gaps has been carried out based on the delta descriptions. Table 12.9 provides an overview of the issues that have been identified for further research. The specific knowledge gaps/research questions raised in the delta descriptions were aggregated in the broader issues presented in the table. This process inevitably goes with some information loss, but on the other hand facilitates comparison and identification of potential opportunities for collaboration. Opportunities for collaboration concern the issues that were put forward as research gaps in multiple delta descriptions. In the table the issues have been ranked per category (spatial layers and governance) based on the number of deltas for which related research gaps were mentioned.

Important issues for knowledge exchange and collaboration obviously are ‘socio-economic scenarios’, ‘water use and treatment’ and ‘integrated spatial planning’ (occupation layer), as well as ‘freshwater management’ and ‘dikes and dams’ (network layer). The most prominent field of potential inter-delta research cooperation concerns various base-layer issues, ranging from monitoring and predicting changes, through understanding cause-and-effect relationships and ecosystem functioning, to natural safety and ‘building with nature’. As to governance, the major issues identified for cooperation are ‘governmental roles and arrangements’ and ‘integrated delta management’.

Table 12.9 Inventory of issues for which research gaps have been identified in various deltas.

	Nile	Tana	Incomati	Zambezi	Ganges-Brahmaputra-Meghna	Yangtze	Ciliwung	Ayeyarwady	Mekong	Rhine-Meuse	Danube	California Bay-delta	Mississippi River delta	Parana
Occupation layer														
Socio-economic scenarios (6)	•	•	•			•	•	•			•		•	•
Water use and treatment (5)	•	•	•	•	•		•	•		•				•
Integrated spatial planning (5)	•	•	•	•	•		•	•		•				•
Ecosystem services (5)	•	•		•		•	•	•		•	•			•
Land-use change modelling (4)	•	•		•	•		•	•				•		•
Adaptation to salinisation (2)	•	•			•			•						
Network layer														
Freshwater management (7)	•	•	•	•	•		•	•	•	•		•		•
Dikes and dams (5)	•	•			•		•	•		•		•		
Transport (3)	•		•	•			•	•						
Flood forecasting/early warning systems (1)		•		•	•			•						•
Base layer														
Effects of changes/ eco-system functioning (9)	•	•	•	•	•	•	•	•		•	•	•	•	•
Building with nature and natural safety (8)	•	•			•	•	•	•	•	•	•		•	
Monitoring changes (7)	•	•		•	•	•	•	•	•	•		•		•
Predicting changes (7)	•	•		•	•		•	•	•	•	•	•		•
Base-layer data management (3)		•		•	•		•	•					•	•
Governance														
Governmental roles and arrangements (6)	•	•		•			•	•	•	•		•	•	•
Integrated delta management (6)	•	•	•	•	•	•	•	•			•			•
Communication/capacity building (4)	•	•	•		•		•	•						
Financial arrangements (4)		•			•		•	•		•		•		
River basin cooperation (2)			•		•			•						
Policy impact studies (1)		•					•	•						

13 Summary of Findings

There is still little experience with integrated delta planning and management in Myanmar. A very sectorial approach is still being applied, with relatively low level of cooperation between the various governmental agencies. There is a growing understanding that the real challenges (now and in the future) can only be tackled through an interdisciplinary, integrated approach. Knowledge development and capacity building are high on the priority list of key issues identified during the Delta Alliance workshops organised in July 2013 and June 2014.

The Ayeyarwady Delta will inevitably factor significantly into Myanmar's economic development and emergence as a major regional trade route. At present, however, the Ayeyarwady Delta is still largely undeveloped and the uncoordinated exploitation of its resources in some (upstream) areas may pose serious threats to the health of the delta. Thus one of the country's major challenges will be to develop effective, cross-sector management of this system in order to ensure that its development will be sustainable and that decisions made now will not bring later regret, as can be seen in deltas elsewhere.

Delta ecosystems like the Ayeyarwady Delta have a substantial adaptive and resilient capacity. In contrast to e.g. inland forests, which require decades to centuries to reach a climax succession stage, delta ecosystems, such as mangroves and marshes develop fairly quickly into rich habitats once the environmental conditions are favourable again. Worldwide successful examples show the importance of good knowledge of the basic physical and ecological processes, early involvement of local stakeholders leading to a participatory planning process and an integrated and sustainable approach to manage and develop the delta to cope with the new economic situation in Myanmar.

At present the Ayeyarwady Delta already demonstrates the first signs of significant changes (exploitation of the mangroves, overfishing, river bank erosion and deterioration of water quality). However, using the ecosystem approach, deltas can be used by the local people without compromising the integrity of these systems or overexploiting their natural resource.

This approach is also advocated by the Convention on Biological Diversity (Wildlife Conservation Society, 2013) and denotes a strategy for the integrated management of land, water and living resources. The strategy promotes conservation and sustainable use in an equitable way. At the same time it is stressed that additional measures should be adopted like improving conservation awareness, fighting poverty, improving the weak systematic biological monitoring systems, stimulate grassroots support for conservation and strengthen law enforcement.

Ensuring the integrity of the linkages between delta and the river usually requires to take measures upstream. Although the highly dynamic estuarine ecosystems and their species are adapted to seasonal changes in freshwater flows, upstream activities that permanently change the total flow (such as dams, deforestation, climate change) may have significant consequences.

Finally, the stakeholders participation and multi-criteria analysis as applied during the workshops should be continued in order to develop a widely accepted action plan for the delta.

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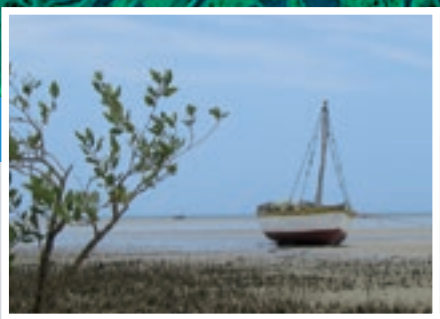
Annex A: Comparative assessment of 14 deltas

DeltAlliance



7

Deltares
Enabling Delta Life

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Knowledge for Climate

Comparative assessment of the vulnerability and resilience of deltas

Extended version with 14 deltas

synthesis report

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Internet

For more information about the Delta Alliance and to download this Synthesis report and related Work documents (with full delta descriptions) go to **www.delta-alliance.org**

Citation

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Comparative assessment of the vulnerability and resilience of deltas

Extended version with 14 deltas

synthesis report

Table of Contents

Introduction

Chapter 1

Rationale

Worldwide, deltas host dense populations and are important centres of agricultural and industrial production, and economic activity. Many deltas are areas of great ecological importance as well, featuring wetlands of high and unique biodiversity. Deltas are vulnerable to changes by natural forces and human activities. Major drivers of change are population growth, economic development, climate change and subsidence. This is being addressed by the Delta Alliance, an international knowledge driven network organization with the mission to improve the resilience of deltas worldwide.

This report is an extended version of the Comparative assessment of the vulnerability and resilience of 10 deltas, published by the Delta Alliance in December 2010 (available at www.delta-alliance.org). In this extended version four additional deltas, the Ayeyarwady, Parana, Tana and Zambezi delta, are elaborated in the same way as in the earlier version, by means of score cards and (summarized) delta descriptions. However the overall synthesis and conclusions chapters in this report involve all 14 deltas.
The paragraphs below are summarizing the framework of delta assessment, pragmatic choice of deltas and delineation, elements of delta descriptions and target groups.
For details about the approach and for the descriptions and score cards of the other 10 deltas is referred to the earlier version of 2010, available at www.delta-alliance.org. The current report is also available at this website as well as a separate working document with the full version of the four additional delta descriptions

Framework for delta assessment – an integrated approach

In this collaborative project of the Delta Alliance a framework for delta assessment is applied, combining a DPSIR approach with a Spatial Layer model. This Integrated Approach takes into account long term and short term drivers and pressures (a.o. climate change and socio-economiic developments) the impacts in tthree spatial planning layers of the delta system and the governance regarding organisation and institutional aspects of adaptive responses. The three physical planning layers are the Occupation layer (land and water use), the Network layer (infrastructure), and the Base layer (natural resources), each with different but interrelated temporal dynamics and public-private involvement.

Introduction

Chapter 1

Pragmatic choice of deltas and delineation

The framework is used for describing deltas in a uniform format in order to make a comparative overview and analysis easier. Building on the contacts of the Delta Alliance each delta description is prepared by a Delta Wing Coordinator of the Delta Alliance (or another main contact person), in most cases in cooperation with several (sectoral) experts.
For pragmatic reasons the delta wing coordinators themselves were free to choose the appropriate definition for their delta description, to decide which (sectoral) experts should be involved and to determine the score in the score card. We are confident that this does not significantly influence our overall conclusions, as long as due attention is given to referencing to the area of interest wherever quantitative indicators are used.
This report provides a comprehensive overview of the current and future state of the following 14 deltas (with additional deltas in green):

Elements of delta descriptions

For each delta an 'indicative' score card gives an impression of the current and future state of the different layers and governance issues, summarized in an overall Resilience and Sustainability Index. The rationale of the resilience and sustainability indicator is that sustainable development of a delta depends on a combination of the status of the three layers. Resilience and sustainability is good if the provision of goods and services equals the demand, without deterioration of the base layer. Besides the current situation two development scenarios are recognized: 1) Scenario1, moderate perspective 2050 with medium economic growth and related medium technological developments, combined with medium climate change and sea level rise, 2) Scenario2, extreme perspective 2050 with high economic growth and related high technological developments, combined with high climate change and sea level rise.

The scorecards are based on an analysis of drivers of change and pressures on the different layers of each delta and governance issues, based on, as much as possible, quantitative indicators. It is emphasized that in this report first versions of delta score cards are presented, based on above mentioned 'framework for delta assessment'. The score cards need further development and elaboration, which is envisaged in near future.

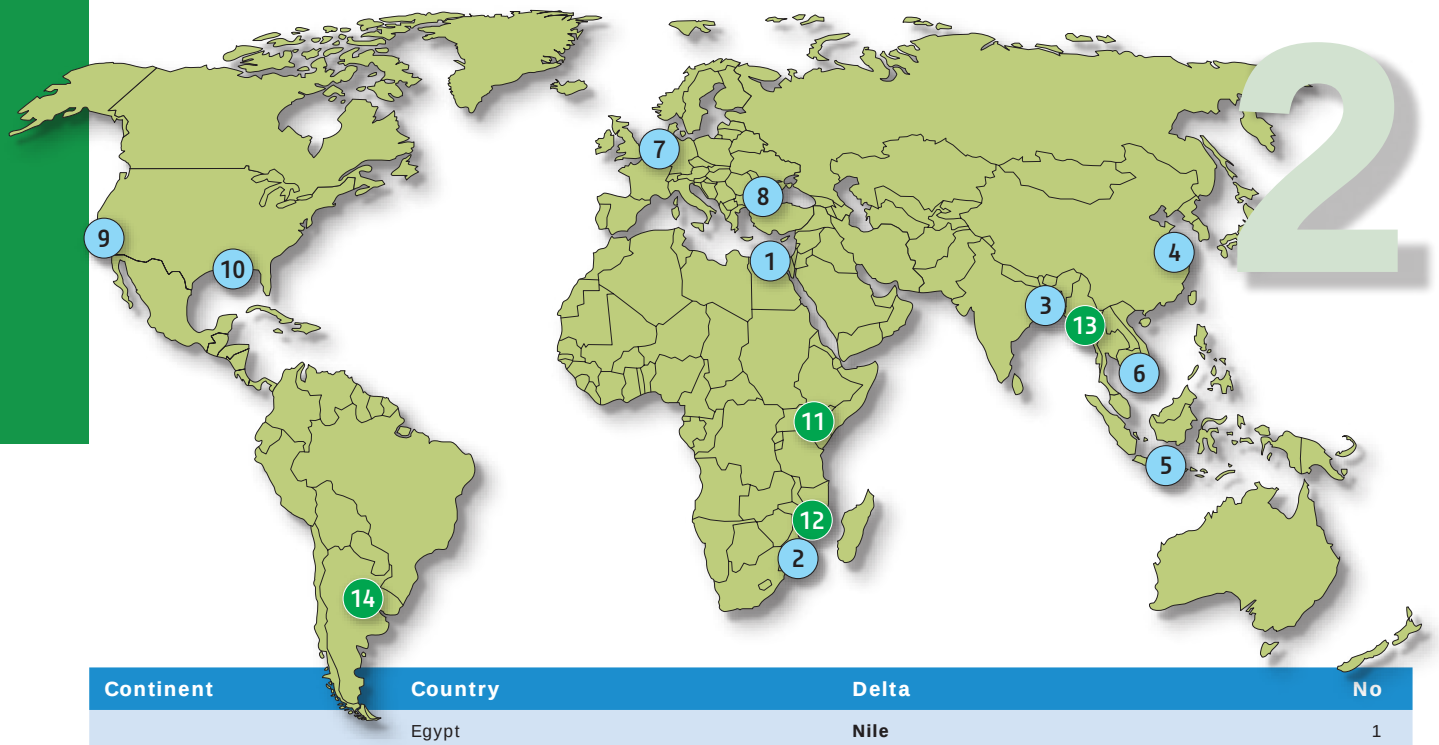
Moreover for each delta a brief overview is given regarding currently applied adaptive measures and technical methods and tools to support delta management. Also an overview of research gaps and opportunities for collaboration is presented in order to contribute to the development of collaborative research projects across deltas.

Target groups

The proposed framework for delta assessment and especially the score cards are intended to enhance awareness raising, discussion and prioritization on most relevant delta issues, in each delta but also in comparison with other deltas. This should lead to more efficient and effective (multi-sectoral) policy formulation, management design and implementation, in concrete Delta plans, pilot-projects and (research) programmes. The target groups are all stakeholders who are involved in delta management at different levels and with different interests (government, private companies, NGOs, public), and who wish to contribute to the resilience of their own delta and other deltas worldwide.

Overview
of Delta Scorecards

Chapter 2

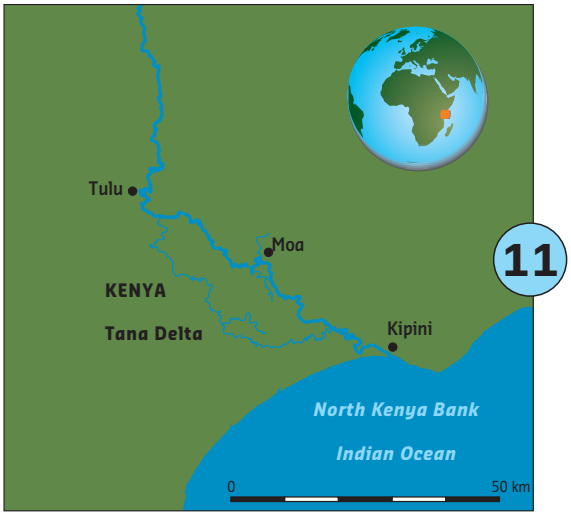


Continent	Country	Delta	No
Africa	Egypt	**Nile**	1
	Kenya	**Tana**	11
	Mozambique	**Incomati**	2
	Mozambique	**Zambezi**	12
Asia	Bangladesh	**Ganges-Brahmaputra-Meghna**	3
	China	**Yangtze**	4
	Indonesia	**Ciliwung**	5
	Myanmar	**Ayeyarwady**	13
	Vietnam	**Mekong**	6
Europe	The Netherlands	**Rhine-Meuse**	7
	Romania	**Danube**	8
N-America	United States of America	**California Bay-Delta**	9
	United States of America	**Mississippi River Delta**	10
Z-America	Argentina	**Parana**	14

The map and table above give an overview of all 14 deltas with in green the four additional deltas elaborated in this synthesis report.

The Delta Assessment approach as described in chapter 1 is applied for each delta, by the elaboration of delta descriptions. In the following paragraphs for each of the additional four deltas the scorecards and some clarification notes on the scorecards are mentioned. The main items of the delta descriptions are summarized in the Appendix and the full delta descriptions (of the 14 deltas) are available in separate 'Working documents' at www.delta-alliance.org

Tana



Scorecard

Tana delta	Land and water use (occupation layer)	Infrastructure (network layer)	Natural resources (base layer)	Governance	Overall resilience & sustainability indicator
Current situation 2010	–	–	0	–	–
Scenario 1 moderate 2050	––	–	–	–	–
Scenario 2 extreme 2050	––	0	––	–	––

resilience / sustainability: *++ (very good), + (good), 0 (medium), – (low), –– (very low)*

Concluding remarks on score card

The current situation in the delta can be described as moderate to low in terms of sustainability. Land and water use is high, infrastructure is poor and natural resources are dwindling. The pressures on the occupation layer and the base layer are likely to increase due to significant economic development combined with higher dependence on ecosystem goods and services supporting the livelihoods of the communities in the delta.

The anticipated changes in climate change, sea level rise and upstream hydropower engineering are likely to worsen the situation for all layers with unpredictable and uncontrolled erosion patterns in the delta and at the coast. Many legal frameworks are in place but mainly uncoordinated. Attuning and implementation is needed for assuring the sustainability of the delta and its resources.

Tana, due to its richness, has to cope with very high land and water demands due to high population pressures, which combined with a moderate to inadequate infrastructure lead to significant problems. Furthermore, due to engineering, flood hazards can decrease but due to community behavior and lack of protection systems flood vulnerability remains high.

It is unlikely that the projected improvements of the network layer following the Lapsset/ Lamu corridor developments will outweigh the current rapid and negative developments of the occupation and base layers of the Tana delta, leading to an overall decrease of sustainability of the Tana delta.

Zambezi

Scorecard

Zambezi delta	Land and water use (occupation layer)	Infrastructure (network layer)	Natural resources (base layer)	Governance	Overall resilience & sustainability indicator
Current situation 2010	+	–	+	–	0
Scenario 1 moderate 2050	0	–	0	0	0
Scenario 2 extreme 2050	–	0	–	+	–

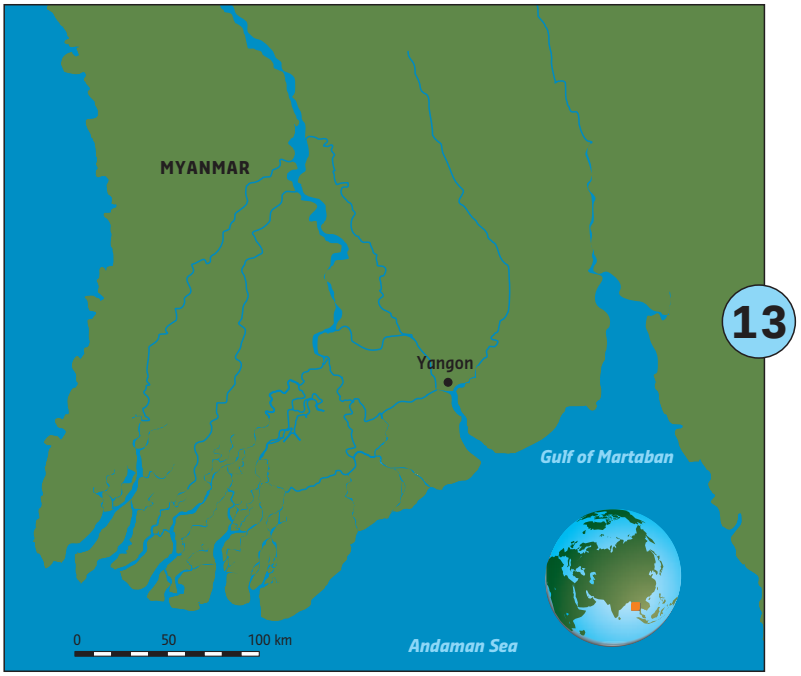
resilience / sustainability: *++ (very good), + (good), 0 (medium), – (low), –– (very low)*

Concluding remarks on score card

Pressure on land and water use (occupation layer) is considered good due to the low population density. The delta has very good natural resources (base layer) as it has abundant water, little pollution and natural delta processes with respect to sedimentation and erosion. However it is worth to note that the delta area, flow regime and ecosystem have changed considerably due to the construction of Kariba dam (1958) and Cahora Bassa dam (1974). For the future scenarios the pressures on the land and water use and natural resources are expected to increase due to the economic growth in the country and the river basins specific developments such as expansion of irrigated agriculture, impacts of upstream mining activities and effects of climate change and sea level rise. Frequency of floods and droughts may increase and with sea-level rise salinity intrusion problems may arise. The infrastructure (network layer) is scored low at present as the population has limited access to safe drinking water, no sanitation and mainly secondary roads and dikes. With the strategy plans for science, technology and innovation put in place and with the economic development the situation is expected to improve with time. The governance in Mozambique is transforming to a decentralised administration that is still following vertical channels of communication leading to fragmented actions to deal with natural resources management. There are also weaknesses in term of absence of the necessary cooperation with the private sector and in involving stakeholders and citizens. It is however in its early stages and process is going slowly due to low technical, human and financial capacity.

Mozambique has one of the fastest growing economies in Africa which is very encouraging. However, socio-economic development, infrastructure and governance still largely depend on donors. But even with the development of technology, awareness about the importance of the environment and good governance the pressure in the occupation and base layer is expected to increase so the overall resilience and sustainability will decrease proportionally in time.

Ayeyarwady delta



Scorecard

Ayeyarwady delta	Land and water use (occupation layer)	Infrastructure (network layer)	Natural resources (base layer)	Governance	Overall resilience & sustainability indicator
Current situation 2010	–	––	––	–	–
Scenario 1 moderate 2050	0	+	–	0	0
Scenario 2 extreme 2050	–	–	––	0	–

resilience / sustainability: *++ (very good), + (good), 0 (medium), – (low), –– (very low)*

Concluding remarks on score card

The population density is relatively low compared to the one of the Mekong or the Ganges-Brahmaputra-Meghna Deltas, but yet 3 to 4 times as high as the country's average. The pressure on space is not that high. The demand for fresh water and the flood vulnerability score high. It is expected that through economic development the livelihood conditions might improve under the moderate scenario.

The current infrastructure concerning transport is badly developed. Many works have been done with regard to river embankments, construction of polders and irrigation systems, of which the maintenance could be improved. In the moderate scenario it is expected that important investments will be done to upgrade the road and other infrastructure. It is expected that the area of irrigated agriculture will increase.
The delta is and will always be very vulnerable in view of the risk of (increasing) extreme events such as storm surges, cyclones and extreme rainfall. Also salinization will be a continuous threat for mainly the Lower and Middle Delta.
The governance of the delta is currently at a rather low level. There are opportunities for the application of more integrated and participatory approaches.

Parana delta

Scorecard

Parana delta	Land and water use (occupation layer)	Infrastructure (network layer)	Natural resources (base layer)	Governance	Overall resilience & sustainability indicator
Current situation 2010	+	0	–	0	+
Scenario 1 moderate 2050	0	0	+	+	0
Scenario 2 extreme 2050	–	+	0	+	–

resilience / sustainability: *++ (very good), + (good), 0 (medium), – (low), –– (very low)*

Concluding remarks on score card

Even though the pressure on land use and the negatives impacts of human activities are high in some sectors of the delta, they are concentrated mainly in the lower delta, which represents 43% of the total area of the region. In both scenarios (moderate and intensive), the pressures on land use and natural resources are expected to increase due to the growth of Buenos Aires Metropolitan Area and other big cities located in the margins of the delta- together with the introduction of "continental" residential typologies into the islands-, as well as a result of the expansion of production activities, especially large-scale agriculture and forestry. In terms of infrastructure, only under an extreme scenario the implementation of innovative technologies for sustainable development is expected because nowadays it is not considered a priority by the governments. On the contrary, the delta is still being underestimated regarding its values and potentialities. In terms of governance, an improvement is expected resulting from the implementation of the integrated plan of PIECAS and the coordination of actions among the different jurisdictions that share the region. Besides, the increasing mobilization and participation of citizens and Civil Society Organizations (CSOs) would contribute to enhance governance through increased adaptive capacity.

Overview of Delta Scorecards

Chapter 2

Synthesis

Current and future state of deltas

Chapter 3

Drivers of change

Based on the delta descriptions an inventory of the drivers of change impacting delta areas has been prepared. Table 1 shows an overview of this inventory. The qualifications should be regarded as an expert judgment at a fairly aggregated level. It enables to draw some general conclusions that are formulated below.

Table 1
Overview of drivers of change in the studied deltas. In green the additional four deltas

Continent	Country	Delta	Demographic trends	Economic developments	Technological developments	Climate change	Subsidence
Africa	Egypt	Nile	•••	••	••	•••	••
	Kenya	Tana	•••	••	•	••	unknown
	Mozambique	Incomati	•	••••	••	•••	•
	Mozambique	Zambezi	•	•••	••	•••	unknown
Asia	Bangladesh	Ganges-Brahmaputra-Meghna delta	••	•••	••	••••	••
	China	Yangtze	•••	••••	••	••	••
	Indonesia	Ciliwung	••••	•••	••	•••	••••
	Myanmar	Ayeyarwady	••	•••	••	••••	•••
	Vietnam	Mekong	••	••••	••	•••	••
Europe	Netherlands	Rhine-Meuse	•	••	•••	••	••
	Romania	Danube	•	•	•	••	•
N-America	USA	California Bay-Delta	••	••	••	•••	••••
	USA	Mississippi River Delta	•	••	•••	•••	•••
Z-America	Argentina	Parana	••	•••	••	••	•••

- • *minimal impacts, now and in the near future (around 10 years)*
- •• *small impacts*
- ••• *medium impacts*
- •••• *severe impacts*

Demographic trends

Most deltas studied are densely populated, especially all Asian deltas (Ganges-Brahmaputra-Meghna delta, Yangtze, Ciliwung, Mekong) and the Nile delta (see table 2). In these deltas urban development has led to mega-cities and some of them are still growing at a very high pace (Ciliwung, Nile and Yangtze delta). In the Yangtze delta the official growth rate is minor, however the population is actually growing fast because of (not registered) large number of migrants. In the Incomati delta urban development is limited to greater Maputo.

Other deltas have a very low population density (Danube, Parana, Zambezi, Tana) and population is located in villages or rural settlements that are randomly located often in the vicinity of the river.

In some deltas there is a clear distinction between a stable or increasing urban area and a rural area with relatively few inhabitants (California Bay-Delta, Mississippi River Delta). The Danube delta is a biosphere reserve with only rural settlements and a small town.

Table 2 Overview of delta population (number, density) and growth rate. In green the additional four deltas

	Population number (in million)	Population density (inhabitants/km)	Growth rate (%)
Nile	35	1000	2,0
Tana	0.1	74	3,2-3,4
Incomati	2,5	44	0.4
Zambezi	0.3	35	2.2 - 4.1
Ganges-Brahmaputra-Meghna delta	156 - 200	1200	1,3
Yangtze	20-85[1]	>1000	0,3 - 2,0
Ciliwung	23	>1000	3,6
Ayeyarwady	8	230	1.52
Mekong	17	425	0,6
Rhine-Meuse	6,5	500	minor
Danube	0,01	5	minor
California Bay-Delta	0,5 – 7,0	?	?
Mississippi River Delta	1,5[2]	<100	minor
Parana	0,024[3]	1[4]	1,3[5]

1 *The total number of population depends on the definition of the delta*

2 *Two-thirds of the population is living in New Orleans*

3 *The delta itself has 24000 inhabitants with a surface of 17500 square km. The delta and the surrounding urban cores of the provinces of Entre Ríos, Santa Fe and Buenos Aires (including the Buenos Aires Metropolitan Area) have around 16 million inhabitants.*

4 *The delta area has a density of 1 inhabitant/km² and the Buenos Aires Metropolitan Area has a density of 5400 inhabitant/ km².*

5 *According to the INDEC (National Institute of Statistics and Census, 2010) the growth rate of the population of the Buenos Aires Metropolitan Area (including the city of Buenos Aires) was 11,7% in the period 2001-2010.*

Economic developments

In half of the deltas economic development is an important driver with medium to severe impacts. This especially pertains to the Asian deltas (Yangtze, Mekong, Ciliwung, GBM). The highly urbanised deltas of the Rhine-Meuse, Ciliwung and Yangtze are of high national economic importance with most people employed in services and industry. In the Ciliwung delta the capital of Indonesia, Jakarta, is located. It's economic development is rapidly shifting from the industrial and manufacturing sector to the services sector. In the Yangtze delta Shanghai is the financial and logistics center of China, with an annual economic growth rate of around 8%.

The agriculturally dominated deltas are the Mekong, GBM and Ayeyarwady deltas, with mainly rice, aquaculture (shrimps, catfish) and related industries. The Mekong delta is a national economic priority area with a target growth of 8% per year for the production of food, commodities and consumer goods. A substantial part of the industry in the California Bay-Delta is also related to agriculture.

In the Nile delta the economic conditions have improved considerably over the years. The tourism, industry, agriculture, and service sectors are significant contributors to Egypt's economy. Also in the Incomati delta the economic development is rapidly increasing. The Incomati catchment is one of the fastest growing socio-economic regions in the SADC region (Southern African Development Community).

For over two centuries agriculture has been a key part of the Mississippi River delta economy. But now offshore oil and natural gas production, along with all its related service industries and the Port of New Orleans dominate the state's coastal economy. Recently eco-tourism is beginning to emerge. In the Danube delta economic development is strictly regulated. Only traditional activities and eco-tourism are permitted.

In the less densely populated deltas, Tana, Zambezi and Parana the economic activities are farming, fishing and livestock but this is often mostly for subsistence use. Plans for large scale agriculture do exist in most of these deltas, which will have many effects. The Tana delta is also much used in the dry season by livestock emanating from neighboring counties. Also the Parana delta has an important regional function as commercial route connecting Chile and Brazil.

Technological developments

In many deltas technological developments focus on water management issues, e.g. in the Mekong for boosting rice production and in the California Bay-Delta for increased efficiency in water use and conveyance on the water supply side. Several deltas have also developments in infrastructure and related (geo-engineering) modelling or ICT services (Ciliwung, GBM, Mississippi River Delta). In the Yangtze delta there is a focus on environmental compensation measures especially regarding infrastructure. In the Incomati delta a strategy for development of science and technology aims at increasing poverty alleviation. A 'Millennium Village' is established in the delta to improve the development and adoption of technology. Research programs (partly) funded by the government and public-private partnerships are stimulating innovative developments in the Nile and Rhine-Meuse deltas.

The Ayeyarwady, Parana, Tana and Zambezi deltas have low scale technological developments such as roads, bridges, information and communication around the villages, irrigation canals and embankments. In several basins large dams have been constructed posing a threat to the ecological integrity and flow regime downstream. In the Ayeyarwady large polders, incl embankments, storage and drainage canals, have been created to prevent salt water intrusion and enable paddy cultivation.

Satellite image of the Ayeryarwady delta

Climate change

Another important driver in the deltas studied is climate change, which is expected to have medium to severe impacts in nine out of fourteen deltas. Often already existing problems in the deltas will be exacerbated by the impacts of climate change. The following impacts, with regional differences, are to be expected:

- Sea level rise, resulting in higher flood risk, salt water intrusion, salinisation and coastal erosion. The Mekong delta for example is very vulnerable to sea level rise, since around 40% may be submerged by one meter of sea level rise.
- More extreme weather events, especially in tropical areas. This involves changes in length and intensity of the rainy season, which may result in more severe floods, longer droughts (e.g. Zambezi) and higher temperatures (e.g. Ciliwung). The frequency and strength of cyclones and related floods seem to be on the rise, especially in the Asian deltas (e.g. GBM and Ayeryarwady), but also in the Mississippi River delta. But also at temperate latitude, in the Rhine-Meuse and Danube deltas, higher peak flows and lower water levels are expected. The climate of the California Bay-Delta is already unusual in its extreme variability and in the Yangtze delta the average temperature is increasing. This resulted in a change in timing and spatial distribution of precipitation and resultant water flow.
- Change in distribution and extent of ecosystems/habitats in many deltas, among others in the Danube delta.

Subsidence

In many deltas considerable subsidence is caused by human activities. This involves drainage, (ground) water extraction and soil compaction (Nile, GBM, Rhine-Meuse, California Bay-Delta, Mississippi River Delta), but also oil and gas production (Nile and Mississippi River Delta).

In the Ciliwung delta subsidence of 10-250 mm/yr is a serious threat, especially in the north of Jakarta, caused by a combination of groundwater extraction, load of constructions, natural

consolida¬tion and tectonic subsidence. Subsidence is also a major issue in the California Bay-Delta, because reclaimed wetlands were converted into housing and agricultural or commercial areas. Some delta islands (polders) have experienced over 9 meters of subsidence in the last 160 years, primarily due to ground water pumping and wind erosion. The entire Mississippi River Delta is subsiding largely because since the early 20th century the Mississippi river has been canalized for flood control and navigation. Consequently water and sediment flow to the wetlands has been denied. Shortage of sediment supply can also be caused by lower river discharge and dam construction upstream, which adds to the problem of subsidence (Mekong and Nile).

The Parana and Ayeyarwady deltas are having a higher subsidence rate than the forecasts of sea-level rise, exacerbating the risks of flooding. Not much knowledge or observation data exists on subsidence of the Tana and Zambezi delta.

Pressures

Occupation layer (land and water use)

Based on the delta descriptions an inventory of the present condition and problems regarding the land and water use has been prepared. Table 3 shows an overview of this inventory. The qualifications should be regarded as an expert judgment at a fairly aggregated level. It enables to draw some general conclusions that are formulated below.

Pressure on space

In almost all deltas limited space is a problem, but this is especially the case in deltas with mega-cities and increasing urban development. In the Nile, GBM and Yangtze deltas urban development results in moderate pressure on space and in the Ciliwung delta even in severe pressure. The core problem for the Ciliwung delta is the out-of-control urbanization of Jakarta, involving among others occupation of floodplains and shortcomings in infrastructure. In California Bay-Delta the pressure on space is high in the Bay area but minor in the Sacramento-San Joaquin delta. Also in the Mississippi River Delta and the Danube delta the pressure on space is minor.

In the Mekong delta pressure on space will increase in future, especially influenced by flood protection measures, agricultural and aquacultural expansion and intensification. In the Yangtze delta land reclamation of wetlands is important for Shanghai to cope with the fast urbanization.

In contrast, the Zambezi Delta is an almost pristine delta with a very low population density, e.g. in the Marromeu district only 6.8% has human occupation. There is however a large interest to have agricultural development in the delta.

Development of large scale agricultural production-processes are also observed in the Tana Delta (export crops, biofuels, next to mineral exploitation) and the Parana Delta (soybean, livestock production and forestry). The pressure on space In the Parana delta is moderate which is also associated with the nearby urban conurbation of the Buenos Aires Metropolitan Area.

Although the population density in the Ayeyarwady Delta is three to four times as high as the country's average, it is still relatively low compared to many other Asian deltas. Pressure is expected in the urban area around Yangon.

In almost all tropical deltas there is a pressure on the mangrove forests, by wood extraction (for charcoal) and the development of aquaculture.

Table 3: overview of status of land and water use in the studied deltas. *In green the additional four deltas*

	Pressure on space (including urbanization)	Water demand / Fresh water shortage	Flood vulnerability	Overall Score
Nile	•••	•••	•••	––
Tana	••	•••	•••	–
Incomati	••	•••	••••	0
Zambezi	•	•	••	+
Ganges-Brahmaputra-Meghna delta	•••	••	••••	––
Yangtze	•••	••••	••	–
Ciliwung	••••	••••	••••	––
Ayeyarwady	••	••••	••••	–
Mekong	••	••	•••	0
Rhine-Meuse	••	••	••	+
Danube	•	•	•	+
California Bay-Delta	••	•••	••••	0
Mississippi River Delta	•	•	•••	0
Parana	•••	••	••	+

• *no (additional) pressure, now and in the near future (around 10 years)*
•• *some pressure*
••• *moderate pressure*
•••• *severe pressure*

resilience / sustainability:
++(very good), + (good), 0 (medium), – (low), –– (very low)

Water demand / Fresh water shortage

Water demand is a main and increasing issue in some highly urbanized deltas (Nile, Yangtze, Ciliwung). In the Ciliwung delta land conversion from forest to agriculture and urban areas, results in water shortages during the dry season. A major breakthrough will be necessary to manage the present situation, both with regard to management of the existing water resources, and with regard to demand reduction. Fresh water shortage is a continuous threat in the Yangtze delta especially by increasing water demand in Shanghai. Water supply mainly comes from upstream and reservoirs. In the California Bay-Delta fresh water shortage is becoming a serious issue as opportunities for increasing supply to satisfy growing demand are limited and California is experiencing severe droughts. During low river discharge the increase of salinity intrusion in coastal areas is making existing water supply sources as well as agriculture and freshwater ecosystems vulnerable (Incomati, Mekong, GBM). In the Rhine-Meuse delta occasionally dry years occur during which serious water shortages are experienced, which affect agriculture, energy (cooling water) and shipping (lower navigation depths).

Increasing salinity intrusion in the Ayeyarwady Delta is a major threat for fresh water supply for drinking water (combined with the arsenic pollution of the groundwater) as well as for agriculture purposes, especially in the Lower and Middle Delta during the dry season.

In the pristine Zambezi delta there is no fresh water shortage. The large percentage of the population without access to safe water is due to lack of infrastructure.

In the Tana delta there is an increasing water shortage due to use upstream and irrigation projects.

In the Parana Delta the urbanization of rural urban areas, the increment of the number of dwellings and the increase of the scale of agricultural production cause an important pressure on the fresh water availability: Buenos Aires needs more than 5 million m^3/day.

Flood vulnerability

In ten out of fourteen deltas the flood vulnerability is moderate to severe. In the Incomati and GBM deltas floods are a permanent threat. Most of GBM delta is still active with very unstable river branches and the delta is prone to tropical cyclones with high storm surges. In the Ciliwung delta almost half of the area is below sea level resulting in some 6 million inhabitants vulnerable to flooding, especially in the northern part of Jakarta. Most of the California Bay-Delta is below or just above sea level and large scale flooding could have immense consequences for the entire state as it would disrupt water supply for an extended period.

In the densely urbanised Nile delta the vulnerability is high, but river floods are minimized by the Aswan Dam. In the Mekong delta moderate floods occur regularly, bringing sediments and nutrients essential to food security (agriculture and fish production) and biodiversity (sustainance of the fresh water ecosystems). However, extreme flood events can be destructive. Hurricanes are a 'way of life' in the Mississippi River delta. The recent hurricanes Katrina and Rita resulted in devastating floods, which triggered intensive flood protection measures.

In the Rhine-Meuse delta flood protection standards are among the highest in the world. Although the flood risk is quite small, potential consequences of a flood are high.

Floods (caused by upstream rainfall) do occur in the Tana Delta. Normally under natural circumstances they are seen as a blessing for farmers and fishermen and also benefit the connected wetlands and riverine forests. However, similar to the Zambezi delta, the timing is changed and the extend is reduced by the construction of large dams and reservoirs. Occasional floods do occur amongst others due to 'uncontrolled' spilling of the reservoir water or extreme rainfall patterns and consequently river discharge. Despite discouragement from the government, people continue to live in the flood prone areas.

The flood vulnerability in the Ayeyarwady Delta is high. The delta is still active with unstable river branches and occurrence of flash floods (mainly in the Upper Delta). The Lower delta is prone to tropical cyclones with high storm surges. Cyclone Nargis in 2008 killed almost 140.000 people.

In the Parana Delta the vulnerability to flood differs between the islands and the coastal area along the delta. Flooding and subsequent negative impacts occur when high river discharges coincide in time and space with elevated water level in the Rio de la Plata due to strong South Eastern winds coming from the Atlantic Ocean.

Network layer (Infrastructure)

Living in deltas has always required human intervention. Infrastructure was and is developed to adapt the natural systems to create more favourable conditions for living and working in deltas. Historically, the infrastructure network used the natural patterns of river channels for transportation and levees on which dikes and roads were built. Evidence can still be seen in the road/railway network in Bangladesh that often runs parallel to major river branches. Ferries are used to cross the many open watercourses. Construction of new roads and bridges requires considerable investment, but can greatly contribute to the economic development of delta areas.

Based on the delta descriptions an inventory of the present condition and problems regarding the major infrastructure categories has been prepared. Table 3 shows an overview of this inventory. The qualifications should be regarded as an expert judgment at a fairly aggregated level. It enables to draw some general conclusions that are formulated below. Note that 'Adequate' does not mean that everything is in order, but that there are relatively minor problems within the network layer. Networks are constantly being adapted to the changing demands, for instance deepening of navigation channels for larger ships. In many countries this is an on-going process of expansion and adaptation. If this goes without many problems, it is scored as 'adequate'.

Many deltas still have a high flood risk

In 8 out of the 14 studied deltas flood protection is not adequate. Upgrading of the flood safety is urgently needed for the Ciliwung, Incomati, GBM, Ayeyarwady, California Bay and Mississippi River deltas. Jakarta has only 25% of its area protected by embankments, leaving some 6 million inhabitants vulnerable to flooding. For the Incomati, flooding occurs in the lower basin at irregular intervals with impacts on agriculture, natural habitats, and damage to infrastructure and loss of life. The most devastating flood occurred in the year 2000. There is no flood protection along the river. In Bangladesh (GBM) about every ten years more than 50% of the area is flooded when discharges reach extreme values. Earthquakes threaten the Sacramento-San Joaquin delta levees. There is a 60% change that the Bay Area will experience a large-magnitude earthquake before 2032, which could cause multiple levee failures, causing thousands of homes and farms to be flooded. As a result of Hurricane Katrina, restoration of damaged infrastructure in the Mississippi River delta is still an important issue. Reconstructions are now underway.

The Ayeyarwady delta is facing an ageing Infrastructure which needs to be maintained and upgraded. The maintenance of embankments, polder sluices, drainage canals and irrigation systems is a recurrent problem. There is a challenge to improve the flood protection due to the threat of cyclones, sea level rise and upstream floodings.

For the other deltas the flood protection system currently does not require urgent measures, although improvements are of course always desirable. The Rhine-Meuse delta has one of the highest safety standards and only needs upgrading on a longer term in view of sea level rise and economic developments.

In the Parana delta flood protection is mainly restricted to isolated polders which create suitable conditions for agricultural production and residential purposes. In the last three years, the polder surface increased around 16.5%, reaching 240.748 ha of polders. The intervention by dikes and ditches alters the regime of the wetland.

In the Zambezi Delta upstream dams and dikes give people sufficient protection against flooding. Railways and roads built in the flood plains also act as flood protection.

In the Tana delta five major reservoirs have been built in the upper basin over the past fifty years. This led to a 20% decrease in the peak flows of May. However these measures have significantly modified the hydrological regime of the river, the flood characteristics of the wetlands and the availability of flood water for riverbank farming downstream.

Table 4: overview of status of major infrastructure in the studied deltas. In green the additional four deltas.

	Flood protection	Irrigation & drainage	Water supply & sanitation	Roads, railways, ports & navigation channels	Overall Score
Nile	••	•	••••	•••	0
Tana	•••	•••	••••	•••	–
Incomati	••••	•••	•••	•••	–
Zambezi	•••	•••	••••	•••	–
Ganges-Brahmaputra-Meghna delta	••••	•••	••••	••••	––
Yangtze	•	••	•	•	+
Ciliwung	••••	••••	••••	•••	––
Ayeyarwady	••••	•••	••••	••••	––
Mekong	••	••	•••	•••	0
Rhine-Meuse	••	••	•	•	++
Danube	•	•	••	•	+
California Bay-Delta	••••	••	•••	•	–
Mississippi River Delta	••••	••	•	•	0
Parana	•••	••	••	••	0

- • *Adequate, now and in the near future (around 10 years)*
- •• *Adequate, but adaptation needed in view of climate change (long term)*
- ••• *Improvements are desirable in view of economic development (medium term)*
- •••• *Rehabilitation or upgrading urgently needed*

resilience / sustainability:
++(very good), + (good), 0 (medium), – (low), –– (very low)

Irrigation and drainage systems need adaptation to changing demands

Most delta land use is or was agriculturally dominated, evidences of which can be found in sometimes age-old irrigation and drainage systems. The Nile delta is a good example of this historical development that led to high water productivity in agriculture. The extensive irrigation system is stretched to its limits; there is a constant need for efficiency improvement. Further improvements cannot therefore be found in better water infrastructure, but require innovations in farming systems, water pricing and water management. In Bangladesh already hundreds of large, medium and small-scale irrigation and drainage projects have been implemented, often in conjunction with flood protection. Nowadays also non-structural measures are being introduced, with policies to encourage small-scale irrigation using treadle pumps and small diesel or electric pumps. For the Incomati especially the upstream extension of irrigation poses significant problems in the delta downstream. There are plans to increase the irrigated areas in all three riparian countries. Population growth and expansion of urban areas and industry demand more water than the river can supply, consequently more dams are being constructed and water from the Incomati is transferred to other basins.

Increasingly deltas are becoming urbanized, which lead to a change in hydrological characteristics (e.g. increased rainfall run-off). This poses new challenges to the water system because the dimensions of the irrigation and drainage network which originally was designed for agricultural purposes may no longer be appropriate. For instance, rapid urbanization of the Ciliwung floodplain led to solid waste disposal in drains that reduce their discharge and as a consequence aggravate flooding problems.

In the Parana delta drainage is mainly linked to creating polders and to the use of islands for large-scale livestock farming, commercial forestry systems and agriculture systems (Soybean crops). The interventions and economic activities depress water table levels, gives soil changes and lead eventually to compaction and subsidence.

In the Zambezi delta area only the SENA Sugar Estate has an irrigated agricultural field. The rest of the agricultural land owned by smallholders is rain-fed.

Maintenance of the water infrastructure is urgently needed for the Ayeyarwady delta This includes improvement of embankments, drainage canals, irrigation systems and dredging of blocked waterways for navigation.

The large scale interventions upstream of the Tana River limit the flooding of floodplains and banks downstream. This reduces the possibilities for floodplain and riverbank agriculture significantly. Farmers will become more dependent on rainfall and expansion of irrigation systems is likely.

Aerial view of part of the Tana delta

Water supply and sanitation still a major challenge for developing deltas

Most highly developed deltas have a more or less adequate water supply and sanitation infrastructure. In striking contrast are the deltas in countries in transition or lesser developed countries. In these deltas, large parts of the population lack safe water supply and sanitation systems. Drinking water production for many of the urban areas in the deltas is sometimes insufficient, as is for instance the case for greater Maputo area (Incomati). The consequences could directly impact on public health, but also indirectly on other parts of the delta system. For instance, inadequate infrastructure for piped water supply influences the flooding problem in Jakarta. Less than half of Jakarta's households have access to piped water supply which results in both households and commercial establishments extracting groundwater for their basic water needs, adding to land subsidence.

The major features of California's water supply system were built between the 1920s and the 1970s. Back then it was supposed to support about half of the population California has today. This infrastructure is now aging and requires updating and maintenance. It is a pressing issue because millions of people in the south are now dependent on fresh water from the delta.

The islands of the Parana delta have no water supply or sanitation network. The cities along the borders of the delta have an average coverage of the water supply network of around 50% and 20% of sewage system. The main source of water is the Rio de la Plata and two aquifers. There are two big water capture and treatment plants for the Buenos Aires Metropolitan Area and the lower delta.

In the Zambezi delta the water supply and sanitation infrastructure is limited to the main villages only. In general, the percentage of population without access to safe drinking water is high (around 50 to 60%) and sanitation services coverage is even lower.
For the Ayeyarwady delta the need for drinking water supply and waste water treatment plants is also high. Salt intrusion and contamination with arsenic create additional challenges to safe water supply.

Local people in the Tana delta depend on water abstracted directly from the Tana River which makes them vulnerable to water-borne diseases. This is due to inadequate investments in water infrastructures downstream.

Roads, railways and ports are constantly expanding

Some of the deltas, such as the Rhine-Meuse, Mississippi River, and Yangtze deltas have a highly developed infrastructure centred around a major harbour and city. River and sea transport has historically been the prime factor for economic development. For instance the US has long utilized the Mississippi river as a major transportation corridor for shipping goods to international markets, as well as supplying goods to the interior of the country. Therefore, ports and navigation channels have been well developed in the delta. Road infrastructure in the Mississippi River delta is concentrated near the city of New Orleans. Downriver from the city the road network is not very well developed as it mainly serves local transport. In the Netherlands, the harbour of Rotterdam is continuously expanding and currently new port facilities are created by reclaiming land from the sea. Along the Yangtze it is the rapidly expanding city of Shanghai and its port that constantly demands an expansion of the infrastructure. The Yangtze estuary deepwater navigation channel project that started in 1998 has now succeeded in reaching a water depth of 12.5 metres.

Road/railway infrastructure in the deltas of the Ciliwung and Ganges-Brahmaputra-Meghna and to a lesser extent of the Mekong and Nile rivers are currently inadequate in the sense that they hinder economic development. The rapid urbanization of Jakarta results in severe shortcomings in the provision of infrastructure. The development of road infrastructure is lagging behind the growth of traffic, resulting in severe traffic jams during almost the entire day. Infrastructure for transport in Bangladesh is rather poorly developed. The infrastructure in the Johannesburg-Maputo international socio-economic axis of development is rapidly improving.

The Parana delta is well connected to the Buenos Aires Metropolitan Area and other urban areas along the deltas by railways and highways. This infrastructure is also integrated with the port system located along the delta, which is the most important fluvial network of the country. Public investment in highways encouraged the integration of the delta into the dynamics of the metropolitan expansion from the basis of private transportation but has also led to urban sprawl and daily commuting to Buenos Aires.

In the Zambezi delta the road network has secondary and tertiary earth roads with good to reasonable conditions. However road maintenance is poor and after long periods of rainfall it is almost impossible to drive these roads.

In Mayanmar the government has taken steps to develop new ports and maintain the existing ones. Still, poor infrastructure, such as the lack of proper roads, electricity, limited

telephone networks and dependency on traditional river transport limits the economic development of the The Ayeyarwady Delta. The Tana delta is not well networked in terms of transport infrastructure. The development of Lamu Port could stimulate other infrastructure developments.

Base layer (Natural resources)

Pressures on the base layer of deltas can be subdivided into geological, hydrological and ecological/environmental pressures. Geological pressures are coastal erosion and river morphodynamics, which may lead to loss of land and infrastructure. Hydrological pressures include flooding, salinisation, and freshwater shortage, of which the latter two are strongly related, and therefore taken together in this study. The category of ecological/environmental pressures includes water and soil pollution, and wetland and biodiversity loss.

Based on the delta descriptions an inventory of the base-layer pressures has been prepared. Table 5 shows an overview of this inventory. Note that the scores mainly indicate whether the pressure presently is a problem, which partly depends on land use and population density. Base-layer pressures in the Danube delta, for example, generally score low in Table 5 because this delta is largely in a natural state and uninhabited. Adequate measures may also mitigate pressures. For example, coastal erosion in the Rhine-Meuse delta could be a severe problem, but at present is well under control due to extensive sand nourishments. It is also important to remember that not all pressures are caused by human interference in the delta system. Especially river morphodynamics (channel migration and distributary shifting) and flooding are natural delta processes that, to some extent, are needed to maintain a healthy natural delta system. In a delta occupation perspective, however, they can be classified as pressures. The scores should be regarded as an expert judgment at a fairly aggregated level. Below, the different pressures and the scores are briefly discussed with some examples from the deltas studied.

Table 5: overview of base-layer pressures in the studied deltas. In green the additional four deltas

	Coastal erosion	River morpho-dynamics	Flooding	Salinisation / freshwater shortage	Water and soil pollution	Wetland and biodiversity loss	Overall Score
Nile	••	•	•	•••	•••	••	–
Tana	•	••	••	••	••	••	0
Incomati	••	••	••	••	••	•••	–
Zambezi	•	•	•	•	•	••	+
Ganges-Brahmaputra-Meghna delta	••	•••	•••	•••	•••	•••	– –
Yangtze	•	•	••	••	•••	•••	–
Ciliwung	••	•	•••	••	•••	•••	– –
Ayeyarwady	•••	•••	•••	•••	••	•••	––
Mekong	•	••	••	••	•••	••	–
Rhine-Meuse	•	•	•	••	•	••	0
Danube	••	•	•	•	•	•	+
California Bay-Delta	•	•	•	•••	••	••	–
Mississippi River Delta	•••	•	••	•	•••	•••	–
Parana	••	••	••	••	••	••	–

• = *minor and/or well controlled*

•• = *intermediate and/or partly controlled*

••• = *major and largely uncontrolled*

resilience / sustainability:

++(very good), + (good), 0 (medium), – (low), –– (very low)

Geological pressures

While coastal erosion is a potential threat that is well controlled by effective measures in the Rhine-Meuse delta, it is still a lesser problem in some other deltas (e.g., Yangtze, Mekong, Zambezi, Tana and Ganges-Brahmaputra-Meghna) due to sufficient sediment supply by the rivers, which compensates for the marine erosion forces.

Severe coastal erosion in the Mississippi River delta is a result of subsidence, recurrent severe storms, and fixed embanked delta distributaries routing fluvial sediments across the continental shelf, where it is trapped in deep waters outside the coastal zone. Significant erosion also takes place in the Ayeyarwady River delta caused mainly by mangrove destruction and decreased sediment load due to dam construction upstream. With strong growing populations in the Tana Delta's flooding-sensitive river banks and erosion-sensitive mangrove coasts, as well as the planned upstream construction of more large dams, this delta is most likely to witness increased erosion as well. Also, in the Nile delta, coastal erosion is a large-scale problem due to fluvial sediment trapping upstream. Several coastal protection measures are taken but are hampered by the strong sediment deficit at the coastline.

The Parana River discharges 160 million ton/year of sediments into the estuary Rio de la Plata. This results in the Delta extending in size (increased surface of ca. 617 km^2/yr) and is expected to reach Buenos Aires city's coast in about 110 years. Nevertheless there is localised coastal erosion.

In most deltas river morphodynamics are not a problem due to effective engineering measures. In very large rivers, however, the standard technical solutions may be insufficient or too expensive for implementation. In the Ganges-Brahmaputra-Meghna and Ayeyarwady deltas riverbank erosion is a serious problem. In the somewhat smaller and pristine delta systems (e.g. Tana and Zambezi) the river morphodynamics can cause local damage and loss of life for especially farming communities that settled in fertile floodplains. This is partly due to dam construction upstream, tempering the natural morphodynamics, allowing people to move closer to the Delta Rivers. Consequently, with high precipitation amounts in the basin, these Delta communities are caught by surprise by the now unpredictable river bank erosion or even river course changes (Tana delta).

Hydrological pressures

With flooding being a fundamental natural process in all deltas, the different scores in Table 5 reflect different natural conditions, but, inevitably, also partly the effectiveness of flood protection measures. The high score for the Ciliwung delta results from inadequate urban water management in combination with strong subsidence, whereas the high score for the Ganges-Brahmaputra-Meghna and the Ayeyarwady deltas partly reflects the vulnerability of these areas for cyclone- or storm-induced surges.

For the latter delta, also high precipitation in surrounding mountains, exacerbated by deforestation, can cause detrimental flash floods in the lower delta regions.

For the Parana delta, with intermediate score, periodic persistent south easterly winds pushing up Rio de la Plata levels, may exacerbate flooding when combined with high precipitation or discharge.

The Mississippi River Delta and Yangtze delta may also be affected by hurricanes, but have better flood protection systems, which explain their intermediate scores. The Rhine-Meuse delta is less prone to flooding than many other deltas, partly because of an well-developed flood protection system, but also because it is located in the temperate climatic zone where extreme storm and precipitation events are much less common than in the tropics.

Flood plain in the Zambezi delta

In some cases also the perception of the delta population partly determines whether flooding should be considered as a pressure. In the Mekong, Zambezi and Tana deltas, for example, the notion that river floods bring benefits for agriculture and nature is acknowledged. Of course, such a perception strongly depends on land use in the delta.
In some deltas (Yangtze, Nile, Zambezi, Tana), upstream engineering (dams and reservoirs) moderate river peak flows, causing lower probability of river flooding.
However, for the Tana and Zambezi, the occasional extreme and rather unpredictable flooding events, caused by emergency dam spilling and high precipitation upstream, may cause significant damage to the communities that moved into the floodplains.

Increased salinisation and freshwater shortage is a problem in most deltas, but is most pronounced in deltas in arid climates, such as the Nile, Tana, Zambezi and the Sacramento-San Joaquin deltas. In these systems river water use has increased considerably (urban development or large-scale irrigation upstream), and salinisation of soils is enhanced by high evaporation.

In the Ganges-Brahmaputra-Meghna and Ayeyarwady deltas saline water intrusion is highly seasonal, due to a strongly seasonal monsoonal climate. Salinity and its seasonal variation in this system are a dominant factor for the coastal ecosystem, fisheries, agriculture and drinking water supply.

Salinisation seems a minor problem in the Mississippi and Parana River delta relative to other pressures, such as coastal wetland loss due to subsidence or eutrophication.

For the Tana and Zambezi deltas, proposed developments in the lower regions or in offshore areas adjacent to delta mouths, will likely lead to increased seawater intrusion and consequently further pressures from increased salinity or sodicity of soils, floodplains and groundwater especially in the lower delta.

Ecological/environmental pressures

Increasing water and soil pollution is a major problem in nearly all deltas studied. The Rhine-Meuse delta is a positive exception, where, for example, due to international cooperation in the whole river basin, the quality of river water has much improved since the 1970s. Also, agricultural and industrial output of pollutants has strongly reduced following implementation of strict legislation. However, in most deltas rapid urbanization, industrial development, agricultural intensification or mining activities strongly compromise water and soil quality. In the Mississippi and Zambezi River deltas for example, eutrophication of surface waters is a real issue. The sources of nutrients are inadequately treated sewage and agricultural and urban runoff.

The reduction of the wetland area has aggravated the problem in most deltas. An example of native habitat loss is found in the Parana Deltas islands where the rate of wetland loss due to polderization has been estimated to around 10.500 ha/year.

An increased loss of wetlands and unique riverine remnant forests has been reported for the Tana River delta. The Tana River delta has been added to the RAMSAR list since 2012 for this reason.

Comparable to the Tana delta, the distributaries of the Zambezi River delta have become disconnected due to construction of flood protection embankments and upstream dam construction. The subsequent lack of flooding changes vegetation patterns in the delta region and leads to a decrease in mangrove area. As in the Ayeyarwady, these kinds of developments allow people to move safer into these areas and as a result the remaining forests and wetlands are degrading further due to increased pressures from encroachment, uncontrolled resource exploitation and coastal development (paddy fields and shrimp ponds).

A dramatic example is the Yangtze delta. Every year, 25 billion tons of sewage and industrial waste is discharged into the Yangtze representing 42 % of China's total sewage and 45 % of the industrial discharge. This severe pollution strongly exceeds the self-purifying capacity of the river, floodplains and wetlands and constitutes a threat to all life in the delta and public health.

Natural delta ecosystems generally deteriorate in two dimensions: (1) area is lost due to urbanization, expansion of agricultural lands and coastal erosion, (2) ecosystem quality including biodiversity is lost due to pollution, changing hydrological conditions, invasion of exotic species, and extinction of species due to loss of habitat or overexploitation. In fact the state of ecosystems is influenced by most of the pressures on deltas described above, and as such ecosystem health can be considered an indicator of the summed effect of multiple pressures on the delta.

On the other hand, healthy delta ecosystems provide many services to the delta communities, which are jeopardized by further delta deterioration. Therefore, loss of wetlands, riverine and mangrove forests and biodiversity also represents a significant pressure on the functioning and resilience of the delta system.

The mangrove forests in several deltas suffer from overexploitation (e.g., GBM, Ayeyarwady, Zambezi and Tana). For the Sundarban mangrove in Bangladesh this also means a decrease in capacity to buffer cyclonic storm surges.

In the Mississippi River delta the conservation of wetlands, as a shield against hurricane impact, is a main issue. About one third of the delta is protected against inundation and part of this area has been converted to dry land. From the 1930s some 4,000 km^2 of coastal wetland has been converted to open water. A number of factors have been linked to this land

loss, including construction of flood control levees along the Mississippi river, a reduction in the amount of suspended sediment load of the Mississippi river due to structures upriver such as dams, oil and gas extraction under the delta, altered wetland hydrology due to canal construction, salt water intrusion, wave erosion along exposed shoreline, sea level rise, and compaction of the relatively young subsoil of the delta.

Governance

Based on the delta descriptions an inventory of the present condition and problems regarding governance issues has been prepared. Table 6 shows an overview of this inventory. The qualifications should be regarded as an expert judgment at a fairly aggregated level. It enables to draw some general conclusions that are formulated below.

Cooperation between government agencies is a major challenge

Although there is a growing awareness of the importance of good cooperation between different echelons and departments within the government, satisfactory results are still scarce.

Even in the US where there is a dense governance framework, with dynamic interplay between local governments, state and federal agencies, this has led to surprisingly little result.

The governance activities in the Mississippi River delta are carried out by a combination of Federal, State and local agencies, which could not prevent the rather dramatic developments of the past decade. For instance, the task force of 5 federal agencies and the state of Louisiana to develop a 'comprehensive approach to restore and prevent the loss of coastal wetlands in Louisiana' did not result as yet in a significant reduction of the ongoing loss of wetlands.

Table 6: overview of status of governance in the studied deltas. In green the additional four deltas.

	Cooperation between levels and sectors of government	Cooperation between government and private sector	Involvement of stakeholders and citizens	Approaches for dealing with risks and uncertainties	Overall Score
Nile	••	••	••	••	0
Tana	••	••	••	•	–
Incomati	••	••	••	•	–
Zambezi	••	•	••	••	–
Ganges-Brahmaputra-Meghna delta	••	••	••	•••	0
Yangtze	••	•••	••	••	0
Ciliwung	••	•	••	••	–
Ayeyarwady	••	•	•	••	–
Mekong	••	••	•••	••	0
Rhine-Meuse	•••	•••	•••	•••	+
Danube	•••	•	••	••	0
California Bay-Delta	••	•••	•••	••	0
Mississippi River Delta	••	••	••	••	0
Parana	••	••	•••	•	0

- • *Practically non-existent, unknown*
- •• *First initiatives*
- ••• *Developing, mixed results*
- •••• *Fully developed, satisfactory results*

resilience / sustainability:

++(very good), + (good), 0 (medium), – (low), –– (very low)

In the Netherlands a Delta Programme was established, which involves integration of land use planning, flood risk management, fresh water supply and urban restructuring. This Dutch Delta Approach consists of involving all relevant stakeholders (multi-governance), joint fact-finding and an integrated (multi-sectoral) approach. The progress of the Delta Program and cooperation between stakeholders is monitored and supported by a politically independent Delta Commissioner.

The Danube delta provides a good example for having an organization specifically responsible for management of almost the entire delta. The Danube Delta Biosphere Reserve Administration coordinates the activities and environmental protection programme in the Danube Delta Biosphere Reserve. The cooperation of the Administration with other ministries and departments is well regulated by laws. Nevertheless sometimes gaps in communication and disputes in case of conflicting interests may appear.

In the Parana delta there is a complex network of institutions that have the competence to decide on the Parana Delta region. The diversity of functional authorities, complex institutional arrangements and conflicting visions on the delta, converge in making the design and implementation of policies and measures, including water management and land use strategies, a difficult task.

Encouraging developments to improve delta governance can be found in those countries that are in the process of administrative decentralization, such as Indonesia, Mozambique and (less pronounced) Bangladesh. Main challenges in this decentralization process are to prevent that governance becomes ineffective and to build sufficient capacity at the regional and local level. Although in Bangladesh most decisions are taken at the centre, even for local matters, efforts are underway to improve governance systems. In Vietnam, provinces already have a considerable autonomy. The government of Mozambique is implementing a decentralized administration by which the decisions are taken at district level, or a bottom up approach. There are regional river basin management units coordinated by water department.
The Mozambican Water Policy created in 1995 pushes toward decentralized administration, where decisions are taken at local/regional levels whereas the government responsibility changes from direct implementation to a more facilitative role. The coordination between different sectors of the government is carried out by technical steering groups which act as advisors to the higher level institutions (the ministries).

The Chinese government has a typical centralized authority. Cooperation between different government sectors in the Yangtze estuary is 'not easy or efficient enough, but it is improving'.

Egypt is subdivided into 26 Governorates, of which 12 are (partly) in the Nile delta. Each Ministry is represented in the governorates by a local authority. The Governor takes the responsibility of the management between all these units and offices to serve the general work-plan of his governorate.

Myanmar counts many ministries which are often working in quite a sectorial way. There is a lack of coordination and collaboration between the different institutions, including a lack of sharing of data and information. Different departments have different acts, proclamations and laws.

Cooperation between government and private sector should be balanced

There is a great variety in how the private sector can cooperate with the government. Privatization is a trend that can be found in many countries. For instance, in Bangladesh the privatization of the public sector industries has proceeded at a moderate pace. In roads, irrigation and power sectors there are good cooperation between the government and the private sector. Increasing public-private partnerships is a major policy of the Bangladesh government. In Vietnam cooperation between government and the private sector in

environmental and climate change issues has just started to develop. In the Danube delta private initiative is not well developed and where it exists it is resumed mainly to agri-tourism and other small fishery, tourism, subsistence business. In the Nile delta financial systems for projects are changing towards PPP. For instance the PPP West Delta is a new project paid totally by farmers[1]. In Mozambique the water sector is undergoing major changes towards less centralised water management, more involvement of private sector and more acceptance economic value of water. The implementation of the Water policy also led to more involvement of the private sector. The government transferred its administration responsibility for some infrastructures (irrigation, water supply systems, etc.) to the private sector and changed to playing a more facilitative role.

Although the private sector is looking into opportunities in Myanmar with great interest, it should be noted that only about 30% of the transactions is successful. This is mainly due to the lack of knowledge and legislation in Myanmar, e.g. in the specific field of Public Private Partnerships.

In the Tana delta government institutions and the private sector have had little constructive dialogue about the future of the Delta. The situation is currently exacerbated by a multitude of large-scale, potentially conflicting development proposals.

Finding the right balance between government and private sector interests is important in this respect. In the Mississippi River delta, the shipping and petroleum industries seem to have the ability to steer the government too much in the delta. While the government may have restorative priorities, in the name of the economy destructive industrial projects will be permitted. A further complicating problem of wetland management in the delta is land ownership. A mosaic of private and public properties exists that rarely coincides with natural drainage basin characteristics. Thus management plans are most often formulated for administrative units instead of natural landscape units.

Involvement of stakeholders and citizens is gaining momentum

Involvement of stakeholders and citizens is important to promote societal support for development projects. Such participation is a precondition for sustainable development if the success of the proposed measures depends on the active co-operation of stakeholders and citizens. In all studied deltas this awareness has taken roots, resulting in many different ways and stages of implementation. In California there is a very strong bottom-up approach to decision making about large infrastructural investments. Public participation is strong through workshops and community meetings. In the Mississippi River delta citizens have had a little more involvement in coastal planning issues since the 2005 hurricanes. However, the gap between the engineers/scientists and the citizens creates communication problems. In the Danube Delta Biosphere Reserve area a number of environmental NGOs are very active. Nevertheless, a lot still has to be done to improve both communication and integration of local views.

The civil society is strongly involved in the Parana Delta, either through research institutions and local groups who fight for the fulfilment of environmental rights and the protection of the region. Today there are more than 35 civil society organizations that focus their work on the Parana Delta and the surrounding area.

In Mozambique the associations of farmers have a sit in the irrigation management board; the ICZM steering committee involves private as well as individuals; WWF, IUCN and local NGO are active in supporting integrated water management.

In the Myanmar stakeholder involvement is in a very early stage. Stakeholder consultation at the planning and implementation phase of a project in different parts of the country needs to be further encouraged.

1 Statement from Delta Conference, Rotterdam

Aerial view of the islands of the Parana delta and the urban area of Buenos Aires (Verónica Zagare, 2014)

Local communities in the Tana delta are not well represented in governance processes affecting the Delta.and their views on development proposals do not have formal recognition within to the decision-making process.

In many countries public participation is regulated by law. In the Netherlands several laws and legal instruments are in place to procure involvement of stakeholders and citizens. In Vietnam all issues, policies and projects related to community development, including environmental protection and climate change must be discussed and agreed by representatives of the communities, according to the 'Ordinance of Grass Root Democracy' issued in 2007. In Bangladesh existing policy and guidelines require public consultations in all development projects. Stakeholder consultation at planning and implementation phase is therefore already practiced.

In Mozambique regular committee meetings are held at basin level and all interested or affected people are invited to join and to express their point of view and get clarifications about important decisions at basin level.

In Argentina the decision making processes is influenced by the regime on Free Access to Public Environmental Information, which seeks to guarantee the right of access to information that is under the state domain, either at national, provincial or municipal level. In addition, the Environmental Public Hearing process provides the community and organizations with the opportunity to learn about the works, activities or projects that are being (or are going to be) developed, and the positive or negative impacts that they may have on the Delta.
The Land Use Plan for the Tana delta is supposed to guide the involvement of all stakeholders in the Tana Delta.

Non-governmental organizations often play an important role in public participation processes. In The Netherlands many NGOs are influencing policy and implementation of plans at national and local level. In the Yangtze Estuary the World Wide Fund for Nature is active in water resource restoration, wetland and biodiversity conservation, low carbon economy development as well as overall policy recommendations.

In the Parana delta the level of participation has increased. Also, an increase in the participation of NGOs in the design of public policies and monitoring processes of territorial planning is observed.

Approaches for dealing with risks and uncertainties: new initiatives

Development of deltas is faced with many uncertainties. This explains a growing interest in risk management and other approaches for dealing with risk and uncertainty in a structured and systematic way. In most of the deltas these approaches are still in an early stage of thinking or implementation. New initiatives are taken with respect to studies and policies.

For instance, recently the Delta Initiative was launched, being a multi-year research and planning effort at the University of California – Berkeley focusing on the multiple risks of river floods, earthquakes and climate change that pose a threat to the California Bay-Delta.

For the Mekong delta in Vietnam several studies are being conducted regarding flood vulnerability and climate change impacts. There are several policies helping local people to deal with risks, such as the Living-together-with-floods National Program, the National Disaster Reduction Program and Central Committee for Flood and Storm Control.

The Danube Delta Biosphere Reserve Authority develops management plans which are discussed and adapted to new situations every few years.

The government of Mozambique adopts a precautious attitude to deal with risks. For instance, the National institute for disaster management, which has the responsibility for coordinating disaster risk management at national, provincial and community levels, organizes campaigns to disseminate information about flood risks prior to flooding season and also advises people to move their settlements to higher/safer grounds.

In the Parana delta there are currently no approaches to deal with risks and uncertainties in terms of processes and policy, however it is expected that this will be developed in near future.

In the delta and coastal areas of Myanmar an early warning system for cyclonic storm surge is operational and Disaster Reduction Plans have been developed for all districts, in the aftermath of the devastating Nargis cyclone.

A typical deltaic country such as The Netherlands is in the forefront in flood risk management, due to their long history of floods. The Netherlands has chosen a flood defense strategy centuries ago, but there is a growing focus on more resilient flood risk management strategies, early warning and recovery programs (pro-action). To safeguard the Dutch Delta for future flooding and to prepare the country for future droughts and water scarcity, a Delta Programme was established to assess impacts of climate change scenarios and socio economic developments and to explore policy options. Based on that an adaptive delta management plan is being elaborated taking into account uncertainties up to 100 year in the future.

Bangladesh also focuses on the development of flood forecasting and early warning systems, which has been practiced for many years already for coastal storms surges. The existing National Water Management Plan and Coastal Zone Policy for Bangladesh show explicit attention to long term sustainability goals and currently a Bangladesh Delta Plan is being developed.

Adaptive measures

Various types of adaptive measures can be proposed to improve resilience and sustainability of deltas. The types distinguished in this study are: technical, ecological, economic and institutional measures. Technical measures comprise all 'hard' adaptations of the physical environment and infrastructure in the delta. Ecological measures are 'soft' adaptations, designed to support, restore or strengthen the natural delta processes that lead to resilience. Economic measures include financial or legal arrangements that can be made to support and promote activities that contribute to delta resilience and sustainability, and, on the other hand, to restrict activities that counteract sustainable delta development. Institutional measures involve adaptations at the level of governance and society.

Based on the delta descriptions an inventory of adaptive measures has been prepared. Table 7 shows an overview of this inventory. The scores should be regarded as an expert judgment at a fairly aggregated level, giving a crude indication of the approach followed/ proposed in the various deltas. Below, the different adaptive measures and the scores are briefly discussed with some examples from the deltas studied.

Table 7 shows that adaptive measures in general tend to be technical and ecological, rather than economic or institutional. In the Rhine-Meuse, Ganges-Brahmaputra-Meghna, Zambezi and Ayeyarwady deltas, there is a relatively strong focus on technical measures, whereas in the California Bay-Delta and Yangtze delta preferentially ecological measures are proposed. For other deltas the picture is more balanced. In the Danube delta, which is largely a nature reserve with very low population density, very few adaptive measures are taken.

Technical measures

The most important technical measure in the Rhine-Meuse delta is re-enforcement of dikes and dams to bring these up-to-date with legal safety levels. Higher safety levels are proposed and will demand further measures. Other technical measures proposed in the Rhine-Meuse delta include land reclamation, by extensive sand nourishments or construction of polders,

Table 7
Comparative overview of the types of adaptive measures proposed for the studied deltas. In green the additional four deltas.

	Technical	Ecological	Economic	Institutional
Nile	••	•	•	•
Tana	••	•	•	••
Incomati	•	••	•	••
Zambezi	•••	•	••	••
Ganges-Brahmaputra-Meghna delta	•••	•	•	•
Yangtze	•	•••	•	•
Ciliwung	••	••	•	••
Ayeyarwady	••	••	••	••
Mekong	••	••	•	••
Rhine-Meuse	•••	•••	••	••
Danube	•	•	•	•
California Bay-Delta	•	•••	•	•
Mississippi River Delta	••	••	•	•
Parana	••	••	••	••

• *none or few*
•• *some*
••• *many*

and compartmentalisation, which involves the realization of extra infrastructure behind the dikes to reduce the flooded area in case of dike-breach event. A slightly different, but equally technical, approach is followed in the Ganges-Brahmaputra-Meghna delta, with investments in flood shelters, early warning systems and floating houses and facilities, as well as further embankments and dams.

Technical measures for increased water supply are planned in the Ayeyarwayd, Tana and Zambezi delta, eg tube-wells or reservoir. Data dissemination and early warning systems is a technology that is developing rapidly and with interest from the Ayeyarwady, Parana, Tana and Zambezi delta.

Ecological measures

A number of adaptive measures proposed for the Yangtze delta aim at restoring and using the natural wetlands to improve resilience. Examples include: green dredging, i.e., using dredged sediments to create new wetlands, enhancing sediment trapping in wetlands, and storing rainwater in wetlands for natural purification. Along with these measures control of invasive species and reintroduction of large mammals to increase biodiversity is proposed. Currently, the Yangtze delta wetlands are under high pressure of strong urbanization and

The Rhine-Meuse delta from space

extensive water and soil pollution. Therefore, the measures are urgently needed, although it can be expected that they will need to be supplemented by short-term technical flood-protection measures. A different situation exists in the Sacramento-San Joaquin Delta, where the delta population is smaller and rural. Many plans exist for restoration of wetlands in this delta and in San Francisco Bay, including measures to enhance peat growth on delta islands to reverse subsidence. Important ecological adaptive measures in the Rhine-Meuse delta are taken in the Room for the River project, which involves the creation of extra flow and storage capacity for river floodwaters, along with floodplain ecosystem rehabilitation.

Plans do exist for sustainable delta management that include measures such as restoration and reforestation (Ayeyarwady), creation of protected areas (Ayeyarwady and Parana) and environmental flows (Tana, Zambezi).

Economic and institutional measures

Hardly any economic measures are proposed in the studied deltas. For the Rhine-Meuse delta a few measures are considered that, at least partly, relate to economic activities: (1) adapted forms of building and construction, (2) financial instruments to support/promote 'delta-friendly' economic activities, (3) risk-based allocation policy, in which economic activities (land use) are dependent on agreed safety levels and related zoning. Currently, these measures need elaboration and are far from large-scale implementation.

Institutional measures

Many institutional measures are being implemented in the Rhine-Meuse delta referring to the Dutch Delta plan and Dutch Delta Approach, which focuses on involving all relevant parties (multi-governance), joint factfinding and an integrated (multi-sectoral) approach.. Others examples are educational programs on hazards, vulnerability and risk management, and insurance products for damage due to storms and floods. Especially the latter two need further development. In the Ciliwung and Mekong deltas programs for public awareness-raising and disaster-preparedness are proposed as institutional adaptation measures, along with initiatives for integrated coastal zone (Ciliwung) and trans-boundary river basin management (Mekong).

The different additional four deltas have undertaken interesting economic and institutional measures, such as community programs on health, flood and/or sustainable land use (Ayeyarwady, Zambezi), establishment of river basin committees for improved governance at basin level (Zambezi), stakeholder participation (Tana) or multisectoral dialogue (Parana), management plan for the delta (Parana) or forest management plan (Ayeyarwady).

Technical methods and tools

Technical methods and tools supporting delta management and development reported from the deltas studied can be subdivided into two categories: (1) process models that describe physical processes in the base layer of the delta system; (2) decision support systems and integrated assessment and management tools that use, often rule-based, process information from the three layers of the delta system for scenario analysis of future developments. Below, the two categories will be illustrated with examples from various deltas.

Process models

A suite of advanced process models is available for the Ganges-Brahmaputra-Meghna delta. Examples for the river system include the 2D HD and 1D HD models of hydrodynamic and morphological processes in key rivers in the delta. Coastal/marine process models are the Bay of Bengal (BoB) model, which includes a storm-surge prediction tool, and the SAL model, which is a salinity model for the near-coastal river system. All these models have been developed by the Institute of Water Modelling in Bangladesh. In the Rhine-Meuse delta and the Ayeyarwady, Delft3D, developed by Deltares, is the leading modelling system to investigate hydrodynamics, sediment transport and morphology and water quality for fluvial, estuarine and coastal environments. For the river system, SOBEK and WAQUA are alternatives for, respectively, 1D and 2DH studies.

In the USA (Sacramento-San Joaquin and Mississippi River deltas), HEC-RAS of the US Army Corps of Engineers is the standard model for one-dimensional flow and sediment transport computations, and water temperature modelling. A different kind of process model is a geological delta evolution model. The National Center for Earth Surface Dynamics in the USA has developed a theoretical framework for the quantification of the response of deltaic systems to the effects of subsidence and rising sea level. In addition, NCED has developed a numerical model that can quantitatively predict land-building by means of river diversions in the Mississippi River delta.

Decision support systems/ integrated assessment and management tools

Regarding adaptive delta management in the Netherlands several tools are applied to support decision making, such as scenario analyses, and adaptive tipping points and pathways approach. The Institute of Water Modelling in Bangladesh has issued a range of decision support systems (DSSs) for water resources management, reservoir operation and coastal zone management. In the Netherlands, the river basin model STREAM was developed by the Institute for Environmental Management (IVM). STREAM is a spatial hydrological model that allows for assessing hydrological impacts due to changes in climate and socio-economic drivers in river basins. STREAM has been applied to various rivers basins in the world, including the Rhine-Meuse, Ganges-Brahmaputra-Meghna, Yangtze, Nile and Incomati basins.

In Myanmar RIBASIM is applied, a generic model package developed by Deltares for simulating the behaviour of river basins under various hydrological conditions,. The model package is a comprehensive and flexible tool which links the hydrological water inputs at various locations with the specific water-users in the basin. Also WFlow is used, a distributed hydrological modelling platform generating rainfall-runoff for all major river basins and serves as input for RIBASIM and SOBEK.

In Mozambique several tools for hydrological modeling, integrated water resources management and flood protection are applied (DRIFT, HEC, VIC, MIKE Flood ARA, WEAP, HUGO and WRSM2000 Zambezi).

In the Parana delta many methods and tools are applied for assessment of ecosystem functions, socio-economic valuation of ecosystem services (including sustainability indicators), scenario analyses regarding urban and environmental impacts, mapping and GIS analyses.

A different type of tool is ARK Routeplanner, which constitutes a framework for assessment and cost-benefit analysis of climate adaptation options, developed by Wageningen University and Research Centre in the Netherlands.

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Chapter 4

Comparison of delta score cards

Comparing the score cards of the deltas produces a broad picture regarding the problems and sustainability of the major deltas in the world (table 8). It also has the advantage that it identifies in what way deltas resemble or differ from each other. Scores for each of the deltas are based on indicators as well as interpretation of the extended descriptions, which can be found in a separate working document. For some indicators quantitative data are available. For other indicators these data are lacking, incomplete or only available in qualitative format. The combined scorecard, below, should therefore be used with care. It will certainly lead to discussions and questions why a certain delta has a higher score than another delta. But this should not be seen as a weakness, but as an intended spin-off of this scorecard: only by such discussions better insight can be gained regarding the interpretation of concepts such as resilience and sustainability, which are difficult to define and quantify. And they may eventually lead to an update of the scorecard altogether.

Comparison of the scorecards for the different deltas clearly shows that current overall sustainability (column 6 in table 8) is not satisfactory for most of them. Many are in the danger zone (orange), which means that they are very vulnerable to adverse drivers of change. The GBM and the Ciliwung deltas are in a critical state and score lowest (red), because they have major problems for all layers and also governance has not yet been capable to improve this situation.

For the deltas that are in or beyond the danger zone the reasons for this position differ. The Ciliwung delta, GBM delta and Nile delta are examples of deltas that have to cope with very high land and water demands due to high population pressures, which combined with a moderate (Nile) to inadequate (Ciliwung and GBM) infrastructure lead to significant problems. The California Bay-Delta and Mississippi River delta have moderate land and water pressures, but their major problem lies in the rapid declining nature values (e.g. ongoing wetland loss in Louisiana). Furthermore, their current flood vulnerability in combination with the weak flood protection system results in relatively high flood risks. The Ayeyarwady delta faces a similar situation with underdeveloped infrastructure and high vulnerability to extreme events such as cyclones, storm surges and extreme rainfall. Also the Incomati and the Tana delta combine a moderate land and water pressure with degrading natural resources and an insufficient infrastructure.

Positive exceptions are the Yangtze, Mekong, Rhine-Meuse, Danube, Zambezi and Parana deltas. The Rhine-Meuse delta can currently be considered to have a relatively good sustainability, mainly because of the high score for infrastructure, moderate land and water use and relatively good governance. The Danube delta scores positive on the status of all three layers, which is not a surprise considering the very low population density of around 5 inhabitants per km^2. The Yangtze delta (and maybe the Mekong delta) seems to be in a transition zone: currently the demands on land and water use can be balanced by the infrastructure. But the natural resources are in decline and land and water use are on the rise, which in due time could affect sustainability negatively.

In the Zambezi delta the pressure on land and water use is considered low due to low population density and the delta has good and sufficient natural resources. However, the flow regime and ecosystem has changed considerably due to the construction of upstream dams.
The average land and water use in the Parana delta is still estimated to be sustainable but in the lower delta the pressure is increasing because of the growth of the Buenos Aires Metropolitan Area with expected negative impacts.

Table 8: Comparative overview of the score cards of 14 deltas studied. In green the additional four deltas.

Current situation	Land and water use (occupation layer)	Infra–structure (network layer)	Natural Resources (base layer)	Governance	Resilience & Sustainability Indicator		
					Current	Moderate Scenario	Extreme scenario
Nile delta	––	0	–	0	–	–	––
Tana	–	–	0	–	–	–	––
Incomati delta	0	–	–	–	–	–	––
Zambezi	+	–	+	–	0	0	–
Ganges-Brahmaputra-Meghna delta	––	––	––	0	––	–	––
Yangtze delta	–	+	–	0	0	0	––
Ciliwung delta	––	––	––	–	––	––	–
Ayeyarwady	–	––	––	–	–	0	–
Mekong delta	0	0	–	0	0	+	0
Rhine–Meuse delta	+	++	0	+	+	0	–
Danube delta	+	+	+	0	+	0	0
California Bay–Delta	0	–	–	0	–	0	–
Mississippi River Delta	0	0	–	0	–	0	–
Parana	+	0	–	0	+	0	–

resilience / sustainability: *++(very good), + (good), 0 (medium), – (low), –– (very low)*

With regard to the developments on the medium term (2050), we can distinguish two counteracting drivers of change: on the one hand there is the expectation that with economic growth, technological improvements and improved governance, the current problems stemming from inadequate infrastructure and poverty can be ameliorated. On the other hand we find also negative impacts of growth by increased pressure on land use and natural resources, and climate change (including extreme events) impacting the natural systems and their resources (base layer), which reduces the enabling conditions for continuing working and living in a delta.
The challenge is to have a socio-economic development that will be sustainable, also contributing to improved resilience of deltas.

For several deltas (e.g. the GBM, Mekong, California Bay-Delta, Mississippi River and Ayeyarwady deltas) there is slight optimism that with a moderate economic and climate change scenario the improvements in infrastructure will outweigh the adverse effects of climate change, resulting in better sustainability. However, in a more extreme scenario it is expected that the balance will tilt to the negative side, leading to an overall reduction of sustainability.

For all the other deltas it is expected that both scenarios make it a lot more difficult to maintain the present resilience and sustainability status, leading to lower scores in 2050 for most of them.

Chapter 4

Research gaps and opportunities for knowledge exchange and collaboration

An inventory of research gaps has been carried out based on the delta descriptions. Table 9 provides an overview of the issues that have been identified for further research. The specific knowledge gaps/research questions raised in the delta descriptions were aggregated in the broader issues presented in the table. This process inevitably goes with some information loss, but on the other hand facilitates comparison and identification of potential opportunities for collaboration. Opportunities for collaboration concern the issues that were put forward as research gaps in multiple delta descriptions. In the table the issues have been ranked per category (spatial layers and governance) based on the number of deltas for which related research gaps were mentioned.

	Nile	Tana	Incomati	Zambezi	Ganges-Brahmaputra-Meghna
Occupation layer					
Socio-economic scenarios (6)	●	●	●		
Water use and treatment (5)	●	●	●	●	●
Integrated spatial planning (5)	●	●	●	●	●
Ecosystem services (5)	●	●		●	
Land-use change modelling (4)	●	●		●	●
Adaptation to salinisation (2)	●	●			●
Network layer					
Freshwater management (7)	●	●	●	●	●
Dikes and dams (5)	●	●			●
Transport (3)	●		●	●	
Flood forecasting/early warning systems (1)		●		●	●
Base layer					
Effects of changes/ eco-system functioning (9)	●	●	●	●	●
Building with nature and natural safety (8)	●	●			●
Monitoring changes (7)	●	●		●	●
Predicting changes (7)	●	●		●	●
Base-layer data management (3)		●		●	●
Governance					
Governmental roles and arrangements (6)	●	●		●	
Integrated delta management (6)	●	●	●	●	●
Communication/capacity building (4)	●	●	●		●
Financial arrangements (4)		●			●
River basin cooperation (2)			●		●
Policy impact studies (1)		●			

Important issues for knowledge exchange and collaboration obviously are 'socio-economic scenarios', 'water use and treatment' and 'integrated spatial planning' (occupation layer), as well as 'freshwater management' and 'dikes and dams' (network layer). The most prominent field of potential inter-delta research cooperation concerns various base-layer issues, ranging from monitoring and predicting changes, through understanding cause-and-effect relationships and ecosystem functioning, to natural safety and 'building with nature'. As to governance, the major issues identified for cooperation are 'governmental roles and arrangements' and 'integrated delta management', which involves risk based approaches and dealing with uncertainties.

Of course, the mere identification of shared problems and issues for further research is no guarantee for successful collaboration. Especially, geographical variation among deltas

Table 9: Inventory of issues for which research gaps have been identified in various deltas. Between brackets for each issue the number of deltas for which this issue is identified as a research gap. In green the additional four deltas.

Yangtze	Ciliwung	Ayeyarwady	Mekong	Rhine-Meuse	Danube	California Bay-delta	Mississippi River delta	Parana
•	•	•			•		•	•
	•	•		•				•
	•	•		•				•
•	•	•		•	•			•
	•	•				•		•
		•						
	•	•	•	•		•		•
	•	•		•		•		
	•	•						
		•						•
•	•	•		•	•	•	•	•
•	•	•	•	•	•		•	
•	•	•	•	•		•		•
	•	•	•	•	•	•		•
	•	•					•	•
	•	•	•	•		•	•	•
•	•	•			•			•
	•	•						
	•	•		•		•		
		•						
	•	•						

needs to be taken into account. Developed solutions, for one issue in a certain delta need not to be applicable to the same issue in another delta. For example, dikes and dams designed for the temperate-zone storm surges in the Rhine-Meuse delta may not be able to withstand the tropical cyclone-induced storm surges in the Ganges-Brahmaputra-Meghna delta. Conditions of salinisation in arid environments with a high evaporation (e.g., the Nile delta) may be very different from those in a temperate humid environment (e.g., the Rhine-Meuse delta), and this will certainly affect management solutions. Also, ecosystem-functioning in deltas varies widely as a function of geographical location. As to governance, socio-cultural differences between deltas will be reflected in different governmental styles. It seems that especially base layer and governance features are highly delta-specific, which needs to be acknowledged in inter-delta knowledge exchange and research collaboration.

Satellite image of the Ganges-Brahmaputra delta in India and Bangladesh

Opportunities for follow-up

This current report can be considered as a starting point for further research and knowledge exchange on the current and future state of deltas. The tables above make very clear that deltas deserve attention and (innovative) solutions and best practices are very much needed. For this we can build on already available knowledge and expertise available in many deltas. Latest delta technologies can be tapped from highly developed deltas , but also indigenous knowledge should be mobilised in order to account for diversity in natural and socio-cultural environments.

Although the problems in deltas need tailor-made solutions, a change of perspective, by inter-delta comparison and cooperation, can lead to new and unexpected opportunities. Acknowledging differences between deltas will help to better single out the key points of shared interest and focus research cooperation. There are major opportunities for knowledge exchange and collaboration at the level of understanding the processes in the base layer and their interactions with the network and occupation layer. But the governance and planning processes will play a vital role in sustainable development. In other words delta management needs an integrated approach covering governance and all three layers, and

thus delta knowledge development ideally needs a similar balance. This means also that a good dialogue is needed between all 'delta stakeholders': government, knowledge institutes, private companies, NGOs and the delta society.

Some additional questions which require attention are:

- Which solution oriented Best Practices are available that can be of use for other deltas?
- Which deltas are in lack of monitoring data to assess what is going on?
- Which issues are most relevant in urbanised deltas and which in rural deltas?

Envisaged role of Delta Alliance

Delta Alliance is an international knowledge-driven network organization for deltas worldwide, a vehicle for increased cooperation between many parties involved in delta management. The Delta Alliance was initiated in 2010 by the Netherlands addressing the need for more international knowledge exchange for improving the resilience of deltas worldwide, building on the own long term experiences in the Dutch delta. Its mission is to improve the resilience of deltas through more integrated and effective efforts, building on scientific research and knowledge exchange. It aims at disclosure of knowledge for application by a wide audience of end-users from the knowledge, public and private sectors, as well as to identifying upcoming research agendas.

With increasing pressure from population growth, industrialization and a changing climate, it is more important than ever that these valuable and vulnerable locations increase their resilience to changing conditions. Delta Alliance brings stakeholders involved in delta management together in order to benefit from each other's knowledge and experience and as such contribute to an increased resilience of their delta region.

When talking about delta knowledge, it's meant knowledge for an integrated approach. Apart from the water sector this includes among others socio economic aspects, ecosystems, land use and relevant governance aspects. Advocating and applying an integrated delta approach is part of the mission of the Delta Alliance.

Delta Alliance has currently ten network wings where activities are focused: California Bay (USA), Ciliwung and Mahakam (Indonesia), Mekong (Vietnam), Rhine-Meuse (the Netherlands), Nile (Egypt), Pantanal (Brazil), Ganges-Brahmaputra (Bangladesh), Mississippi (USA), Yangtze (China) and Parana (Argentina). Some other 10 deltas have shown keen interest to join the Delta Alliance network, notably from Ghana, Taiwan, Senegal, Kenya, Ghana, Benin, Rumania, Myanmar, Italy, Spain.

Delta Alliance will continue to implement its resilience strategy by:

- Assessing and monitoring the resilience of deltas to climate change and other pressures (including a regular update of the current and future state of deltas)
- Creating pressure, awareness and momentum for improved resilience through knowledge sharing and capacity building activities.
- Providing knowledge generating activities for improved resilience of deltas to climate change and other impacts.
- Showcasing best practices and lessons learned from across deltas for both preparedness and
- Response building on examples in the Delta Alliance wings
- Hosting Delta Alliance wing sessions in during regular events or conferences, which include practitioners and experts from deltas around the world
- Hosting an internet platform with information about deltas, including a toolbox for Adaptive Delta Management with overview of methods and tools, examples of their applications and best practices (www.delta-alliance.org)

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Chapter 4

Cooperation with other networks and programs

Research and investment in addressing the unique challenges of river delta regions are happening in many projects and programs around the world. Delta Alliance provides a framework to support the symbiosis of these countless on-going activities in delta regions, reducing unnecessary overlap and identifying gaps in efforts.

The Delta Alliance has currently many linkages with other delta related networks and initiatives such as the Global Water Partnership strategy 2014-2018, the Belmont Forum Deltas project, the GEF Transboundary Waters Assessment Programme, the Alliance for Global Water Adaptation, and the SIWI/UNEP initiated From Source to Sea partnership.
Delta Alliance is also involved in the network and knowledge sharing activities envisaged in the Sustainable Delta 2015 initiative endorsed by ICSU.

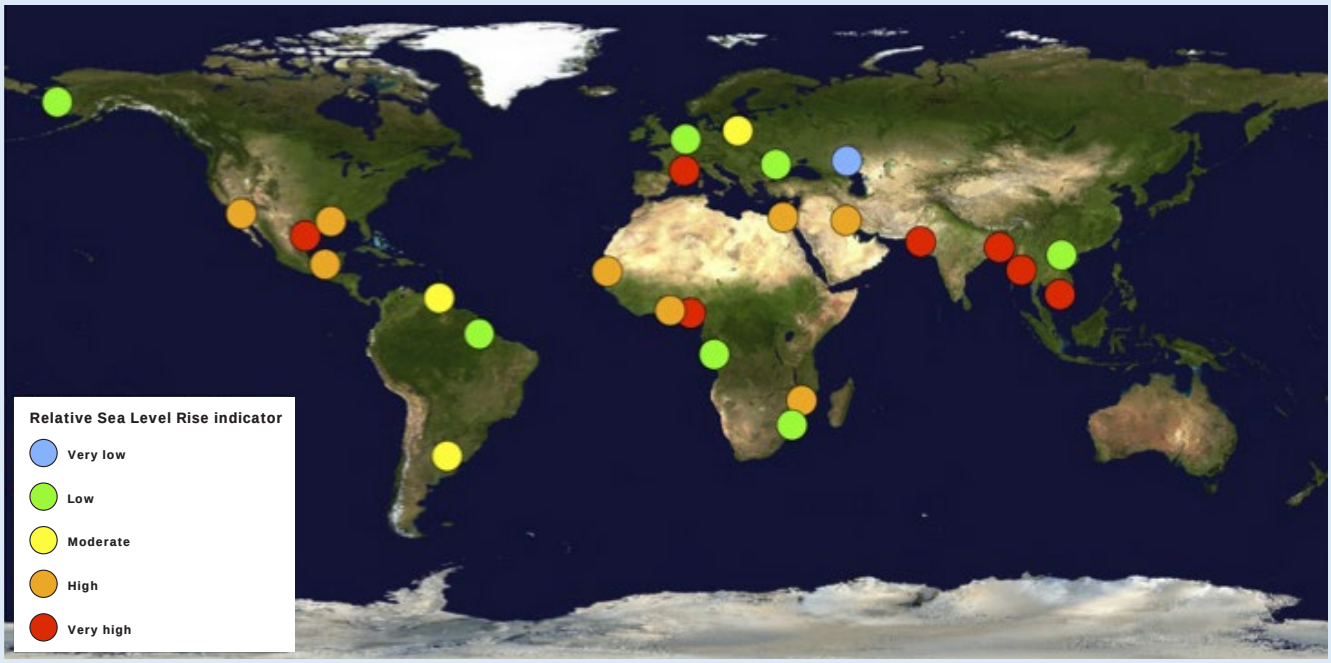
TWAP delta vulnerability assessment of 26 deltas

The results of the TWAP delta vulnerability assessment are elaborated on the basis of a risk categorisation for four indicators: relative sea level rise, population pressure, wetland ecological threat and governance, building on already existing information. The results of the relative sea level rise indicator are illustrated below.

For the TWAP assessment aggradation, subsidence and sea level rise is assessed for each delta, with a transboundary river basin, from published data (Syvitski et al 2009 and Ericson et al 2006). Based on the available quantitative data, each delta is assigned to one of five relative sea level rise (RSLR) categories, largely following Ericson (2006), with category 1 representing no RSLR (<= 0 mm/yr) and category 5 representing high RSLR (>5 mm/yr).

From the 26 deltas assessed the most at highest risk are in Asia (Ganges, Indus, Irrawaddy and Mekong). In Africa and America also a considerable number of deltas are at (high) risk, especially the Niger and Rio Grande. Europe has the least transboundary deltas with only the Rhone at high risk.

One of the important factors for the RSLR is increasing population in delta (mega) cities, especially in Asia. This results often in less delta aggregation and increased human induced (accelerated) land subsidence caused by severe ground water extraction in order to comply with high(er) water demand.



Global map with relative risk categories for Relative Sea Level Rise for the selected deltas (see table 10 for detailed data)

Global Water Partnership and Delta Alliance have started in 2012 with the support of the Netherlands International Development Program – DGIS – a cooperation program that aims at developing a joint Global Program of Action on Deltas titled the 'Enabling Delta Life Initiative'. The general objective of the program is to strengthen the management of deltas. Four main work packages are envisaged about Capacity Development, Demonstration projects, Knowledge and awareness and Governance and Fundraising.

Delta Alliance has been asked to participate in **GEF funded Transboundary Water Assessment Programme** (TWAP-Rivers) for the vulnerability assessment of 26 deltas, coordinated by the UNEP-DHI Centre. The overall objective of TWAP is to undertake the first global assessment of transboundary water bodies, through a formalized consortium of partners, that will assist GEF and other international organisations to have a base line,

		Relative risk category	RSLR (mm/year)	Source
America	Amazon	2	0 - 1.5	Ericson
	Colorado	4	2- 5	Syvitski
	Grijalva	4	3 - 5	Ericson
	Mississippi	4	2 - 5	Syvitski
	Orinoco	3	0.8 - 3	Syvitski
	Parana (La Plata)	3	2 - 3	Syvitski
	Rio Grande	5	5 - 7	Ericson
	Yukon	2	0 - 1.5	Ericson
Europe	Danube	2	1.2	Syvitski
	Rhine-Meuse	2	0 - 1.5	Ericson
	Rhone	5	2 - 6	Syvitski
	Volga	1	0	Li et al
	Wisla	3	1.8	Syvitski
Asia	Ganges-Brahmaputra-Meghna	5	8 - 18	Syvitski
	Hong (Red)	2	0 - 1.5	Ericson
	Indus	5	> 11	Syvitski
	Irrawaddy (Ayeyarwady)	5	3.4 - 6	Syvitski
	Mekong	5	6	Syvitski
	Shatt-al-Arab	4	4 - 5	Syvitski
Africa	Congo	2	?	Syvitski
	Limpopo	2	0.3	Syvitski
	Niger	5	7 - 32	Syvitski
	Nile	4	4.8	Syvitski
	Senegal	4	3 - 5	Ericson
	Volta	4	3 - 5	Ericson
	Zambezi	4	5	IPCC

Table 10: Relative risk categories for Relative Sea Level Rise for the selected deltas (in blue the deltas studied in the Delta Alliance Comparative assessment of 14 deltas)

Legend

RSLR (mm/year)	*Relative Risk Category*
<=0	*1 Very low*
>0 - 1.5	*2 Low*
1.5 - 3	*3 Moderate*
3 - 5	*4 High*
> 5	*5 Very high*

Source of map and table: TWAP FSP River Basins Component – Vulnerability Assessment of Deltas in Transboundary River Basins, final draft report July 2014, Delta Alliance, UNEP-DHI

to improve the setting of priorities for funding and to formalize the partnership with key institutions aimed at incorporating trans boundary conditions into regular assessments programs. It is anticipated that this baseline will serve to assist international funding agencies in tracking the impacts of their interventions in terms of changes in state of the aquatic environments under consideration.

References

This synthesis report is based on the working documents with 14 delta descriptions, referring to many literature. For this (very) long list of literature please see the reference sections in the working documents available at www.delta-alliance.org

Appendix

Summary of delta descriptions

In the following paragraphs the main issues of the additional four delta descriptions are summarized. This involves drivers of change, pressures (in occupation layer, network layer and base layer), governance and related research gaps. The full delta descriptions (of all 14 deltas) are available in separate 'Working documents' at www.delta-alliance.org

11 Tana delta

Summary of drivers of change

Demographic trends: The Tana Delta has ca. 100,000 residents. With the total number of households of 12,457, and a mean household size of ca. 7 persons, the Delta population is growing at an estimated 3,62% a year. Over the past decade, conflicts have been increasing in the Tana River Delta as a result of increasing population, the majority of whom (over 90%) live in the rural areas

Economic developments: The main economic activities are farming, livestock keeping (pastoralism) and fishing. The settlement patterns are random but are concentrated close to the river. The Tana Delta a dry season grazing area for livestock emanating from other Counties. Fuel wood is derived from forests and woodlands located in the delta. Other products include medicinal herbs, honey and eco-tourism, including several lodges and a wildlife conservancy. Strong developments are expected in the delta due to the implementation of the Lamu Port Southern Sudan-Ethiopia Transport (LAPSSET) Corridor (see 1.1.4 for more information).

Climate change: Wide fluctuations in climatic conditions including pronounced flooding and droughts are experienced. In the next 20 years rainfall may be more prolonged, bimodal erratic, unreliable, and consequently cause more flooding events (although these may be counteracted by the building of the High Grand Falls Dam, see). In the next 40 years a possible increase of 15-25 cm in mean sea level could significantly reduce the scope of farming on those parts of the lower floodplain lying within 20 to 30 km of the coast.

Subsidence: Unknown due to lack of data. However, human induced subsidence is likely to occur when downstream sediment supply decreases due to upstream dams and reservoirs, promoting the net change in sea level rise at the coast. Subsidence due to tectonic activity or by compacting organic layers is assumed to be small.

Technological developments: The technological developments in the delta are currently limited in comparison to dams and reservoirs for power and irrigation upstream. However, the planned LAPSSET foresees major development push in infrastructure, large scale agriculture, logistics, and energy and water production.

Research gaps

Research is required in the development of impact assessment tools for various climatic impacts on delta health and functioning. The complete impact of climate change and the planned developments on delta morphology is unknown.

Summary of pressures in Occupation layer

Pressure on space: Space in the delta is currently under threat as government, corporations and foreign agencies are implementing large-scale land acquisitions (LSLA). Nomadic pastoralists as well as communities engaging in small-scale subsistence farming will be affected more with current Delta development plans. Driven by high population growth and densification of settlement the pressure on space is likely to increase further.

Vulnerability to flood: Floods have become less frequent and predictable due to dam and reservoir construction upstream. With the further development in the delta the vulnerability to flooding will increase especially at moments when dam regulation in the upper catchment fails and emergency spilling surprise growing floodplain communities with flashfloods.

Water demand / freshwater shortage: Water availability per capita in Tana Delta is today ca. 22% of the amount it was 50 years ago. The whole catchment is classified as 'water scarce' mainly as the result of a growing number of farming or pastoralist communities and increasing number of commercial irrigation schemes. With projected socioeconomic developments, water demand will increase leading to prolonged fresh water shortages in time and space throughout the whole Tana delta.

Appendix

Research gaps

- *There is need to expand the hydromet services for the delta; currently, only KENWEB appears to do substantive work on continuous data collection.*
- *In 2007, Tana River changed course near Mnadzini; it is not fully known what are the determinants of course change; hence it cannot be predicted.*
- *Food and water demand in the delta is not clearly known.*
- *With projected land use changes a detailed water balance of the delta is required.*

Summary of pressures in Network layer

Flood protection: There is iimproved upstream land use. Also, five major reservoirs have been built in the upper basin that have significantly modified the hydrological regime of the river, with a 20% decrease in the peak flows of May.

Irrigation and drainage: Upstream dams and the biofuel and large irrigation schemes impact downstream flooding processes by diminishing the possibilities for floodplain agriculture and limiting scheme cropping to the riverbanks. Generally, irrigation and drainage infrastructure are limited and poorly developed.

Water supply and sanitation: Due to inadequate investment in water infrastructure, the locals depend on surface water taken directly from the Tana River, making them vulnerable to water-borne diseases. Currently supply and sanitation are worsening and little infrastructure is implemented.

Roads, railways, ports and navigation channels: The delta is not well networked in terms of infrastructure. Although roads and power supplies do connect the major towns in and just outside the delta, the structure is aging and insufficient. With the projected plans in the delta, large infrastructural investments are expected for industrial and urban developments.

Research gaps

- *Sustainable water engineering is required for allowing full development of the Delta's limited resources now and in the future.*
- *Knowledge on implementing waste water treatment is lacking.*
- *A detailed allocation assessment, including a comprehensive water quantity and quality balance, is needed.*

Summary of pressures in Base layer

Coastal erosion: With increased pressure on the lower biotopes (forests, mangroves and reef) and a disturbed sediment and water discharge it is expected that structural integrity of the lower regions of the delta will decrease and consequently coastal erosion to increase.

River morphodynamics: A rapid analysis of river discharges at Garsen shows that peak discharge rates are largely attenuated and smoothed out between the two stations, with an average decrease in transiting volume of 76%.

Flooding (flood hazard): The flooding characteristics of wetlands, particularly the flood extent, timing, frequency, duration and flood peaks, have decreased (ca. 20%) but are more irregular.

Salinisation / salt intrusion: Salinity and sodicity problems are common in the Tana Delta where they have naturally formed under the prevailing climatic conditions and due to high rates of evapotranspiration and lack of leaching water. Land degradation by salinization is on the increase in irrigated deltaic areas where irrigation of unsuitable soils or use of poor quality irrigation water is a common practice.

Water and soil pollution: Pollutants from agriculture sector are relatively high due to lack of standards implementation. Nutrient run-off can cause eutrophication locally with possible algal blooms (including toxic blue green algae) and lowered oxygen content.

Wetland and biodiversity loss: Biodiversity loss, environmental degradation and poverty is high, resulting from increased human pressures on available delta resources and the disturbance of the (natural) structural functioning of the delta.

Research gaps

Lack of hydrological, climate and topographical data hampers the characterization of the flood events. Commonly, water fluxes are un-gauged and models too course with little predictive power.

Summary of governance issues

Cooperation between (scale) levels and sectors of government: Although 14 government institutions are currently involved in the management of the Delta and significant legislation and policy are in place at the national level to guide sectorial developments e.g. water, agriculture and mineral resources policies, the development agenda in the Delta remains largely uncoordinated.

Cooperation between government and private sector: The Physical Planning (PPA) Act mandates Local Authorities (LA) to regulate development within their areas of jurisdiction to foster orderly and sustainable development. However, government institutions and the private sector have had little constructive dialogue about the future of the Delta. The situation is currently exacerbated by a multitude of large-scale, potentially conflicting development proposals.

Involvement of stakeholders and citizens: Local communities are not well represented in governance processes affecting the Delta. The communities are largely unorganised; especially the most isolated and marginalised and their views on development proposals do not have formal recognition within to the decision-making process.

Approaches for dealing with risks and uncertainties: The Land Use Plan (LUP) for the Tana River Delta is supposed to guide the involvement of all stakeholders in the Tana Delta. The LUP framework will guide strategic Planning in the Delta to lower risks and uncertainties, and specifically addresses resource conflicts between local agriculturalists, pastoralists and large-scale agricultural schemes

Research gaps

- *Uncoordinated research and monitoring programmes that do not adequately inform the management of Delta resources on issues affecting them.*
- *A lack of adequate mechanisms to address risk management issues affecting the Delta such climate change, drought, floods and tsunami and storm surges.*
- *Inadequate partnership and cooperation between government and non-governmental organizations.*
- *Lack of coordinated institutional governance of natural resources and development.*

12 Zambezi delta

Summary of drivers of change

Demographic trends: Although Mozambique has currently a high economic growth (GDP is 14.59 billion USD with an economic growth rate of 7 %), it is considered one of the poorest countries in the world. A large part of the population lives below the poverty line, with huge disparities between rich and poor, in income between urban and rural population. Around 328,000 inhabitants (1.4% of the total population of Mozambique) live in the Zambezi delta region. The average population growth rate for the main village is around 4.1 %/ year, whereas the average growth rate in Mozambique is 3 %/year.

Economic developments: Agriculture is the largest water consumer after hydropower (open water evaporation losses). The main economical developments in the delta region are the SENA Sugar Estates and the shrimp industry. The main highway connecting the South and North of Mozambique also crosses the delta at Caia together with the railway linking the Tete coal mining hub to Beira port further south. More upstream, in the Tete Province there are huge economical developments, mainly hydropower and coal mining which has consequences for the delta.

Climate change: According to the IPCC (Intergovernmental Panel on Climate Change) prognosis the Zambezi River Basin exhibits the worst potential effects of climate change among the eleven major African river basins, mainly due to the combined effect of temperature increase (order of 0.3 - 0.6 °C) and rainfall decrease (order of 10 - 15 %). The climate changes forecasts for Africa also predict that the risk of extreme events like droughts and floods will increase including inundation due to sea-level rise in coastal areas. Estimates suggest that the Lower Zambezi runoff will decrease by 13 - 14 % and sea level is expected to rise as well. The World Bank study (2010) shows that the impact of climate change on the Zambezi delta (mainly the increase in temperature) could lead to an irrigation deficit of 27% and a reduction of basin yield of 13% by 2030.

Subsidence: A topical area in many delta's in the world. Land subsidence has not been reported for the Zambezi Delta so far. Although more than 50% of the population uses groundwater as source of water, mainly from shallow open wells or wells equipped with hand-pump, groundwater exploration is still low in the region so land subsidence due to excessive groundwater abstraction and consequent soil compaction is very unlikely

Technological developments: The Zambezi delta is developing slowly in terms of technological developments. Small scale farmers and fishermen use old fashioned technology and electricity supply is very limited. Solar panel technology for electricity supply is being promoted. Telecommunications with 3G network and access to internet is available around the main villages. There is a railway branch to Marromeu sugar plantation connected to the SENA railway. Plans for expansion of hydropower also exist with construction of Mphanda Nkuwa and expansion of Cahora Bassa by including turbines on the North Bank.

Research gaps

- *There is a need for the development of the monitoring network (eg. river discharge, reliability of rating curves, monitoring of discharge through distributaries, etc.);*
- *Monitoring of water quality to assess impacts of small scale and large scale agricultural developments, as well*

as the impacts of the large mining ventures taking place upstream;
- *Research to understand the combined river and coastal dynamics and roles of flow regime changes in these dynamics, and monitoring of sediment transport;*
- *Assessment of potential threats related to delta subsidence;*
- *Research for diagnosis and economic valuation of ecosystems as well as identification of sound management measures to protect it;*
- *There is a need to develop integrated urbanization plans taking into account flood hazard and other aspects.*

Summary of pressures in Occupation layer

Pressure on space: Pressure on space is in general low due to low population density. Nevertheless, illegal hunting and wood cutting on mangroves pose some pressure in direct vicinity of the main villages. There is large interest to have agriculture development in the delta area which can lead to significant water abstractions and subsidence.

Vulnerability to flood: After the construction of the Kariba and Cahora Bassa dams the floods became less frequent and timing is less predictable. As a consequence population felt safer and moved their settlements to the fertile floodplains and are sometimes caught by surprise during years with high floods resulting in damage and loss of lives. This encroachment results in high exposure of the community and reduced reaction time to flood waves therefore increasing the vulnerability of the population. Cyclons do occur quite frequently in the Mozambican coast. Over the last 75 years before 2005, the Zambezi Delta was hit by 9 to 15 cyclones (MICOA, 2005). But the flooding events recorded in the Delta region were mainly due to high flows in the Zambezi River coming from upstream. Flooding from sea has not been reported to affect the local communities of infrastructure so far.

Water demand / freshwater shortage: At the moment water demand is very low compared to the Zambezi average discharge and there is no freshwater shortage in the delta area. Water abstractions are regulated by ARA Zambezi. Water is abstracted from the aquifers in small urban areas but due to limited infrastructure only a small part of the population is covered by the water supply systems and this water abstraction can be considered low. Water for domestic use and farming small areas (less than 1ha) is free of charge

Research gaps
- *There is a need for improved planning to control the development of settlements in inappropriate locations such as low lying lands prone to flooding;*
- *There is a need to develop flood hazard maps to assist in the development of population settlement planning;*
- *There is a need to develop a flood forecasting model for flood management.*

Summary of pressures in Network layer

Flood protection: Flood protection dikes where built around 1893 to protect sugar fields in Mopeia, Marromeu and Luabo. Railway and roads built in the floodplains also act as flood protection. Two large dams (Kariba and Cahora Bassa) were built for flood protection, in addition to hydropower.

Irrigation and drainage: In the delta area only the SENA Sugar Estate has an irrigated agricultural field. The rest of the agricultural land owned by smallholders is rain-fed.

Water supply and sanitation: Water supply and sanitation infrastructure is limited to the main village only. In general, the percentage of population without access to safe drinking water is high (around 50 to 60 %) and sanitation services coverage is even lower.

Roads, railways, ports and navigation channels: The road network has 630 km of secondary (earth) roads with good to reasonable conditions and 330 km of tertiary roads in reasonable conditions. Road maintenance is poor. There is a 88 km railway that links with the greater SENA railway. A new railway line between Tete and Macuze in Zambeze province north of Chinde is under development by a Thai enterprise. The railway will cross the northern margin of the delta with a crossing in Shire river at a point called Shire batelão. There are three small airports and barges to transport people and goods from/to Chinde and Marromeu.

Research gaps
- Research to assess low cost water supply and sanitation alternatives;
- Research to study the effects of the flood protection measures in terms of flood risk reduction and impacts to the environment;
- Research to investigate the effect of the new proposed embankments associated with the new Macuze line over the flooding in the delta;
- Feasibility studies for the development of infrastructure in the delta region.

Summary of pressures in Base layer

Coastal erosion: Recent studies carried out during the preparation of the environmental impact assessment for the navigation of the Zambezi River have shown that the

mouth of the Zambezi is very dynamic in terms of sediment transport.

River morphodynamics: The Zambezi river is a braided to anabranched sand bed river with high sediment transport dynamics, and presenting migrating bars. Sediment trapping at Cahora Bassa dam impacts on the river morphology resulting in a colonizing and stabilizing river bed.

Flooding (flood hazard): Flooding in the Zambezi delta became less frequent and timing is less predictable after the construction of the large dams upstream. Off-season flooding associated with dam operation has been reported in the Zambezi. The floods were mostly associated with spilling in preparation for the rain season or to accommodate higher than normal flows into the reservoir. The dam releases when done without proper notification to local communities often resultin in loses of agriculture produce by farmers along the flood plain.

Salinisation / salt intrusion: Salinisation of soils has been reported. The annual floods that became less frequent had an important function of flushing accumulated salts on floodplain soils.

Water and soil pollution: The cities along the Lower Zambezi river release sewage water without adequate treatment which leads to eutrophication of the river and spreading of water related diseases. Car washing near river banks is also contributing to pollution of the river. With a low population, a low water supply coverage and a high dilution potential from the Zambezi discharge, the problems are however still small.

Wetland and biodiversity loss: Tributaries of the Zambezi river have become disconnected due to construction of flood protection embankments and change in flow regime has contributed to changes in vegetation patterns in the delta region, including decrease in mangrove area and wildlife numbers. Praagman etal 2013 report that near-coast and riverine fishery have replaced floodplain fishery, although industrial prawn catch has also reduced due to decreasing numbers of prawn. The natural reserve of Marromeu experienced reductions in numbers of waterbirds and wildlife, some of which are already classified as endangered species (Beilfuss 2012). Biodiversity lose as a result of the changes in the extent of the wetland areas have been reported in the Zambezi delta. For the entire Zambezi delta the biggest landuse is grassland (50 - 60 %) and mangroves contribute about 3 %. The mangrove cover was reduced by 24 % with a recovery of 18 % for the 1972 - 1979 period and during the 1989 - 2013 the decline was at 14% and recovery at 26%. However the reduction takes place with different rates and in different periods for the different parts of the Zambezi Delta and is not a continuous process in all areas of the delta. Poacher activities cause uncontrolled and devastating forest fires.

Research gaps

- Data collection (sediment characteristics, sediment transport, coastal erosion, salinity intrusion, improved discharge monitoring network, including development of more accurate rating-curves and accurate topographic and bathymetric surveys to produce a digital elevation model) to support analysis, model calibration and validation;
- Community programs to disseminate information about importance of ecosystem services and to tackle issues of illegal hunting and wood extraction as well as water pollution;
- Development of an integrated morphological model (for river and coastal dynamics) to study the main drivers of morphological changes and predict impacts of proposed activities and proposed environmental flows;
- Development of a salinity intrusion model to study the main drivers affecting the salinity intrusion and impacts of proposed flow regimes, other proposed activities and sea level rise including impacts on estuary vegetation and fisheries;
- Research on status of the environment, especially the biodiversity;
- Research on the quantification and importance of ecosystem services benefiting the population livelihoods and economy of the delta region;
- Topographical monitoring for land subsidence evaluation.

Summary of governance issues

Cooperation between (scale) levels and sectors of government: The Water Policy created in 1995 pushes toward decentralized administration, where decisions are taken at local/regional levels whereas the government responsibility changes from direct implementation to a more facilitative role. The coordination between different sectors of the government is carried out by technical steering groups which act as advisors to the higher level institutions (the ministries).

Cooperation between government and private sector: The implementation of the Water policy also led to more involvement of the private sector. The government transferred its administration responsibility for some infrastructures (irrigation, water supply systems, etc.) to the private sector and changed to playing a more facilitative role.

Involvement of stakeholders and citizens: Stakeholders, interested citizens in general and national and international NGO's can get involved and participate in the definition of

policies and decision making process in different ways, such as in basin committees where activities at basin level are discussed.

Approaches for dealing with risks and uncertainties: The INGC (National institute for disaster management) is an autonomous government institution with the responsibility for coordinating disaster risk management at national, provincial, district and even community levels. The government adopts a precautious attitude to deal with uncertainties.

Research gaps

- *Study of adaptive management alternatives for better implementation of the decentralization;*
- *Research on better institutional structures and capacity building for the government lower levels to enable direct implementation of the administration tasks with success;*
- *Development of integrated policies (cross-sectoral integration) and integrated master plans for basin level development activities including programs to improve living standards of rural populations;*
- *Integrated river and coastal management approach;*

13 Ayeyarwady delta

Summary of drivers of change

Demographic trends: Population of the country was estimated at 58.38 million during the census of 2008-2009. Taking into account a growth rate of 1.52 percent the actual population will be approximately 62 million. Ayeyarwady Region, covering a large part of the Ayeyarwady Delta has a population of 8,041,084 on an area of 35,032 km^2, hence a population density of 230 inhabitants/km^2. With 250 inhabitants/km^2 the delta is one of the most densely populated regions in Myanmar. This population density in Ayeyarwady Region is e.g. relatively low compared to the one of the Mekong Delta (approx. 500 inhabitants/km^2, excluding Ho Chi Minh City) and the Ganges-Brahmaputra-Meghna Delta (more than 1200 inhabitants/km^2), (Driel and Nauta, 2013).

Economic developments: The country is one of the poorest nations in Southeast Asia, 37% of the population is unemployed and 26% live in poverty. Myanmar's economy is one of the least developed in the world. In the past, GDP growth has been relatively slow averaging ~2.9% annually. A change of government in 2011, however, induced a number of policy reforms that increased GDP growth to 7.8% per annum. In 2011, Agriculture contributed ~43% to GDP, services ~36.6% and industry ~20.5% (CIA, 2011). Agriculture, forestry, and fisheries constitute the largest contribution to the economy. Approximately 75% of the rural population rely on the agriculture, livestock and fisheries sectors for their livelihoods. Other major livelihood activities in Myanmar utilise the following major products: i) wood and wood products (amongst others through destructive mangrove exploitation for charcoal); ii) copper; iii) tin; iv) tungsten; v) iron; vi) cement; vii) construction materials; viii) pharmaceuticals; ix) fertilizer; x) natural gas; xi) garments; xii) jade; and xiii) gems (Hadden, R. L. 2008). The GDP growth will be around 6.8% (2013) being the GDP per capita $1,700 (CIA, 2013; Ministry of Transport - NAPA, 2012).

Climate change: The Myanmar's National Adaptation Programme of Action (NAPA) to Climate Change (Ministry of Transport, 2012) includes the climate change predictions as presented in Table 1.

Table 1 Climate change predictions (Source: NAPA)

Climate change predictions for 2001-2020 include:

Climate change predictions for 2001-2020 include:	Climate change predictions (compared to 2001) for 2021-2050 include:	Climate change predictions (compared to 2001) for 2051-2100 include:
• an increase in temperature of ~ 0.7 ºC in the Ayeyarwady region • an increase in clear sky days in Northern and Central Myanmar exacerbating drought events • highly variable rainfall changes throughout the country with however only small increase in the Ayeyarwady region • an increase in floods and droughts resulting from variable rainfall conditions	• an increase in temperature of 1.4 ºC in the Ayeyarwady region • an increase in rainfall of approx. 250 mm in Ayeyarwady Delta • periods of heavier rains • longer dry spells	• an increase in temperature of 3.5 ºC in Ayeyarwady region • an increase of approx. 450 mm of rainfall in Ayeyarwady region • a weakened monsoon climate supported by decreased cloud coverage • an increase in drought periods across most of Myanmar

In Slangen et al. (2013) updated projections for twenty-first century regional sea-level changes are given for two sea level change scenarios (A and B) based on the IPCC-RCP climate scenarios 4.5 and 8.5 with a temperature increase

of 1.2°C–2.7°C and 2.7°C–5.4°C, respectively, between 1986–2005 and 2081–2100.

In total scenario A yields a net global mean sea-level rise of 0.52±0.19 m (mean±1σ) between 1986–2005 and 2081–2100, while scenario B yields a net global mean sea level rise of 0.70±0.26 m for the same period.

According to the Asian Development Bank (ADB), "many more people" in Southeast Asia died as a result of natural disasters between 2001 and 2010 than during the previous decade, primarily due to the 2004 India Ocean tsunami and 2008's Cyclone Nargis, whose aftermath showcased the Myanmar government's inability to respond to extreme weather. Although not directly to be related to climate change, the devastating Cyclone Nargis hit Myanmar with resulting waves of more than 6 meters in May 2008, the strongest ever (U Nyan Win, 2010) killing 138,373 people and leaving about 2.4 million affected. Total damage and loss was estimated at approximately 11.7 trillion Kyats, i.e. 4.1 billion US$ (Ministry of Social Welfare, Relief and Resettlement, 2012).

Subsidence: Most deltas are subjected to the natural geological process of long-term subsidence. Additionally, extraction of groundwater and fossil fuels may cause significant lowering of the delta surface on the short term. Other short-term processes leading to delta surface lowering at a more local scale are shallow compaction and oxidation of organic sediments, which may also result from human activities such as ground water pumping for drinking water supply of fish and shrimp ponds. However, so far, no real field observation data have been found on subsidence in the Ayeyarwady delta. Syvitski et al (2009) estimated a Relative Sea Level Rise (= Sea level rise plus compaction/subsidence minus delta aggradation trough sedimentation) of 3.4 – 6 mm/year, and categorised herewith the Ayeyarwady Delta as a delta in peril: 'reduction in aggradation plus accelerated compaction overwhelming rates of global sea-level rise'.

Technological developments: Myanmar´s science and technology infrastructure is mainly focussing on agriculture research, due to the importance of the agriculture sector for the national development. It includes the development of agricultural products and methods as well as sustainable forestry. Many dams have been built in the mountainous areas around the Upper Delta and more upstream in the Ayeyarwady basin, mainly for irrigation purposes. It is expected that the existing irrigation systems and the polders (to protect the agricultural land from salt water intrusion) will be upgraded and extended. The annual rice production of Ayeyarwady Region of about 6 million tons accounts for 30 percent of the total production in Myanmar of about 22 million tons annually (FAO, 2001/2002). This situation is mainly due to the increase of farmland area, with a rapid 25 percent increase between 1990 and 1994.

Other research focuses are set on biotechnology, renewable energy, health, internet technology and marine science and technology.[1]

According to the World Energy Council, in 2007, Myanmar had coal resources estimated at around 2 million tons, 447.7 TCF of natural gas and 206.9 million barrels of oil. The hydropower potential of Myanmar's four main rivers is estimated at 40,000 megawatts, of which only a small portion has been harnessed. The Myanmar government is undertaking ventures to exploit these energy resources, both as a basis for accelerated overall economic development and for direct social benefit to their residents[2], (Driel and Nauta, 2013).

Research gaps

- *Apart from statistical data on for instance agricultural production there is not much recent information available on the Ayeyarwady delta, mainly due to the fact that in the last 20 years not much research has been done and most of the monitoring programs have been halted. Therefore research gaps exist for all drivers of change.*
- *The recently performed census 2013 will give new data on the population in the Delta: population number, density, composition, growth rates, etc.*
- *It is expected (and the first signs are clearly visible) that the recent opening of the country will also create new rapid economic developments. Not much information has been found on the expected developments. To stimulate economic development and foreign investments so-called 'special economic zones' are and will be created in the neighbourhood in Yangon, however outside the Ayeyarwady Delta. The special economic zones and other business developments will likely on the urban infrastructure and the availability of fresh water.*
- *In face of climate change developing countries are facing different weather patterns than in the past. They cannot rely on 200 years of past data to prepare for the following years. Bringing a new kind of uncertainty: dry areas get much drier, wetter areas get much wetter, and there is greater unpredictability of rainfall. More knowledge has to be developed on how e.g. hydrological systems will change. New infrastructure needs to be planned accordingly. Apart from the NAPA (Ministry of Transport, 2012) study not much research has been done on the extent and impacts of climate change.*

1 Facts on Science, Technology and Innovation. South Asia and European Union. (SEA-EU-NET) http://www.sea-eu.net/facts/sea/myanmar

2 http://www.myanmarenergyinvestmentsummit.com; http://www.worldenergy.org/documents/ser2007_final_online_version_1.pdf

- *Moreover, investments in research and development are needed in the agricultural sector, being the most important contributors to the GDP (World Bank, 2005). During three Delta Alliance workshops held in respectively Pathein, Hinthada and Yangon in June 2014 the key issue 'knowledge development and innovation' scored among the participants second highest (after flooding) out of 8 key issues for the delta.*

Summary of pressures in Occupation layer

Pressure on space: The delta is one of the most densely populated regions in Myanmar. Ayeyarwady Region, covering a large part of the Ayeyarwady Delta has a population of approximately 8 million on an area of 35,032 km^2, hence a population density of 230 inhabitants/km^2, which is three to four times as high as the country's average.

Vulnerability to flooding and erosion: Most of the delta is still active with unstable river branches and the delta is prone to tropical cyclones with high storm surges. Many people are yearly affected by bank and coastal erosion and also floods are a permanent threat. Floods can be of different nature: floods from the rivers (mainly in the Upper Delta), floods caused by storm surges (mainly in the Lower Delta) and flash floods from the surrounding hilly and mountainous regions.

Agriculture under pressure by climate change, flooding and salinity intrusion: Agricultural production is facing challenges due to increasing risks of flooding and salinity intrusion.

Overfishing: The fishery in the Ayeyarwady Delta encounters the pressure of overexploitation, which has been impacting already the livelihood of rural poor. (MYFish, 2013).

Shift in land use upstream: The effects of the dams are producing a reduction of the sediment supply and therefore erosion of the delta.

Water demand / freshwater shortage: Due to upstream developments, climate change and sea level rise, critical low flow conditions of the Ayeyarwady River tributaries are likely to increase. Increase of salinity intrusion in the coastal areas is making existing water supply sources (domestic and agricultural) and freshwater ecosystem vulnerable.

Need for more livelihood opportunities: For a sustainable development of the (rural) Ayeyarwady Delta there is an urgent need for improvement of the livelihood opportunities for the local population. The majority of the people in the Delta is landless and are therefore placed in a non-voluntary dependent position. Lack of or limited access to credit hampers also the economic development of the rural population. Multi-sectorial development is needed to increase the livelihood of the rural population (MMRD Research Services, 2014).

Impact of climate change on public health (directly derived from the NAPA) Effects of increasing temperatures and erratic precipitation patterns are the spread of infectious diseases, heat stress, heat exhaustion and dehydration. The greatest concern at present is however related to freshwater resources (Lian and Bhullar, 2010).

Research / knowledge gaps

During the Delta Alliance missions in July 2013 (Driel and Nauta, 2013) and June 2014 the following research and knowledge gaps have been observed:

- *Data on population: density, growth rate, current unemployment, projections and current situation.*
- *Migration both into the delta and out of the delta, due to loss of livelihoods, needs to be considered.*
- *More insight needed in fishing rights, not aquaculture alone, but captures fisheries in river, estuary and those on delta dependent on marine fisheries as well.*
- *Inventory of existing (development) plans needed.*
- *There is need of socio-economic and livelihood profiling of the population to understand the actual vulnerability*

Summary of pressures in Network layer

Demand for more transportation facilities (roads, ports and waterways): Road transportation is the most important way of transport in Myanmar, but until rather poorly developed. Most towns and cities are accessible only by land route. Myanmar has 5.099 km of railway, only a few towns and cities are connected by railway lines, but the condition of train services in Myanmar make it too difficult. There are currently no rail links to adjacent countries. Some towns are also reachable by rivers, but river travel is very slow compared to road transportation. Most people have to rely on road transportation to travel in Myanmar. The lack of infrastructure is hampering the economic development.

Maintenance and upgrading of agricultural engineering works

In the last four decades important infrastructure has been constructed for agricultural production: dams, diversion weirs, irrigation systems, and polders. There are plans to further increase agricultural production by the construction of new irrigation systems and the upgrading and repair of existing infrastructure.

Need for embankments against flooding: In order to prevent flooding from the river extensive flood protection embankments have been constructed along several rivers in the Ayeyarwady Delta, mainly in the Upper Delta. Similar embankments have also been constructed in areas that are prone to flash floods. Some of these embankments need maintenance.
More embankments are needed against flooding in the Middle and Upper Delta. Due to the expected more extreme weather events this need will increase the coming decades.

Lack of water supply and sanitation: Only a small percentage of the rural population is connected to a public drinking water supply system. Due to climate change and sea level rise the need for drinking water supply systems will only become more urgent, certainly in the areas that are affected by salinity intrusion and arsenic contamination and waste water treatment plants. Urbanisation and industrial development of Yangon (and some major cities in the Delta like Pathein and Hintada) will articulate the need for proper sanitation facilities, waste water treatment plants and water quality monitoring.

Impact of dams: The constructions of dams pose a threat to the ecological integrity and flow regime of the river basin. Dams also result in adverse impacts to the flow regime of a river with grave implications to the health of floodplains and delta ecosystems and the ecosystem services they provide to local livelihoods

Lack of and ageing infrastructure: Infrastructure to support transportation, water supply, communications, and power supply is generally rather poorly developed. Maintenance of roads, embankments, polder sluices, drainage canals and irrigation systems is a recurrent problem. (Driel and Nauta, 2013).

Research / knowledge gaps
During the Delta Alliance missions in July 2013 (Driel and Nauta, 2013) and June 2014 the following research and knowledge gaps have been observed:
- *Present status and future plans of the transportation sector (Ministry of Public Works).*
- *Current programs and plans, for drinking water supply and sanitation facilities, etc.*
- *Plans for township development (Min. of Border Affairs, DRD).*
- *Cost-efficient and innovative infrastructure*
- *Innovation in agricultural engineering*

Summary of pressures in Base layer

Impact of climate on water resources: Climate change-induced changes to hydrological cycles will deteriorate water quality, quantity, and accessibility. Several sections of the hydrological cycle are vulnerable to climate change: flooding, contamination of water resources, erosion and limited replenishment of waterways, increase of risk of flash floods as well as decrease ground water recharge. Conversely, increases in drought events will increase utilisation pressures on ground water for expanding irrigated agriculture. Rising sea-levels, however, will lead to salt-water intrusion. (NAPA, Ministry of Agriculture and Irrigation, 2012).

Coastal and riverbank erosion: Riverbank and coastal erosion is one of the major issues. River bank erosion takes mainly place in the Upper Delta, where the river geomorphology is still very dynamic. Coastal erosion is mainly due to mangrove destruction and the decrease in sediment load caused by the construction of dams upstream. There is a lack of legislation, regulation and enforcement to avoid the settlement of (mainly fishermen communities on the erosion (and flooding) sensitive coasts and river banks.

River hydrology and hydrodynamics: Given all the projected water uses (hydropower, irrigation, drinking water supply, navigation, industrial and mining abstractions) water allocation priority problems may arise and an impact on the minimum environmental flow requirements may exist. Water balances and allocation studies are necessary to address these future water resources problems.

Flooding (flood hazard): Myanmar is prone to cyclones, mainly during the months April, May, October, November and December. The coastal region such as the Lower Ayeyarwady Delta is also prone to storm surges. During Cyclone Nargis, 90 percent of the 140.000 deaths were caused as a direct consequence of the storm surge.
The Ayeyarwady Delta is a fragile and intricate ecosystem of mangrove swamps and tidal estuaries. Non-saline arable areas are limited and becoming scarce due to the erosion of riverbanks, saltwater intrusion, and increasing soil salinity. Poor water control and drainage works contribute to periodic flooding and crop losses.
The effect of an increase in rainfall and its intensity is the increase in run-off. Deforestation contributes to these processes. Also it can damage vulnerable crop and can create flash floods from the surrounding mountain ranges in the lowland areas of the delta (Hassman, 2013)

Drinking water: quality and quantity: Water scarcity has become a daily challenge in Myanmar's Ayeyarwady Delta in the dry season, especially in the Lower Delta where the river water (and often also the groundwater) is saline. The

delta's inhabitants traditionally source drinking water from rainwater harvesting.
Arsenic contamination of drinking water sources is an emerging public health issue in Myanmar. However, the magnitude of arsenic contamination of groundwater sources in Myanmar is still rather unknown.

Salinization / salt water intrusion: Salinity and its seasonal intrusion gradients are dominant factors for coastal system, fisheries, agriculture and drinking water supply. Therefore, any changes on present spatial and temporal variation of salinity will affect the biophysical system of coastal area.

Water and soil pollution: Agricultural inputs, such as chemical fertilizers and pesticides are increasingly being used. The utilization rate of chemical fertilizers in the delta happens to be the highest among the agricultural regions in Myanmar. This will result in an increasing state of pollution.
Water quality concerns are also being raised with regard to mining activities and the growth of cities and industrial zones. The disposal of untreated domestic wastewater and the increase in industrial and mining activities will further affect the water quality in the delta with a range of additional parameters (heavy metals, organic micro-pollutants and oils).

Mangroves and biodiversity loss: Especially the mangrove forests are highly valuable but also under high pressure from encroachment and exploitation and are largely in a degraded state due to human activities such as wood harvesting (mainly for the production of charcoal) and coastal development (paddy fields and shrimp ponds). Most of the remaining forest is in various stages of regrowth.
Moreover, they are also vulnerable to accelerated climate change and sea level rise, as they pose major new challenges to biodiversity conservation and nature in general.
The root causes of these threats are low conservation awareness, poverty, poor livelihood conditions (lack of alternatives), weak systematic biological monitoring systems, low grassroots support for conservation and weak law enforcement. Environmental conservation in parallel with economic development opportunities is one of the greatest challenges for Myanmar in the 21st century (Wildlife Conservation Society, 2013).

Research / knowledge gaps
During the Delta Alliance missions in July 2013 (Driel and Nauta, 2013) and June 2014 the following research and knowledge gaps have been observed:

- *Need for overview of all hazards and consequences.*
- *Hydrological and monitoring data*
- *Water balances and allocation studies are necessary to address future water resources problems.*
- *Information on Ayeyarwady tributary behaviour and characteristics.*
- *Trends, programs, leading to water quality problems. Baseline conditions.*
- *Knowledge on arsenic contamination of groundwater.*
- *Monitoring system needed for anthropogenic subsidence and groundwater exploitation*
- *Size of loss of wetlands.*
- *Potential impacts of climate change and sea level rise on mangroves and biodiversity conservation.*

Summary of governance issues

Cooperation between (scale) Levels and Sectors of Government: Myanmar counts many ministries which are often working in quite a sectorial way. Efforts are underway to improve core governance systems. In Myanmar land and water are managed by many ministries, agencies and departments. Several departments, under their respective ministries, remain for instance responsible for the supply and management of water for agriculture, industrial, domestic and sanitation purposes. Different departments have different acts, proclamations and laws, but most of them need to be strengthened in order to overcome problems caused by the lack of regulations on land and water. There is also a lack of coordination and collaboration between the different institutions, including a lack of sharing of data and information.

Cooperation between Government and Private Sector: Economic santions on Maynamr prevented western investments and trade for most of the last twenty years). The recent relaxation of sanctions and political change have led to both the Myanmar government and foreign investors seeking to significantly increase investment across economic sectors (Henley, 2014). Although the private sector is looking into opportunities in Myanmar with great interest, it should be noted that only 30 percent of the transactions is successful according to McKinsey (2013). This is mainly due to the lack of knowledge and legislation in Myanmar, e.g. in the specific field of Public Private Partnerships. The privatization of public sector industries need to be further developed

Involvement of Stakeholders and Citizens: Stakeholder consultation at planning and implementation phase of a project in different parts of the country needs to be further encouraged.

Approaches for dealing with Risks and Uncertainties: To reduce loss of lives and property, Myanmar needs to focus on the development of flood forecasting and warning systems. Coastal area has already been practiced the

early warning system for cyclonic storm surge and got the benefit. Disaster Reduction Plans have been developed for all districts.

Research gaps

- *Lack of knowledge and legislation in Myanmar, e.g. in the specific field of Public Private Partnerships.*
- *Improved land administration by increasing dialogue on land issues with political leaders, by funding technical expertise to assist land administration functions and land governance processes. (Henley, 2014)*

14 Parana delta

Summary of drivers of change

Demographic trends: About 24.000 inhabitants are living in the Delta, resulting in a density of 1 inhabitant per km2. More than half of the population is concentrated in the Lower area, which represents around 43% of the total surface of the delta. The Delta is located near the most populated conurbation of the country, Buenos Aires Metropolitan Area, which has more than 12 million inhabitants with a density of around 5.400 inhabitants per km2.

Economic developments: The Parana Delta is a heterogeneous region with a wide range of resources and, consequently, many production related uses. The main economic activities that characterize the islands of the delta are forestry, cattle raising, beekeeping, fishing, hunting and recreation and tourism. Nowadays, these traditional activities are threatened by new production processes originally designed for terrestrial systems, like large-scale agriculture and particularly soy crop and cattle industry on a large scale. Cattle raising contributes to approximately 85 % of the GVP estimated for the main economic activities carried out in the Delta. But livestock overload gives consequent effects of overgrazing, soil erosion and possible biological and chemical contamination of water resources with negative impact on the ecological integrity of the wetlandsFisheries in the delta involve different modalities: subsistence fishing, commercial/artisanal fishing, commercial/industrial fishing and recreational fishing.The conflicts between them have been exacerbated as a consequence of the increase of industrial fishing for export, dissimilar provincial legislations, presence of new actors and climate change impacts.
Along the borders of the delta, different cities have based their development on industrial or port activities, being the Lower Delta the area which is most influenced by the dynamics of the Buenos Aires Metropolitan Area, essential in Argentina's economic life. This region concentrates most of the industrial and financial activity of the country, contributing with around 55% of the countries' GVP (Gross Value of Production). As illustration the iron and steel industry located in the province of Buenos Aires provides more than 60% of the value generated by this sector. The per capita GDP is USD 16.840 and most people are employed in services and industry.

Climate change: There are observed and future (direct and indirect) impacts of climate change on the Parana Delta, related to the variations in the Parana River discharge and sediment load, changes in the river´s hydrologic regime and streamflow variability might affect the frequency of occurrence of extraordinary floods and droughts. and temperature increases. Streamflow variability primarily affects the Lower Delta and is mainly influenced by the Rio de la Plata and by the climatic events such as the "Sudestada", which consists of persistent South-eastern winds coming from the Atlantic Ocean. Those drivers may accelerate trends in land use change, including extensive conversion to commercial forestry, livestock production and, less frequently, to agricultural uses with extended biodiversity alteration and loss.

Subsidence: At regional level, the Parana River Delta is considered at great risk because the subsidence rate is higher than forecasts of sea-level rise. The rate of surface mineral soil subsidence is 60 mm per year as a result of porosity losses in the top 10 cm of the profile (Ceballos et al. 2013). This finding confirms that wetland soil compaction is an important and intense process in the system, suggesting that profile de-saturation is a key driver (Hadas 2006).

Technological developments: The large scale infrastructural interventions located along the River and its Delta are: five big dams built upstream the river (Ilha Solteira, Jupia, Porto Primavera, Yaciretá and Itaipu), the Parana-Paraguay Waterway, two viaducts (Zárate-Brazo Largo and Rosario-Victoria) and one re-gasification port in Escobar built on the Parana de Las Palmas river. In addition, the construction of the Atucha Nuclear Power Station, located in Zárate in the coasts of Parana de las Palmas River, represents a potential risk to the delta region. Besides large infrastructure works, other low scale technological developments are also developed such as polders and embankments mostly associated with production activities such as agriculture, cattle industry and urban developments. Other heavy engineering works have been realised to expand shipping and spur economic development throughout the region.

Research gaps

- *Need for the development of climate change projections at the Delta and local scales.*

- *Multi- disciplinary assessment of the combined impacts of human activities on the wetland and its resilience capacity in a context of climate change. Generation of future scenarios.*
- *Research on strategies to include climate change projections and impact assessments into policy and guidelines.*

Summary of pressures in Occupation layer

Pressure on space: In the Parana Delta there is a clear trend towards land use. concentration, which consists mainly in land property and use changes from many small producers to just some few big companies. The pressure on space is mostly associated with large-scale production processes, such as cash crops agriculture as Soybean, livestock production and forestry. Nevertheless, it is also related to the influence of the nearby urban conurbation of the Buenos Aires Metropolitan Area, which expansion leads to the introduction of metropolitan patterns in the delta.

Vulnerability to flood: The Parana Delta is a wetland system that is exposed to pulses of floods and droughts. Vulnerability to flood has different implications on the islands and on the continental area of the coasts along the delta, where cities are located. The waterfront of the Upper and Middle Delta usually gets flooded as a result of precipitations and the increase in river discharges, while the Lower Delta is also affected by the Sudestadas, strong South Eastern winds coming from the Atlantic Ocean, which increase the level of the Rio de la Plata blocking the natural drainage of the delta (and the cities located in the coasts). When all these events coincide in time and space, it leads to floods and their negative consequences for areas which should not have been urbanized in the first place. The latter as consequence of unplanned urban growth and the prevalence of the private interests on the urban decision-making. The result is a mosaic of large private (protected?) elevated areas and public (vulnerable) depressed zones.

Water demand / freshwater shortage: Changes in land uses such as the urbanization of rural areas, the increment of the number of dwellings and the increase of the scale of production cause a rise of water demand in the cities. The average water demand of the Metropolitan Area of Buenos Aires in 2003 was estimated in around 4.179.000 m^3/day.

Research gaps

- *Comprehensive database on climatic, natural resources and socio-economic parameters in order to support research and development of initiatives. Availability of the information for research purposes.*
- *Study on the effects of the different occupation typologies on the wetland (residential, production, recreation, etc.). Research on innovative solutions to prevent the increase of the terrestrialization trend, finding new ways of occupation according to the context.*
- *Research on innovative solutions for the government to recover its key role on territorial planning and management.*
- *Development of models regarding flooding scenarios in order to integrate them to planning decision-making. Study of the vulnerability to flood of coastal cities.*
- *Production of detailed land use maps*
- *Impact assessment of large-scale cattle raising on wetlands, biodiversity and other local productions like beekeeping.*

Summary of pressures in Network layer

Flood protection: Flood protection is built in the Parana Delta for production and residential purposes. In the last three years, the polder surface increased in around 16.5%, reaching 240.748 ha of polders. Apart from the polders, other used technique is the open ditch system, usually developed in small family production units, which consists in opening small channels or ditches connected with a watercourse to allow runoff from the fields by the action of gravity. Both types of works are developed by privates and alter the regime of the wetland. Thus, some other land movements have been carried on for the construction of residential developments. The topography of the affected islands has been modified to create marinas, clubs and large-scale residential areas, even reaching to a level of 5 m AMSL. These works are a clear consequence of the introduction of the concepts of gated community and consumption areas on the islands, as a product of the metropolitan model of urban growth

Irrigation and drainage: In recent years, the Parana Delta has been a centre of attention due to wetland degradation and the modification of the hydrologic pattern (building of embankments, polders and paths, closure of water courses and streams), to favour large-scale livestock farming, commercial forestry systems and agriculture systems (Soybean crops). In the case of forestry, new technologies are under development to manage water entrance into the polders (with lock-gates) in order to avoid hydric deficit during the periods of droughts.,

Water supply and sanitation: The islands of the Delta have no water supply or sanitation network. On the contrary, the cities along the borders of the Delta (including the Metropolitan Area of Buenos Aires) have an average coverage of the water supply network of around 50% and 20% of sewage system. Water supply captured from surface water courses represents 96% of the total daily production, while the rest 4% comes from yhe underground aquifers.

The main source of surface water is the Rio de la Plata and the underground water sources are the Pampeano and Puelches aquifers.The aquifers are located between 20 and 120 m (lower sea level) and present flows between 3 and 100 m3/h. Regarding sanitation, the system is divided into four areas and the catchment of the North area is treated in a plant located in San Fernando (in the Lower Delta), which has a capacity of treatment of 78.000 m3/day and serves 270.000 dwellings of the departments of San Isidro, San Fernando and Tigre.

Roads, railways, ports and navigation channels: The Parana Delta is connected to the metropolis and other urban areas by railways and highways. At the beginning of the urban expansion, the train had an essential role for the area as transport modality for passengers and freight. During the last decades of last century, public investment on highways encouraged the integration of the Delta into the dynamics of the metropolitan expansion from the basis of private transportation and favoured rapid access through land connections. The mobility network runs along the perimeter of the Delta, only crossing it through two systems of bridges and the routes run parallel to the coasts in the continental area. The terrestrial mobility network of railways and highways has always been deeply integrated with the port system that is located along the delta, which is the most important fluvial network of the country. It is the connection with the Atlantic Ocean and also holds the Parana-Paraguay waterway or ship channel (Hidrovía Parana-Paraguay) that links Nueva Palmira port in Uruguay with Caceres Port, located in Brasil

Research gaps

- *Research on the positive and negative impacts of infrastructure for production purposes on the community and the delta. Innovative solutions to decrease negative effects of infrastructure.*
- *Studies of the consequences / impact of polders and embankments in terms of lost of wetland good and services, using and "accumulated impacts" approach.*
- *Studies on the impacts of the waterway development on the local economy and natural environment.*
- *Introduction and assessment of new approaches like natural infrastructure and hybrid engineering*

Summary of pressures in Base layer

Coastal erosion: Although most coastal erosion existing on the Parana Delta is caused by natural processes, it is also induced by cattle raising, intensive agriculture and navigation.

River morphodynamics: The Parana Delta is a complex estuarine system because, in contrast to other deltas, it does not discharge its sediments directly to the sea, but through the estuary of the Rio de la Plata. The Parana River presents a discharge of 18.000 m3/sec and transports around 160 mill ton/year of sediments (28% clay, 56% mud and 16% sand). The sand which is deposited on the river mouth increases the length of the delta, while the mud influences on incrementing the size through the emergence of banks that become islands. In consequence, the delta has a rate of increased surface of around 617 km2/year and in spite of a slight decrease of the growing rate during the latest decades, the delta front will continue advancing being expected to reach Buenos Aires city's coast in about 110 years.

Flooding (flood hazard): The functioning and structure of the Delta wetlands are conditioned by periodic flooding influenced mainly by the discharges of the Parana river but also, in a lesser degree, by precipitations contributed by the tributaries of the continental margins, tides and the meteorological phenomenon known as "Sudestada". Those consist on persistent South-eastern winds coming from the Atlantic Ocean which increase the level of the Rio de la Plata.

Salinisation / salt intrusion: Even in an extreme condition, the levels of salin ization will not bring any consequence on the water quality for consumption supplied by the Rio de la Plata (surface source) for the Buenos Aires Metropolitan Area. Nevertheless, it could generate local negative effects that will have to be consequently evaluated. The estimated salt concentration is expected to reach 17% by the end of this century. Underground source of water (aquifers) suffers from salinization near the coast of Rio de la Plata and the Lower Delta, and below water courses, which may alter the quality of extracted water.

Water and soil pollution: Water quality in the Parana Delta region is good, however there exists some evidences of organic pollution and eutrophication in some specific areas, mainly caused by te effects of agricultural expansion like livestock waste, pesticides, urban and industrial waste and sewage. The tributaries of the Parana River are examples of the adverse impacts of the anthropic activities due to their high levels of pollution, which exacerbates in the middle and lower sections of the rivers, where the water is not suitable for human consumption and even worse

Wetland and biodiversity loss: The use of natural levees (albardones) that surround the Lower Parana Delta's islands by settlers has resulted in the loss of native woodlands, Besides, the polders and embankments produce a drastic change in the structure and performance of the wetland as it prevents the entry of water into the islands leading to a "terrestrialization" of the area. The rate of wetland lost due to polderization was estimated in around 10.500 ha/year.
The Delta region includes also 25 protected areas of different

size, jurisdiction and degree of implementation, totalling 488.000 ha under protection. Except those of national jurisdiction, the other protected areas lack of management plans or effective control measures.

Research gaps

- *Study the impact on biodiversity and ecosystem services resulting from human intervention and particularly those related to large-scale productions.*
- *Interdisciplinary research on water and soil pollution and their effects on biodiversity and local communities. Particularly studies regarding the impact of agrochemical use in the aquatic biota, fisheries and other traditional production activities, including and assessment of economic losses.*
- *Studies on the invasion and impacts resulting from alien species.*
- *Studies and monitoring of the fish stocks and local fisheries of the Parana Delta*

Summary of governance issues

Cooperation between (scale) levels and sectors of government: The network of jurisdictional authorities, competences and boundaries is complex. It is divided into three subnational jurisdictions (Provinces) and 19 local governments (Municipalities or Departments). There is a complex network of institutions that have the competence to decide on the Parana Delta region. The diversity of functional authorities, complex institutional arrangements and conflicting visions on the area's role, converge in making the design and implementation of policies and measures, including water management and land use strategies, a difficult task. In addition, frequently decisions taken by agencies are conflicting with the functions allocated by the regulatory framework and their legal assignment of competences, and in between government agencies, so the conflict on environmental issues is reflected within the institutions, at the different levels of government and even in the decision making process itself

Cooperation between government and private sector: The private sector is very diverse and includes from small scale cooperatives up to large institutions. Beyond some initiatives developed by the INTA (Instituto Nacional de Tecnología Agropecuaria) and the INTI (Instituto Nacional de Tecnología Industrial) or programs like PROSAP (Programa de Servicios Agricolas Provinciales), the level of cooperation between the public and private sector is low. One remarkable Public-Private enterprise is the Management Plan for the Delta of Tigre (Plan de Manejo de las Islas del Tigre), developed by Fundación Metropolitana and the government of the Department of Tigre in 2013.

Involvement of stakeholders and citizens: The civil society is strongly involved in the Parana Delta, either through research institutions and local groups who fight for the fulfillment of environmental rights and the protection of the region. Today there are more than 35 civil society organizations that focus their work on the Parana Delta and the surrounding area. The level of participation has increased as the threats manifest more visible. Also, an increase in the participation of NGOs in the design of public policies and monitoring processes of territorial planning is observed.

Approaches for dealing with risks and uncertainties: The National Water Institute (Instituto Nacional del Agua, INA) has an important role through hydrological alerts and warnings of flood events, which has a great importance Apart from that, there are no approaches to dealing with risks and uncertainties in terms of processes and policy.

Research gaps

- *Need for enforcement of existing legislation and plans.*
- *Increase of the tools for citizen participation in decision making process.*
- *Development of integrated management plans taking into account the heterogeneity of the delta and the different kinds of actors involved*

Annex B: Main indicators for drivers, pressures and governance

DRIVERS	Main indicators	Values/comments
Demographic trends	Growth rate of the delta population	Estimated at1.52%
Economic developments	GDP/capita GDP av. Growth	$1,700 (2013) 6.8 %(2013)
Technological developments	Research and development Knowledge-intensive industry	Low Low
Climate change	Increase mean temperature change in 2050 Increase mean precipitation change in 2050 Increase in river peak discharge Sea level rise in 2050 Extreme events	+ 1.4 °C. + 250 mm Unknown Approx. + 0.30m More cyclones, strong winds, flooding, drought.
Subsidence	Tectonic subsidence Human induced subsidence	No data available
PRESSURES/ PROBLEMS	**Main indicators**	
Land and water use (occupation layer)	Population density Urbanization Fresh water demands Flood vulnerability	230 inhabitants/km^2 Increasing in and around Yangon High High
Network / infrastructure (network layer)	Flood protection standards Irrigation and Drainage Water supply and sanitation Road, railways and ports	Rivers: moderate. Coast: low Moderate condition Low Low
Natural resources (base layer)	Storm surges/cyclones Coastal/fluvial erosion Ecosystems health Biodiversity loss Water quality Freshwater shortage/salinity intrusion	Up to > 6m (Nargis) High Moderate Moderate (mangroves loss) Moderate Problem in lower delta
GOVERNANCE	**Main indicators**	
Multi-level and multi-sectorial cooperation	Existence of integrated plans Existence of multi sectorial/multilevel committees	No integrated plans. IWRM strategy in development NWRC (National Water Resources Committee)
Public-private partnerships	Number of PPPs Scale of PPPs (geographically/financially)	Low No information
Involvement of stakeholders and citizens	Existence of legal instruments for participation Number of NGOs involved	No information NGOs present, no information on their role
Approaches for dealing with risks and uncertainties	Existence of adaptive management (strategies) Existence of risk management and emergency systems	No Yes

Bangladesh, India, Indonesia, Malaysia, Maldives, Myanmar, Sri Lanka and Thailand are working together through the Bay of Bengal Large Marine Ecosystem (BOBLME) Project to lay the foundations for a coordinated programme of action designed to better the lives of the coastal populations through improved regional management of the Bay of Bengal environment and its fisheries.

The Food and Agriculture Organization (FAO) is the implementing agency for the BOBLME Project.

The Project is funded principally by the Global Environment Facility (GEF), Norway, the Swedish International Development Cooperation Agency, the FAO, and the National Oceanic and Atmospheric Administration of the USA.

For more information, please visit www.boblme.org

Food and Agriculture Organization of the United Nations