BANDUDELTAS
BDP 2100

BANGLADESH DELTA PLAN 2100

Bangladesh Delta Scenarios

Process of scenario development and draft scenarios for the BDP 2100

Maaike van Aalst, William Oliemans, Fulco Ludwig, Leo Beumer, Catharien Terwisscha van Scheltinga, Kymo Slager, with contributions from the BDP2100 team

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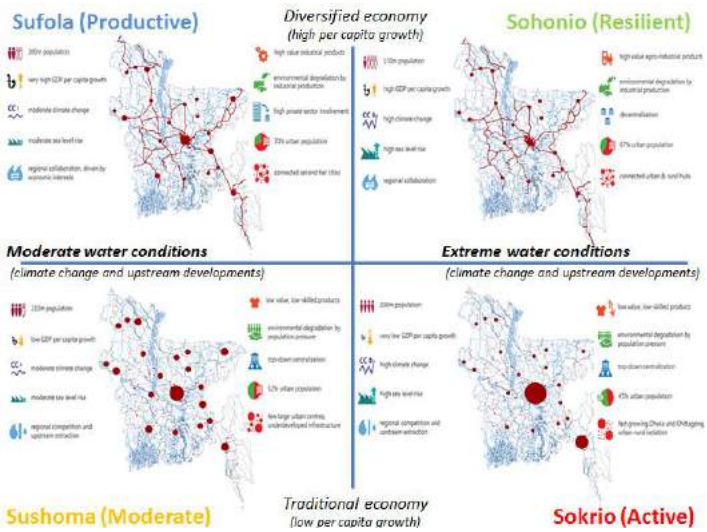

Introduction

Title	Bangladesh Delta Scenarios
Subject	Process of scenario development and draft scenarios for the BDP 2100
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Disclaimer: *The data and quantification of the scenarios in this report are not be interpreted as accurate projections or forecasts; they represent a quantified backbone of the scenario narratives and are the resultant of expert judgments and existing projections and models of different climatological and socio-economic sources. The specific data sources are indicated below each data table in the report. The data and quantification of the scenarios is only to be used for the purpose of an assessment of strategies under different possible futures (or scenarios). The scenarios represent broad ranges, or 'plausible edges' of different possible future outcomes.*

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Executive summary

Like other deltas, Bangladesh is facing immense challenges related to rapid population growth, urbanization and industrial development. These challenges coincide with more extreme climate events and decreasing dry season flows as a result of developments in upstream countries. Salinity intrusion in the coastal belt and competing (fresh) water demands for agriculture, industry and drinking water compound these natural and, in some cases, man-made challenges. At the current rate of economic development and urbanisation, floods will have a growing negative impact on the countries' economy.

These developments are likely to continue in the future, but to what extent is unknown. Decision-makers in Bangladesh have the difficult task of identifying the best policy options that will work now and in the future, while financial resources are scarce almost per definition. Scenarios are a tool to help policy makers to make a well-informed choice in prioritizing current measures and strategies. Scenarios are not developed to predict one single future; rather they describe different plausible stories of possible future developments in an inherently uncertain world. For the Bangladesh Delta Plan 2100 (BDP2100) scenarios have been developed to describe these uncertain futures and identify potential impacts that have an important influence on the success or failure of a given strategy or measure. The scenarios are used to evaluate the effectiveness of measures and strategies for each scenario, which helps decision makers to prioritize their choices today. For this reason, the scenarios represent 'extreme edges' of possible outcomes, so those strategies can be selected that perform well in *different possible* future state conditions of Bangladesh.

Process towards the BDP scenarios

For the BDP, four diverging scenario narratives have been drafted, based on an extensive stakeholder consultation process in combination with data from UN, IPCC and BDP2100 Baseline studies. The first building blocks were developed during a scenario workshop in February 2015 in Dhaka. These were subsequently further developed and substantiated through the input of experts and validation workshops. The quantification of the scenarios is based on climate change model analyses, current and historic trend analysis and benchmarking with comparable economies currently ahead of Bangladesh in economic terms. The scenarios represent possible 'business as usual' developments (continuation of current policies), which makes them well suited to evaluate and assess investment options as part of the country's 5-year planning process.

The General Economics Division (GED) of the Government of Bangladesh (GoB) has experience with the use of scenarios, both through the CCAFS and the ESPA Deltas Project (http://www.espadelta.net/). The ESPA Deltas Project has developed scenarios focused on food production and ecosystem services. These scenarios have a different scope, however and are used directly to design strategies. The two approaches are however highly complementary. In follow-up work in Strategy development in the Delta Plan, impacts of scenarios at the level of the Coastal Hot Spot, as well as impacts of potential measures, will be carried out as a cooperative effort of both projects.

The process towards the drafting of the BDP scenarios is illustrated in figure 1, describing process steps and outputs. The figure also includes the subsequent steps of impact and strategy assessment. In this document a first impact assessment draft table per scenario is included.

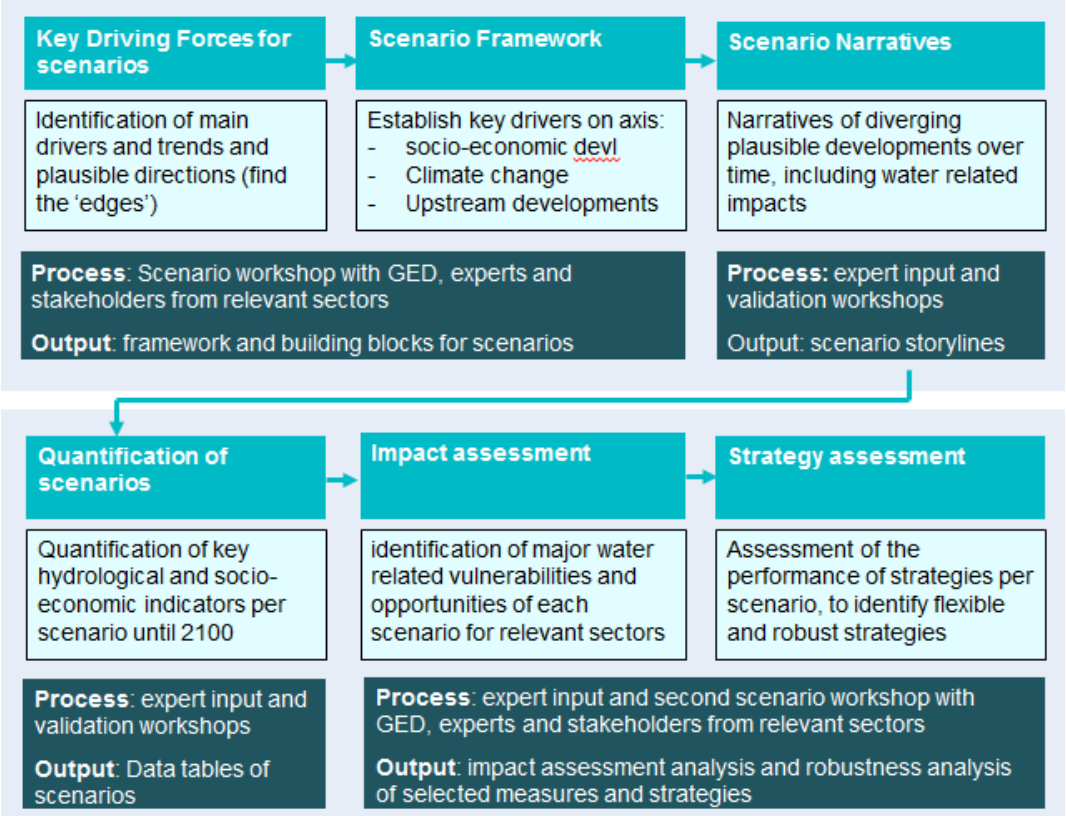

Figure 1: Overview of the Scenario Development Steps in the BDP2100 (Scenario Development Team)

Bangladesh Delta Plan Scenarios

The BDP scenario narratives are concentrated around two key drivers: 1) future water conditions based on transboundary developments and climate change and 2) economic development and related land use changes. This approach follows the IPCC climate scenario approach and is both simple and effective and allows other key drives to be included using a consistent approach. Main drivers have been quantified for each scenario.

BDP2100 Scenario Narratives

SUFOLA (PRODUCTIVE), *"market driven delta"*

The **Sufola** scenario is characterized by moderate water conditions, growing population and an increase of per capita GDP growth as a result of fast global economic growth and a transition of Bangladesh towards an industrialised and moderately diversified economy. Driven by strong global trade liberalization and a high international demand for manufacturing products, large foreign and domestic firms invest in the manufacturing and agro-processing industries, leading to higher labour and land productivity. Although the overall income level rises, the gap between rich and poor also increases. (Public) Investment in infrastructure is necessary to enable transport of goods and services to the markets, and other economic centres besides Dhaka and Chittagong emerge. The positive effects on the economy instigate further (private) investments in technology, human capital and infrastructure, leading to many more high-skilled job opportunities. As the middle income population increases, food security objectives slowly shift to food variety, with an emphasis on a nutritious and varied offer. By 2050, Bangladesh has developed into a diversified market-driven economy in which the industry and service sector dominate, little regulation and in which large internationally operating firms dominate.

Towards 2100, Bangladesh has become a high-income and highly urban country, dominated by services and technology, driven by private investors and well connected to international markets.

Water demand for irrigated rice will reduce due to changes to less water demanding crops, varieties and agricultural practices. A secure water supply will be become more important. Urban (domestic and industrial) water demand and water network requirements will increase due to rapid economic development and population increase. Water quality standards will increase significantly as a result of a growing and wealthier population with higher consumption standards. Competition between the agriculture, domestic and urban water supply needs will increase, with the share of agriculture becoming less important, especially up to 2030 and 2050. **Water and environmental quality** will be under severe pressure in this period. The decrease of the population after 2050, accompanied by a higher standard of living and global environmental awareness will enable investment in clean technologies, a much more efficient use of water and an increased allocation to meet environmental needs. Ecosystem services will become more valued as economic goods. Increased living standards, assets and globalisation will lead to a proportionate increase in **flood** risks, for which the Government will want to ensure an adequate level of protection.

SOHONIO (RESILIENT), *"dynamic delta"*

The **Sohonio** scenario describes a future with a stable increase of GDP per capita, driven by favourable global economic conditions leading to a transformation to a fully diversified economy, but hampered by more extreme water conditions, due to rapid climate change and increased upstream flow abstraction. Aware of its vulnerability to natural events, and enabled by favourable global growth conditions and technological changes, Bangladesh puts priority on an equal, stable and sustainable growth and avails of a strong public sector equipped to deal with rapidly changing circumstances. Due to increased water scarcity, the urgency to increase water productivity is high and agricultural research and technology advances are considerable, as well as investments in human capital and services. Growing high-value industrial and agricultural output requires better connectivity between rural and urban areas and secure infrastructure. A substantial of the agricultural labour force is now employed in the agri-food processing sector, leading to high rural to urban migration. Also many people seek opportunities outside Bangladesh, which stabilizes the population growth in combination with declining fertility rates. By 2050, the country has developed in a resilient country with a stable economic growth per capita that is more equally distributed and well equipped to adapt to natural hazards and climatic conditions.

Towards 2100, Bangladesh develops into a high-income country, which has mastered in technological adaptation and sustainability to cope with the harsh climatic conditions. Agro-technology and services drive the economy, as well as high international mobility of people, which has decreased the population significantly.

Water shortages for the agricultural sector due to climate and upstream abstraction for irrigation will be severe. This is (partly) mitigated by water saving technologies, the cultivation of high-value and low water demanding crops in the dry season and the application of sound zoning policies for agriculture, housing, industry, critical infrastructure and environment. There will be a large increase in **flood** risks due to the increase of extreme events and continuing increase in asset value of industries and other valuable assets. Sea level rise and increased cyclone intensity will further increase the flood risk in the coastal zone. **Water quality** will initially deteriorate due to water shortages, pressures from urban areas and industry as well as salinity intrusion in relation to (relative) sea level rise. A growing economy and income level, especially of the middle class, in combination with a stronger enforcement of environmental standards will lead to improvements from the middle half of the century onwards.

SUSHOMA (MODERATE), *"delta under pressure"*

The **Sushoma** scenario is characterised by a slower GDP per capita growth, due to moderate global economic growth with competition over labour-intensive production and a fast growing population in combination with low climate change and limited upstream developments. Due to slow economic growth, competition between Bangladesh and other developing economies over low value production is high and protectionism grows. GDP per capita growth slows down, due to an increasing supply of low-skilled labourers and a slow pace of technological enhancements and inherent stagnating productivity increases. Thanks to moderate climate change and limited upstream developments, there is sufficient opportunity to develop and exploit traditional economic growth and industrialization. As output is not reinvested in much needed infrastructure, R&D, agriculture, education and human capital, inequality is rising. The large cities, Dhaka and Chittagong, grow rapidly and in an unplanned manner, due to a lack of spatial planning and enforcement, connectivity between urban and rural areas and urban facilities. Other urban and rural centres remain isolated. In this scenario, environmental degradation due to overexploitation of natural resources, agricultural and industrial pollution is severe.

Towards 2100, as a result of slow global economic growth in decades, the rise of the middle income class has not sufficiently taken off and inequality has grown substantially, both within the large urban areas and between urban and rural areas.

Urban **water demand** will increase due to a higher population up to 2050, slowly declining up to the end of the century. A substantial part of the population will however not avail of improved water supply and sanitation, resulting in many diffuse and uncontrolled pollution sources and low **water quality** This will lead to increased (peri-)urban health problems and deteriorating soil and agricultural/livestock productivity. As climate change is relatively mild and upstream abstractions increase only gradually, transboundary low flows decrease slowly. Water demand however still increases, due to a higher rural population and water use, but less than in the Sokrio and Sohonio scenarios. The urban population is at high risk of **floods and drainage congestion**.

SOKRIO (ACTIVE), *"basic needs first"*

This scenario is characterised by a **stagnating** per capita GDP growth due to unfavourable global economic growth and an exponentially growing population, in combination with extreme water variability due to climate change and uncoordinated and growing upstream water abstraction. Stagnation of the global economy leads to a decrease of global demand in low-value manufacturing products, and a fierce competition between countries in the region. Due to limited international and education opportunities, migration is limited. As fertility rates decrease at a slow pace, the population continues to grow. There is a large number of climate refugees that flee Bangladesh in response to longer droughts, increased cyclones and (relative) sea level rise. The population, as a result of natural and man-induced disasters, continues to move to Dhaka and Chittagong, albeit at a slowly increasing pace. Migration to the cities is not attractive die to the low level of urban facilities and Congestion. A sizeable part of the population remains in rural areas, dependent on subsistence rice farming. The increasing salinity and more extreme events due to climate change put a strain on agricultural productivity, leading to further increase of rural poverty and reduced food security. By 2100, population of Bangladesh continues to grow uncontrollably. In combination with harsh climatic and economic conditions, the struggle for food and natural resources is tremendous and Bangladesh is known for the largest number of climatic refugees worldwide.

Due to severe climatic conditions and high rural vulnerability, the increasing **flood** events have dramatic impacts on livelihoods. Flood frequency and intensity will increase due to more severe cyclones, higher peak river flows and sea level rise. This will affect both the rural and urban population. The low economic growth will limit the investment in large scale adaptation and there is a focus on low cost community based adaptation and people struggle to survive. Adaptation will depend highly on foreign assistance. **Water stress** will be severe due to a large population that is dependent on rice cultivation, while water supply in the dry season will be seriously constrained due to high upstream abstractions and climate change.

Environmental degradation will be high and **water quality** will be severely stressed, both due to rural and urban pollution and salinity intrusion.

Update 2016

As a result of different discussions during the Bangladesh Delta Plan process, it was agreed that the scenarios were to be supplemented with two additional scenarios that fall within the 'extreme edges' of the four scenarios summarized above.. One additional scenario represents a *business as usual* development, with a continuation of current trends and policies with an average climate change. The other additional scenario depicts a more positive economic development scenario. To be distinctive from the other positive economic growth scenarios, this scenario is characterized by a growing economy and high population growth, creating extraordinary growth of the largest cities in combination with high climate change & upstream developments.

FAST URBAN GROWTH

The ***Fast urban growth*** scenario is characterized by rapid climate change and increased uncertainty in water availability due to adverse upstream developments. The world economy is favourable and Bangladesh is rapidly transforming into an industrialized and service based economy. The largest cities act as centres of innovation with new service sectors and more industrial processing (such as ICT, finance, shipbuilding industry and alternative textile processing), however fail to relocate the production of mature products to secondary specialized cities. As a result, both more advanced and mature products are produced in the largest cities, which act as a huge pull factor of rural migrations, which are mainly active in the informal economy. Also population continues to grow, and reaches a peak around 2050 with 225 million inhabitants, of which 70% lives in urban areas. As a result, the peri-urban areas of Dhaka and Chittagong are expanding beyond precedence, creating huge agglomeration problems such as congestion, air pollution, illegal

construction etc. The other smaller cities grow at a much slower pace resulting in larger interregional disparities. With increasing GDP, the gap between the rural poor and urban rich also increases.

As a result of overall increase in standard-of living, city liveability becomes increasingly important. At the same time, there are big differences within the urban cities, consisting of a strange pattern of residential areas, industrial zones, still some small agricultural activities as 'green pockets' in grey areas and slums, pushing most of the agricultural activities out of the (peri-)urban areas.

Towards 2100, thanks to stable GDP growth, education improvements and resulting lower fertility rates, both population and poverty levels decrease.

Water demand of the urban regions will increase rapidly due to population growth and increased industrial activities. As a result of a growing and wealthier urban population, food consumption patterns are changing, leading to more animal and vegetable cultivation. Large scale intensive farming will result into higher agricultural water demands, also as more surplus rice cops will be produced for the international markets. Especially in the dry season this will result in increased water scarcity and more competition between urban and rural water use. Given the emphasis on urban development in this scenario, water use will be transferred from the rural to the urban regions. As a result, especially around the larger urban regions, water availability for agriculture will become under pressure due to high demand of the urban area.

Around the urban areas **water quality** will come under increasing pressure due to more industrial activities and increased urban population growth. In the south west, water quality will be affected by increased salt water intrusion which is caused by a combination of sea level rise, reduced dry season river flows and lower dry season rainfall. These higher salt concentrations will make surface water unsuitable for drinking and traditional agriculture. Also increase intensification of the agricultural sector could negatively affect water quality.

Flood risks will increase due to a combination of higher peak river flows, increased rainfall intensities, stronger cyclones and sea level rise. In terms of people, especially the large urban population living in slum conditions will be affected. In term of economic assets the higher value of the developments in the large urban centre will increase the impact of possible future floods. However, also the focus on urban development could reduce the attention and thus the flood risks of people living in the rural regions.

BUSINESS AS USUAL

The ***Business as usual*** scenario reflects a continuation of current policies, economics and priorities. Climate change is expected to be average and upstream water extractions are assumed to be moderate. To further stimulate their economic growth, riparian countries will develop some new infrastructure to guarantee sufficient water supply in the dry season in their countries. There will be an expansion of salinity in the coastal zone due to a combination of reduced run-off from upstream and sea level rise.

The global economy is not characterized by major shocks, but is growing stable at a relatively low rate. The global relations are relatively stable, and international markets are partially functioning and connected. Population growth remains high, as investments in education are not sufficient to rapidly slow population growth. By 2050, over 200 million people live in Bangladesh, of which more than 110 million in urban areas. Although slight progress is made in reaching millennium development goals, still by 2050, a large population lives without access to safe water, improved sanitation and medical care.

Investments in infrastructure are slow, leading to highly polluted and congested cities and badly connected rural areas. As such, transportation costs to transport agricultural products to the markets and cities remains high, creating soaring food prices in times of drought. This is especially impacting the poor urban population that does not have access to food.

In the rural areas, still a large number of people is dependent on agriculture for their livelihoods, most of which continue to grow *Boro* rice through self-subsistence farming on smaller plots of land, as an increase of large-scale farms are producing a surplus of rice and other crops for international markets.

Although rice remains the staple food, the consumption of animal products and vegetables has increased. Due to the large rural and urban population and slowly improving conditions, the vulnerability to climate hazards remains high.

Water demand – The growing population and middle income class will lead to changing food consumption patterns, leading to more animal and vegetable cultivation. Also large scale farming will produce more surplus rice crops for the international market. This will significantly increase the agricultural water demand. At the same time, urban water demand will also increase due to a higher urban population, and increased activities in the industrial sector. At the same especially dry season water availability will reduce due to a combination of climate change and upstream developments. This will increase water scarcity and will increase the competition for water resources between the rural and urban regions. Due to congestion problems, the risk of water pollution and low **water quality** delivery will increase, resulting in health problems for the urban poor.

Flood risks will be high for the large urban population living in slum conditions, as well as for the higher value of the economic assets that are at stake in the large metropolis city centres. Due to increasing extreme event and higher peak river flow flood risks will increase throughout the whole country. Also flash flood frequency will increase.

Objective Bangladesh Delta Scenarios

The aim of the Bangladesh Delta Plan scenarios is to identify key bottlenecks and appropriate measures per scenario. For each (set of) measures, the performance in the next decades is set against several key decision support indicators, both qualitative and quantitative. The outcomes of the decision support indicators will be different per strategy *and* per scenario. Within the overall framework of the BDP, the scenarios are inherently connected with the strategy identification, and form an integral part of the (strategy) assessment framework.

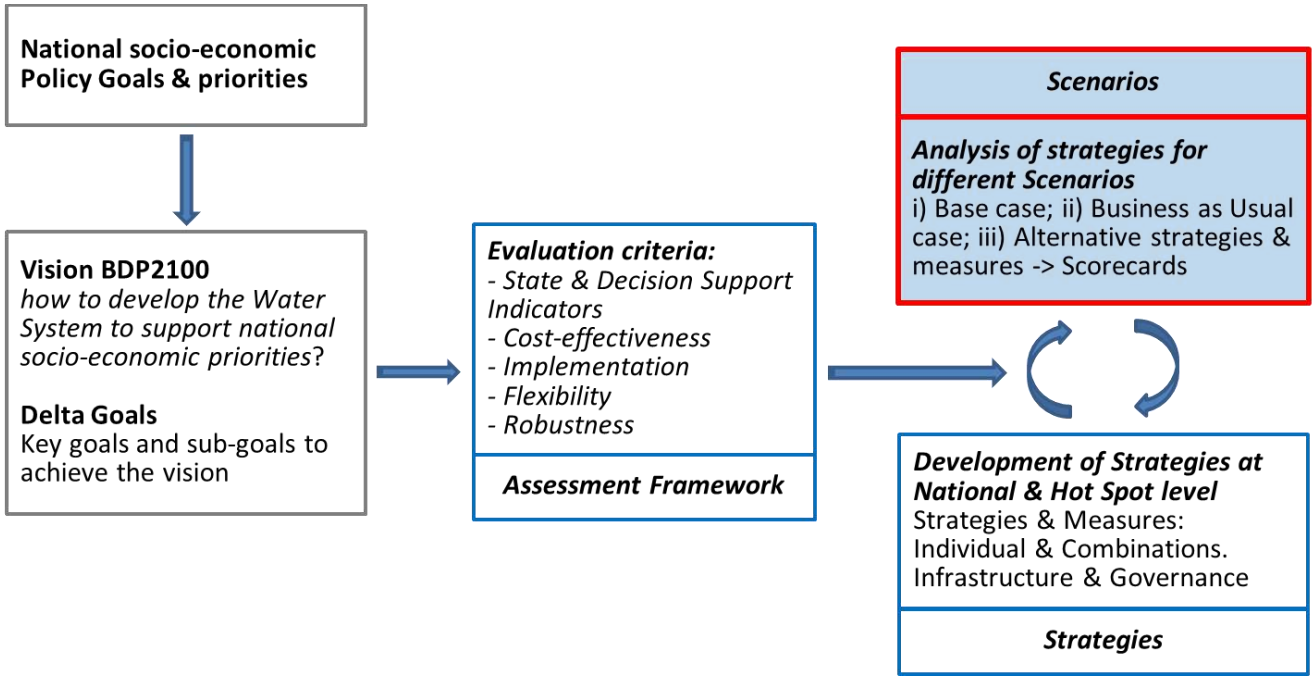

Figure 2: Scenarios as part of the Adaptive Planning approach of the BDP2100

The main aim of scenario analysis is to identify key impacts and to address uncertainty. For this reason, a bandwidth of possible future developments is developed rather than a single or most probable future projection. This bandwidth of possible outcomes is used to evaluate the (cost-) effectiveness of potential measures of adaptation to climate change. The scenarios enable uncertainty to be taken into account when selecting and evaluating strategies for adaptation in the future. In this way a careful assessment can be made to decide which strategies should be prioritized. To properly carry out strategy, assessment, the scenarios were therefore not designed as *projections*. Instead, they depict the 'extreme edges' of possible outcomes to identify those strategies that are well equipped and effective in *all* scenarios, and can thus be considered 'robust' or 'no regret' for today and tomorrow. Also it helps in identifying which measures are flexible versus measures that could create a certain 'one direction only' or 'lock-in' situation. This will create a well-informed basis for decision-makers to prioritize which strategies and measures should be implemented immediately (are '*no regret*') and which measures could be postponed until it becomes clearer how the future of Bangladesh will evolve. The scenarios should be treated as a 'living document' and should be reviewed and updated regularly In this context, combining the results of the Delta Plan and ESPA Deltas will be particularly valuable, albeit only for the Coastal areas covered under ESPA Deltas (the Ganges Floodplain). As the future unfolds it becomes clearer in which direction the economy and climate of Bangladesh is developing, and the scenarios can be adjusted accordingly. This should ideally be done in 5-year periods, connected to the 5-year master plans, and the different strategies and measures should be evaluated simultaneously. In this sense, scenario analysis can be considered as an integrated part of the process of creating a prosperous and sustainable delta.

The following figures summarize the key characteristics of the different scenarios.

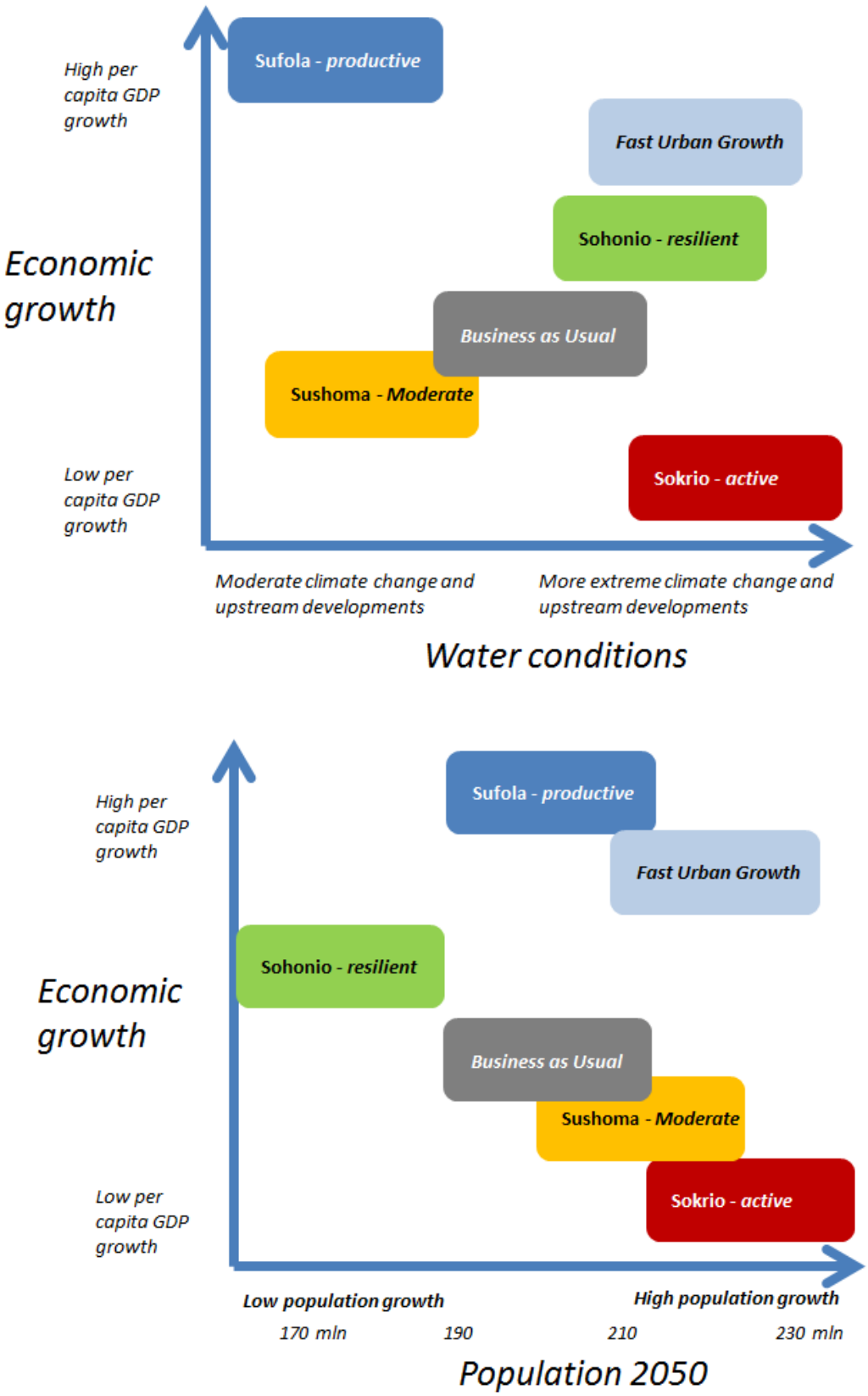

Figure 3: The six scenarios positioned around the key drivers

Key characteristics of the four 'extreme scenarios, a summary table and overview is presented in the figures and table below.

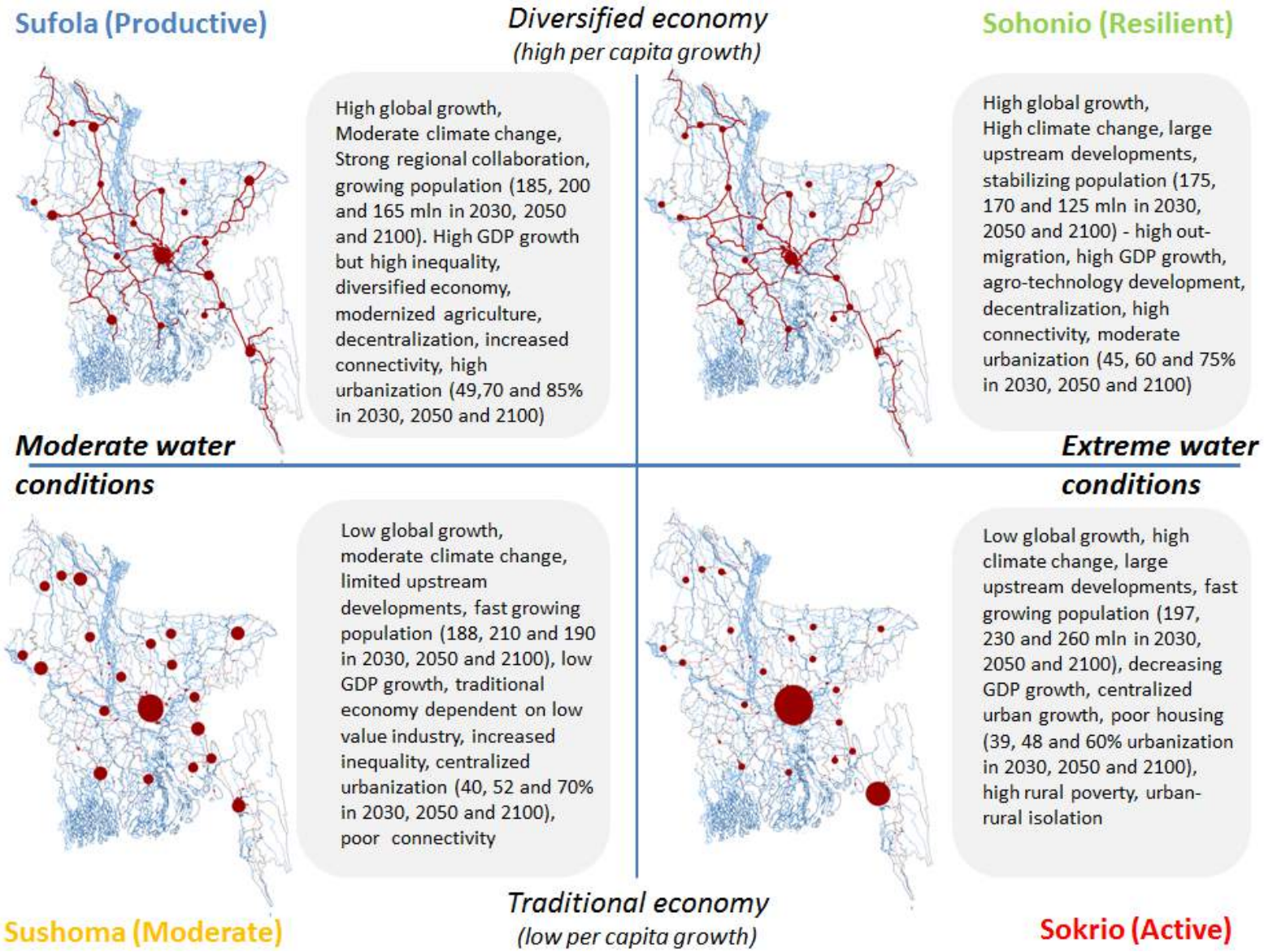

Figure 4: Main characteristics BDP2100 Scenarios – *summary (BDP2100 Scenario Development Team)*

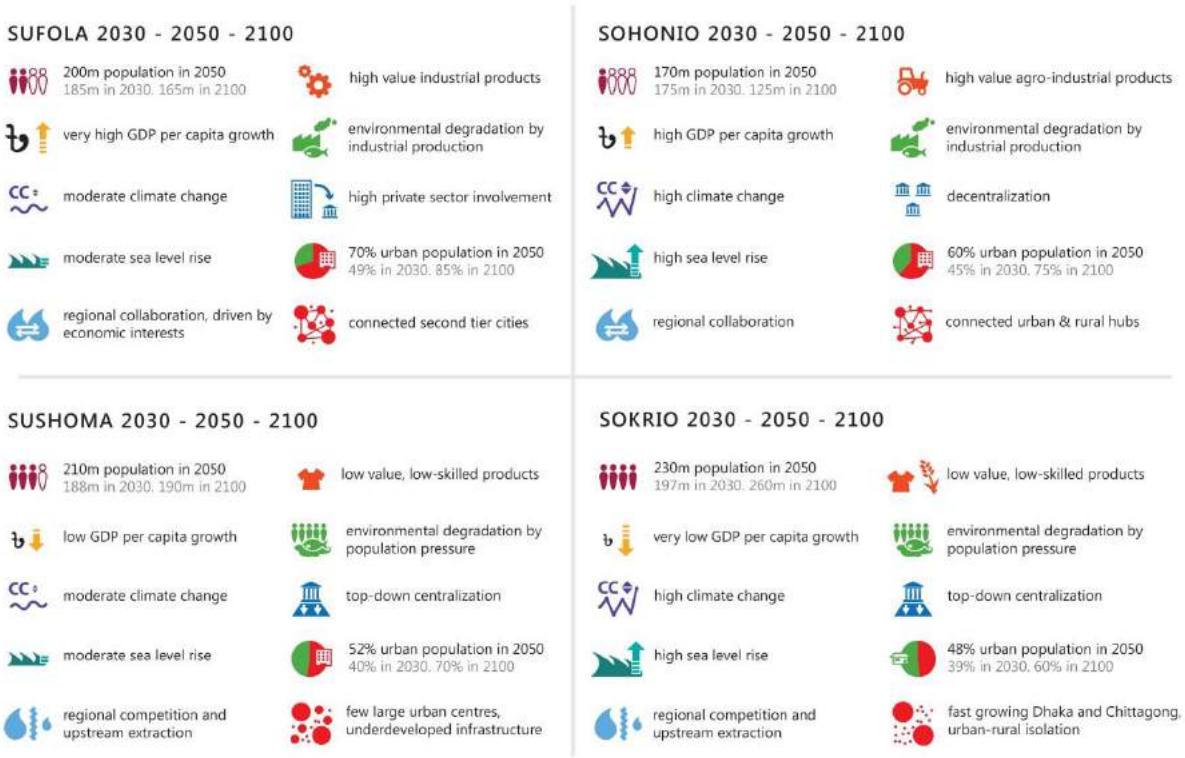

Figure 5: Main characteristics BDP2100 Scenarios – ***icons (Defacto, BDP2100 team)***

Each scenario is characterized by distinctive directions of the key uncertain drivers. The table below summarizes they key characteristics for each of the four basic scenarios.

Table 1: Summary table key drivers and directions BDP2100 scenarios

Scenarios	Sufola (productive), *market driven delta*	Sohonio (resilient), *dynamic delta*	Sushoma (moderate), *delta under pressure*	Sokrio (active), *basic needs first*
Global economic growth	Very high	High	Moderate	Low
Climate change	Moderate	High	Moderate	High
Upstream developments	Limited, planned and timely implementation of interventions	Large, additional interventions built	Limited, slow implementation of infrastructure	Large, many additional infrastructure to protect national economic growth
Regional collaboration	Collaboration driven by economic interests, shared interests riparian countries	Collaboration driven by economic interests, shared interests riparian countries	Competition	Fierce national and international competition
Bangladesh economy	Very high GDP growth, diversified economy driven by market and private investments.	High GDP growth, modernization agriculture and diversifying economy	Low GDP growth, Central economy, Traditional growth with focus on low-value industrial and agricultural products	Very low GDP growth, traditional economy and high informal sector
Trade	Trade liberalization, open access to markets and cross-border trade	Trade liberalization, open access to markets and cross-border trade	Closed economy, protectionism	Closed economy, protectionism
Poverty & equality	Risk of fast but unequal growth, in long run growing middle income class and decreasing inequality	Reduction of inequality in the long run	High inequality, growing wealthy elite and high percentage of poor population	High urban and rural poverty, high percentage of poor population
Population	Increasing, stabilizing and then declining to 185, 200 and 165 mln in 2030, 2050 and 2100.	Stabilizing and declining to 175, 170 and 125 mln in 2030, 2050 and 2100. High migration. Also	Fast growing, stabilizing late. 188, 210 and 190 mln in 2030, 2050 and 2100. High fertility	Fast, continuing population growth. 197, 230 and 260 mln in 2030, 2050 and 2100. High

Scenarios	Sufola (productive), *market driven delta*	Sohonio (resilient), *dynamic delta*	Sushoma (moderate), *delta under pressure*	Sokrio (active), *basic needs first*
	Decreasing fertility rates	climate refugees	rates and low migration	fertility rates and low migration. Climate refugees
Technology & human capital (education)	Rapid technological advancement, increased investments in human capital	Relatively rapid technological change, increased investments in human capital	Limited technological diffusion, low investments in human capital leading to low productivity	Slow technological change, low investments in human capital leading to low productivity
Urbanization	Rapid urbanization and emergence second tier cities. 49, 70 and 85% urban population in 2030, 2050 and 2100	Rapid urbanization, emergence agri-business hubs. 45, 60 and 75% urban population in 2030, 2050 and 2100	Fast growing Dhaka & Chittagong with urban sprawl. 40, 52 and 70% urban population in 2030, 2050 and 2100	Fast growing Dhaka & Chittagong and scattered rural settlements. 39, 48 and 60% urban population in 2030, 2050 and 2100
infrastructure	Increased connectivity and economic hubs	Increased urban-rural connectivity	Underdeveloped urban-rural connectivity	Urban-rural isolation
Perspectives / roles public private sector	Individualistic, market driven, low regulations, high private sector involvement	Egalitarian, decentralization	Hierarchy, centralization, top-down regulation, largely public sector	Reactive, centralization
industry	Focus on high value industrial products and services driven by technological enhancements and human capital	Focus on high value agro-industrial products and services driven by technological enhancements and human capital	Focus on low-value production and low-skilled labor. Unsustainable Garments sector	Focus on low-value production and low-skilled labor
Lifestyle - livelihoods	From food security to food variety, dietary changes, more livestock	Reduction of inequality	Focus on food security, rice farming	Focus on subsistence farming, small-scaled rice farming
Agriculture	Modernization of agricultural	Modernization of agricultural	Production focused on large	Adaptive farming and

Scenarios	Sufola (productive), *market driven delta*	Sohonio (resilient), *dynamic delta*	Sushoma (moderate), *delta under pressure*	Sokrio (active), *basic needs first*
	sector. Diversified and integrated farming, increased productivity, focus on high-value crops, decrease of arable land	sector, emergence of agri-business hubs, adaptive farming and productivity, high technological changes, invention of high tolerance crops	scale farming by elite and small scaled rice farming by rural poor, decrease of arable land	production, focused on small scaled rice farming, significant decrease of arable land and increase of scattered rural settlements
Environment	High pollution in short term, more environmental awareness in longer term	Nature is vulnerable, short term degradation, longer term protection of environment	Increase of environmental degradation	Increase of environmental degradation
Navigation	Significant increase in inland freight waterway transportation (modal share of 23% by 2050)	Increase in inland freight waterway transportation (modal share of 19% by 2050)	Inland waterway transportation lags behind (model share of 15% by 2050)	Inland waterway transportation remains underdeveloped, (model share of 11% by 2050)

1. Process towards Delta scenarios for the BDP 2100

1.1. Introduction

Based on the results from the Scenario workshop BDP2100 held in February 2015 (as documented in the report: scenario workshop: towards Delta scenarios for the BDP (van Aalst, 2015) and further analysis from the core scenario team, four scenarios have been developed and quantified. The current draft scenarios have been validated with key experts during a socio-economic and a physical scenario validation workshop in May 2015. Thereafter, they were further validated in expert workshops focussing on socio-economic and physical parameters and presented in a large stakeholder workshop in September 2015. The scenarios will be used to assess the strategies and measures through an assessment framework. The scenarios are to be seen as a 'living document', and they require regular updates and amendments, based on feedback from different experts and new insights and information as time progresses.

The main aim of scenario analysis is to identify key impacts and to address uncertainty. For this reason, a **bandwidth of possible future developments** is needed instead of a single future projection. This bandwidth of possible outcomes is used to evaluate the (cost-) effectiveness of potential measures of adaptation to climate change. The scenarios enable uncertainty to be taken into account when selecting and evaluating strategies for adaptation in the future. In this way a careful assessment can be made to decide which strategies should be prioritized and can be considered 'no regret' for today and tomorrow.

Scenarios are plausible, and often simplified, representations of future states. A scenario is neither a forecast nor a prediction; rather scenarios represent different plausible stories (= narratives) about the future with a logical plot and narrative governing the manner in which events unfold (Schwartz, 1991). The BDP scenarios consist of storylines (=narratives) describing different future developments of major uncertain drivers. Main drivers of the scenarios are quantified in the next part of this report. The scenarios focus on water related impacts as a result of large changes and developments with regards to the socio-economic and natural system. The inherent implications on food security and other socio-economic indicators are also described.

As the aim of the scenarios is to provide insight in the effectiveness of different adaptation measures, they only include autonomous developments. In other words, they do not include specific policies that are aimed at solving key impacts and bottlenecks. The Delta scenarios presented in this document consist of a scenario 'narrative' and a 'quantification' of the scenarios. The scenario narrative, which is **the storyline of a scenario, has three objectives**:

1. To identify the impacts of different socio-economic developments in combination with hydrological changes
2. To provide inspiration and new insights: to enable a better informed assessment of different adaptation options and/or identifies new options and strategies. They can also create a sense of urgency to alter *business-as-usual* developments
3. As guidance and rationalization for the quantification of the scenarios

The quantification is used for the assessment framework and to assess the performance and robustness of measures and strategies.

Two-axis method

A conscious choice was made during the formulation of the Delta Plan Project (Terms of Reference and Inception Report, Delta Plan Formulation 2100, GED, 2014) to make use of explorative scenarios, using the 'two-axis' method rather than other scenario approaches. The two-axis method, developed first by the RAND Institute in the USA in the 1940s, followed by the Stanford Research Institute and more recently, Shell[1], which used this approach to prepare for the impact of external events on oil prices. In view of the emphasis on long term uncertainties and its strength in assessing robustness and flexibility of strategies related to climate change adaptation, it was recently used by the IPCC and in the development of the Dutch Delta Plan[2]. In the *Guidance Note on Scenario Planning* by the 'Foresight Horizon Scanning Centre, UK Government Office for Science, the two-axis method is indicated as *particularly suited to testing medium to long-term policy direction, by ensuring that it is robust in a range of environments*[3][4].

1.2. Scenarios and strategic vision of the BDP2100

Scenarios are used to assess the performance of strategies. How well do proposed strategies perform under different future situations? In the Bangladesh Delta Planning Process, the purpose of scenarios is to assess to what extent the preferred strategies – which are the result of policy choices– contribute to meeting the Vision and Goals for the Bangladesh Delta. The figure below shows the connection of the scenarios with the strategies and its position within the BDP 2100 (see figure 1.1). The scenarios thus have a distinctive role in the development of the Delta Plan. In annex 4, a practical application for strategy development is further illustrated.

Scenarios are possible future outcomes. They depict circumstances that need to be taken into consideration when planning for the long term vision. Strategies are formulated to reach the vision, based on the regional (hotspot) approach. The scenarios assist, together with the assessment framework, to assess whether the strategies are able to cope with unforeseen circumstances and different future outcomes that are largely beyond our control.

[1] See also Schwartz, P. (1991) The Art of the Long View for a detailed description and analysis of this widely applied approach to long term scenario planning.

[2] Similar approaches have also been used at basin or catchment level in numerous countries, see eg the 'Snohomish basin scenario report (Washington State, USA), Appendix 5 scenario planning approach', 2013

[3] The Guidance refers to the two other frequently used scenario planning methods used by UK Government: *branch analysis* – particularly suited to describe possible (high-impact) events and subsequent action-oriented strategies for the relatively short term (up to 5 years) and the *cone of plausibility* approach, in which likely and logical pathways are described for the short foreseeable term (up to 1 year).

[4] In the formulation of its new Country Assistance Plan for Bangladesh in 2009, the Department of Foreign International Development (DFID) applied a comparable two-axis approach in developing its poverty strategy.

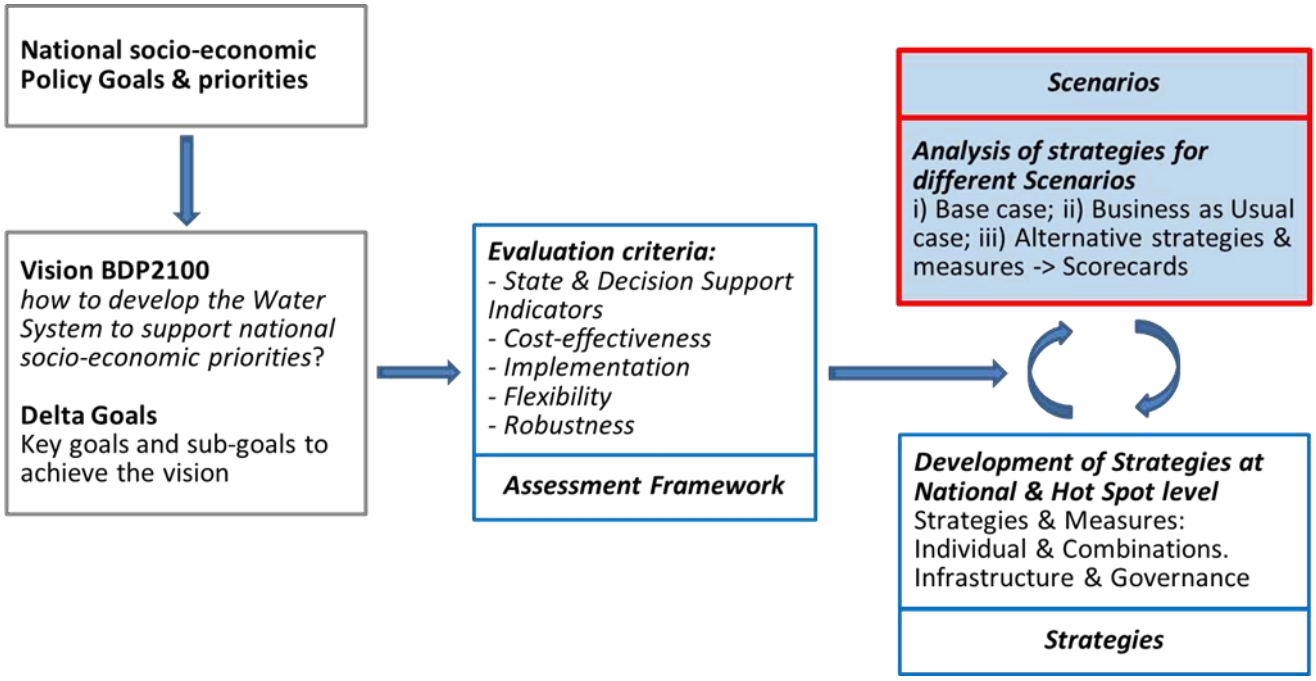

Figure 6: Scenarios as part of the Adaptive Planning approach of the BDP2100

1.3. Approach towards the BDP scenarios

The scenarios for the BDP are being developed in a participatory approach, which is crucial to ensure proper development, including the Bangladesh perspective, and create a common understanding and ownership at national level. The two day scenario workshop that was held on February 11 and 12 at the GED provided the building blocks for the scenarios (note that most of the pictures included in this report, are from this meeting). The scenarios are being further substantiated, validated and transformed to consistent scenario narratives based on the baseline studies and further research and consultation with key experts. The scenarios are being quantified on key indicators that are relevant for the impact assessment and further modeling.

The following process was followed during the workshop:

1. Identify major driving forces based on PESTLE analysis. (PESTLE: Political, Economic, Social, Technical, Environmental and Legal)
2. Plot drivers based on impact and uncertainty (impact-uncertainty matrix)
3. Place two most important drivers along XY-axis: scenario framework
4. Develop narratives based on the scenario framework, including additional drivers - pressures – states
5. Define impacts per scenario – opportunities / vulnerabilities
6. Quantify scenario narratives
7. Test performance of proposed strategies in the different scenarios

Steps 1 to 4 are visualized in the figure here below:

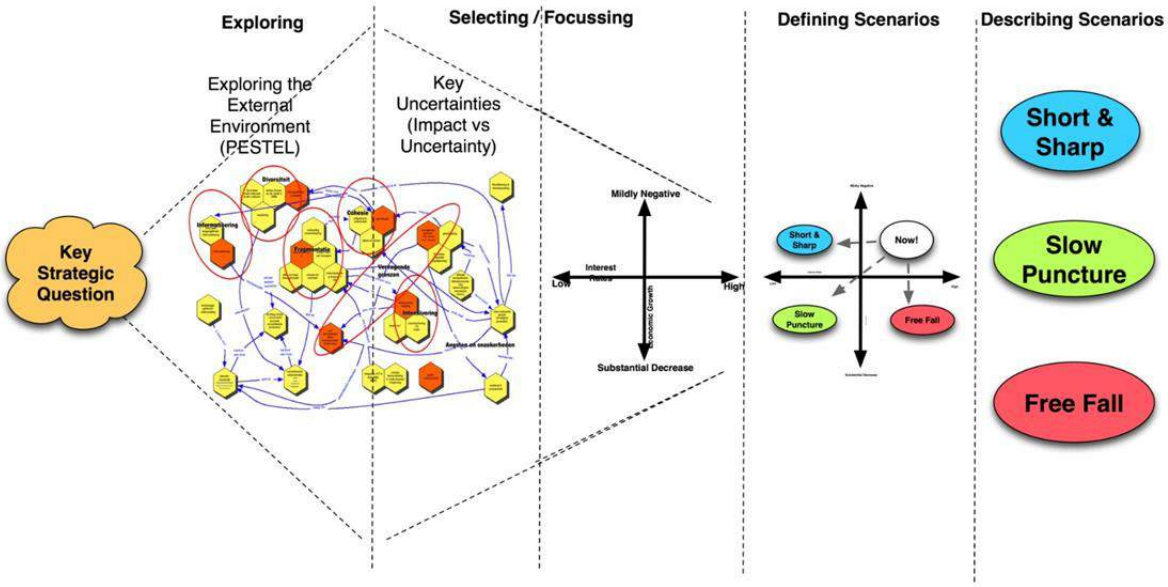

Figure 7: Approach to developing Scenarios in BDP2100 (Source: De Ruijter Strategy)

Drivers

During the workshop an impact-uncertainty matrix was used to identify and discuss the main drivers that are considered to be the most relevant in relation to the future of Bangladesh. The impact / uncertainty matrix is used to identify what key drivers of change should be considered for the scenario development. The delta scenarios should include those drivers that will have the most impact in relation to the objectives of the BDP2100 and that are also very uncertain.

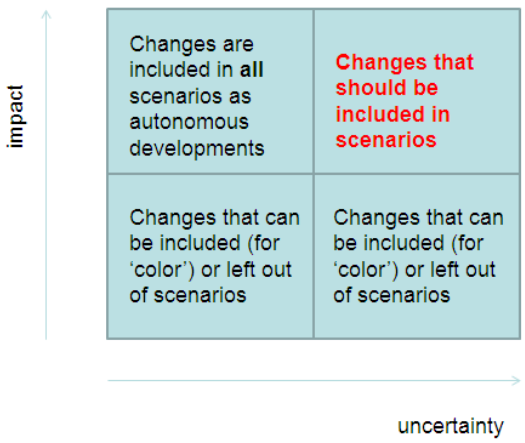

Figure 8: Impact uncertainty matrix as developed for the Dutch Delta scenarios

In different groups, those drivers were identified that could significantly impact the vulnerability and adaptive capacity of Bangladesh with regards to changing water conditions and that are very uncertain and difficult to influence. The key topics are listed below:

Upstream water development

One of the key issues with both high uncertainty and impact defined during the Scenario Workshop was the rate and level of upstream (surface water) abstractions resulting from the Indian River Linking Project (IRLP)[5]. The largest anticipated development is the diversion of flow from the Brahmaputra to the Ganges and further basins within the country. Irrigation development is a key driver for this abstraction. Further upstream abstraction is also expected from regional trans-boundary rivers such as the Dudhkumar, Dharla, Mahananda and Teesta[6] Rivers in the North-Western part of the country and the Surma and Kushiyara Rivers in the North-Eastern part of the country. The flows in these rivers are not regulated through any treaty at present. Low flows in the Ganges are regulated in the 1996 Ganges Water Treaty between India and Bangladesh. In the Treaty, Bangladesh is guaranteed a share of the expected minimum long term average flow of approximately 900 m^3/s (50% of minimum of 50,000 cusecs)[7]. Actual low flows since the ratification of the Ganges Treaty are however 750 m^3/s on average (Zahirl Haque Khan, IWM, 2015, presentation for GED, November 2014). For the purpose of scenario development, this average will therefore be used rather than the long term average mentioned in the 1996 Treaty.

The IRLP also includes diversion from the Ganges to other basins. However, for scenario development, it does not seem plausible that Bangladesh will accept a lower share than the present minimum, as laid down in the treaty. This amount will therefore remain constant as lower level in all scenarios.

Project Documents and articles suggest that the Indian Government has developed a vision of a total abstraction of some 33 Billion m^3 (BCM) annually from the Brahmaputra (Himalayan) to other rivers (Peninsular) in the medium to long term. Assuming such diversions would take place evenly throughout the year, this would amount to approximately 2.75 BCM in the 'final' IRLP situation. Average low flows for the Brahmaputra entering Bangladesh are in the order of 2,700 m^3/s or 7.12 BCM per month (Delta Atelier Coast, September 2015, presentation Mizanur ur Rahman, GED). The abstraction therefore equals some 38% of the total average monthly low flows for the Brahmaputra River. For the purpose of scenario development, this percentage is taken as the upper limit of upstream abstraction. It goes without saying that this approximation is precisely that. Given the importance and potential impact, detailed scenario modeling and monitoring should take place as part of the follow up phase of the BDP2100 formulation.

For the purpose of developing workable scenarios, it is furthermore assumed that the percentage-wise reduction in flows for other regional rivers is equal to the percentage-wise reduction for the Brahmaputra[8] for each scenario.

Given the status of the IRLP there is little uncertainty on whether upstream abstractions will take place or not, the uncertainty concerns the level of abstraction (% of low flows <-> volume of water) and the rate at which the upstream developments are implemented over time, taking into account the relevant time horizons 2030, 2050 and 2100.

Whilst development narratives regarding abstractions for each of the four scenarios, the following factors are also considered:

- Higher global economic growth leads to a higher upstream water demand
- Higher economic growth in Bangladesh leads to a better negotiation position vis a vis its upstream neighbors
- Increased climate change (in Bangladesh and riparian countries) leads to accelerated rate of abstraction

[5] Please see the BDP Baseline Reports on Regional Cooperation and Water Resources for further information
[6] Low flows in the Teesta river, much like the Ganges, are already impacted due to upstream abstractions
[7] Annual Inflows for the three major rivers are 380 BCM for the Ganges, 537 BCM for the Brahmaputra and 195 BCM for the Meghna
[8] It is highly recommended to carry out detailed follow-up studies for the smaller regional rivers to better substantiate these assumptions for each region (e.g. for the North-West)

Key characteristics of the narrative regarding upstream abstractions for each scenario are summarized in the table below.

Table 2: Key characteristics of upstream abstractions for each scenario

SUFOLA (productive)	SOHONIO (resilient)
• Very high economic growth • Moderate climate change • Strongly globalized and diversified economy with many shared interests between riparian countries • Low to moderate increase in upstream abstraction from low to medium in the medium term (2030) and high in the long term (2050 – 2100) • Extensive data sharing and joint (water) knowledge development • Trans-boundary agreements for main and regional rivers • Joint water development projects in upstream catchments	• High economic growth • High climate change • Moderately diversified economy, strong agri-sector, moderate shared interests between riparian countries • Moderate increase in upstream abstraction from low to medium in the medium term (2030) and high in the long term (2050 – 2100) • Extensive data sharing and joint (water) knowledge development • Trans-boundary agreements for main rivers • Joint water development projects in upstream catchments
SUSHOMA (moderate)	**SOKRIO (active)**
• Low but stable economic growth • Moderate climate change • Closed economy with little diversified - shared interests between riparian countries • Moderate increase in upstream abstraction from low to medium in the medium term (2030) and high in the long term (2050 – 2100) • Little to medium data sharing and joint (water) knowledge development • Extension of Ganges treaty only	• Low and decreasing economic growth • High climate change • Closed economy with little diversified - shared interests between riparian countries • Moderate to high increase in upstream abstraction from medium in the medium term (2030) and high in the long term (2050 – 2100) • Little data sharing and joint (water) knowledge development • Extension of Ganges treaty only

Climate change and natural disasters

Both climate change and natural disasters were discussed in all groups as a key driver with high impact and uncertainty. Climate change is driven by increased greenhouse gas emissions resulting in global warming. A warmer climate results in higher temperatures, increased rainfall intensity, more frequent and long dry spells, higher wind speeds, increased cyclone intensity and sea level rise. These changes in the climate systems result in more frequent and severe floods, reduced dry season river flows and more intensive and frequent droughts. This has an impact on food security through changes in agricultural water use and reduced dry season water availability. Also cyclones and major river floods can have devastating impacts on food production systems. Urban flood risks will increase due to a combination of more intensive rainfall, increased cyclone intensity and higher peak river flows. In the coastal region the sea level rise will add to the increased flood risks. Water quality is affected especially by increased salt water intrusion caused by a combination of sea level rise and reduced dry season river flows. Domestic and Industrial water supply will become more erratic due to increased droughts and in the coastal zone by salt water intrusion. Climate change will also affect biodiversity and environmental quality in several ways.

Economic structure, international markets and technology developments

In many groups, drivers related to the economic development of Bangladesh were discussed in relation to international relations and trade and technology enhancements. Key issues that were discussed are:

- Globalization and development of trade
- Human capital development (investments)
- Global market of manufactured products of Bangladesh
- Level and driver of industrial development
- Economic transformation
- Investments in infrastructure
- Digital and agricultural technology
- Modernization of agricultural sector
- Impact of cross-border trade

Demographics, urbanization and land use changes

Developments related to the rapid population growth and inherent urbanization trends were discussed in all groups. Concerns are raised on the impacts on agricultural land due to the continuous urbanization and the pattern to which urbanization is currently stretching the capacity of the major cities. Two extremes are depicted, in which on the one hand unplanned urbanisation is further encroaching large cities and paralyzing city life and on the other hand, outside Dhaka other economic hubs are emerging as second tier cities across the country. This will help to reduce the pressure on Dhaka as the one and only hub, and facilitate spreading of the urbanisation trend.

Main issues that were raised are:

- Population growth and composition
- Land use changes
- Level of unplanned urbanization
- Decrease of agricultural land
- Emergence of 'high input, high investment, high return' agriculture (flowers, strawberries, broccoli etc) as compared to low input low risk types of agriculture
- Food security, livelihoods and poverty
- Access to education
- Change in consumption patterns of Bangladesh
- Equality – differences between rich and poor

Governance and political situation

Governance and political instability was raised in most of the groups. Political and institutional reforms are considered to be key in the further development of Bangladesh. Effective governance will shape the direction of Bangladesh to a large extent. The future situation is seen as volatile and highly uncertain.

Environment

A few groups raised the issue of water quality and environmental degradation, including degradation of biodiversity and wetlands. Salinization is seen as a main driver with regards to environmental degradation in the coastal zone, and industrial pollution is considered an important threat (especially around Dhaka and in other industrial areas). In a few cases agricultural runoff is also considered as a key determinant. Arsenic contamination of groundwater and the use of this water in agriculture are also points that need attention. One group discussed the possibility of a scenario in which the Sundarbans were completely destroyed due to salinity intrusion and unsustainable industrial activities.

1.4. BDP2100 Delta scenario framework

Based on the results of the first day of the workshop, an initial scenario framework was developed, covering the key driving forces. Based on the large number of drivers identified, an unlimited number of scenarios could potentially be developed. However, this would not facilitate the assessment of strategies and measures. At the same time, one scenario can capture many different drivers, as long as they are coherent, relevant and consistent (thus fitting in the scenario storyline). Key to the scenario development is that the different scenarios developed are **Mutually Exclusive and Collectively Exhaustive** (MECE).

An approach that enables an MECE approach and at the same time elucidates scenario formulation is the approach used by the IPCC (intergovernmental Panel of Climate Change) for their SRES (Special report on emissions scenarios) (see figure 1.4), which are the predecessor scenarios of the currently used **Shared Socioeconomic Pathways** (SSPs). These socio-economic scenarios have been developed at a global scale for climate change research.

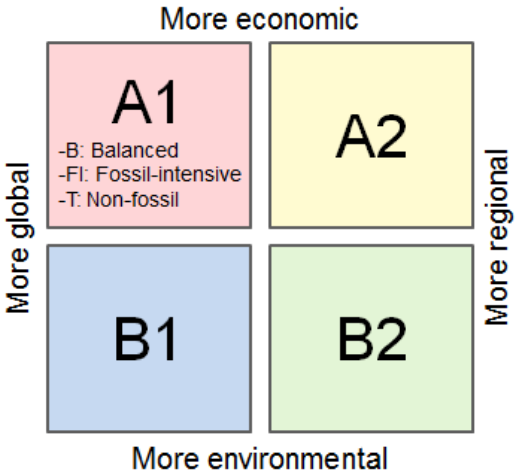

Figure 9: 4-quadrant matrix depicting SRES scenarios of the IPCC

In the IPCC scenarios, the two key uncertain and impactful drivers are placed on different axis. The Dutch Delta scenarios and the Mekong Delta scenarios have adopted a similar approach, in which the different scenarios are designed around a four-quadrant matrix depicting diverting evolutions of the main drivers. This approach allows for the key uncertain and impactful drivers to play a determining role in the scenario narratives, while also enabling the other drivers to be included in a consistent manner. It is mutually exclusive and collectively exhaustive and allows the scenarios to be a good tool when assessing the future measures and strategies. **Therefore, for the Bangladesh Delta scenarios the IPCC approach using two axis is followed.**

Based on the results of day one, the following drivers were identified that should be included on one of the axis:

1. Water conditions based on transboundary developments and climate change
2. Economic development and land use changes.

Both transboundary developments and climate change significantly impact the water system of Bangladesh. To what extent these impacts will develop in the future is however very uncertain. Currently, many of the problems are caused by climate variability, extreme events and – to a growing extent - upstream developments. In the future this might be exacerbated due to climate change. To capture both the impacts of climate change as well as the impacts related to transboundary developments, one axis on the framework

is designed around the water conditions; reflecting to what extent the water conditions will become more, or less, extreme, based on climate variability, climate change and upstream developments.

The other axis captures the uncertainties related to socio-economic development and land use changes, reflecting to what extent the global economy will grow and how fast Bangladesh will transform into a diversified economy. Key questions include: How will the GDP per capita evolve and how equal will the distribution of income be? Also, how will related urbanisation develop, where and how will people live and what will be the agricultural land use? These developments will, to a large extent, determine the vulnerability, potential damage and adaptive capacity of Bangladesh to water related events and conditions. The framework is presented in the figure below.

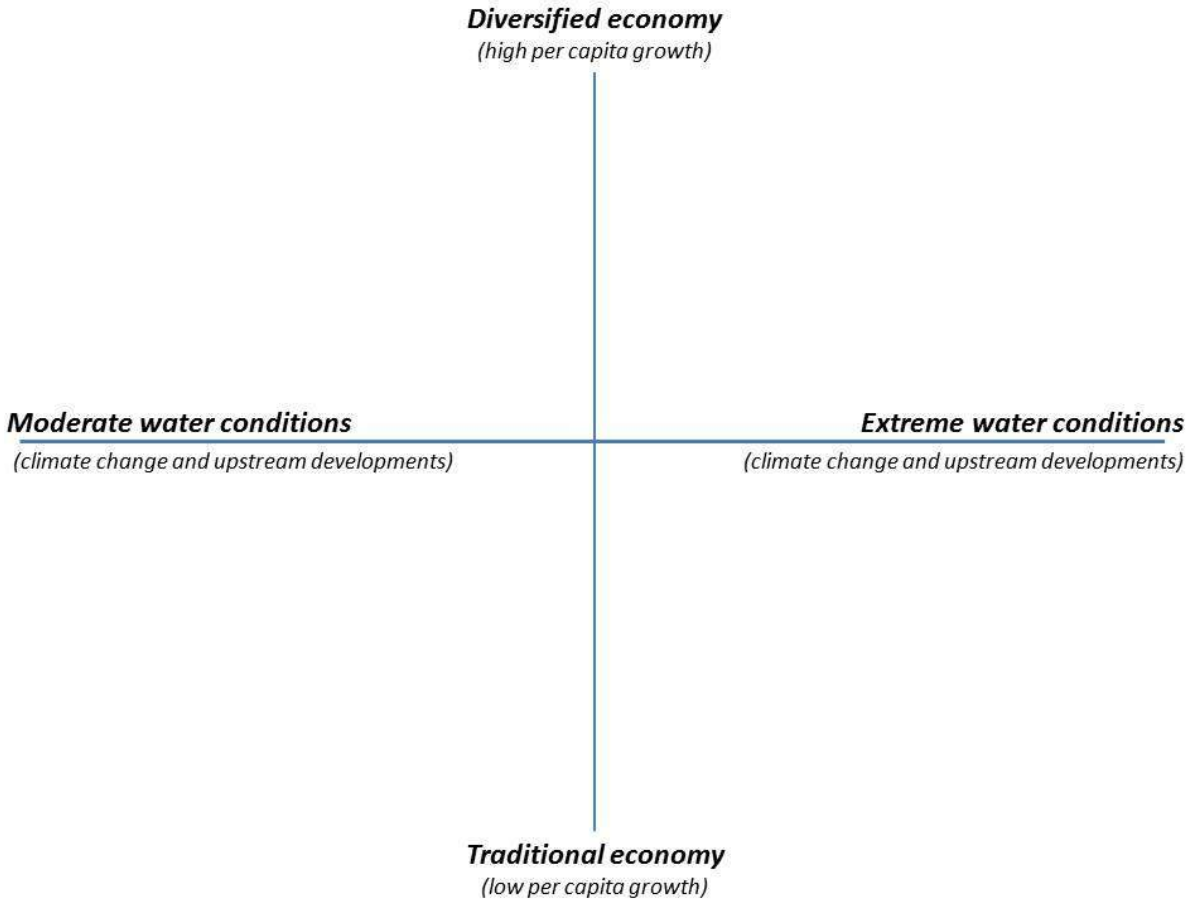

Figure 10: Scenario axis framework as developed in the February 2015 scenario workshop

The main drivers are very interrelated, with many feedback loops and interdependencies. Economic development, land use change, climate change and upstream development are not independent. Rapid climate change and increased upstream water extractions have a negative impact on economic growth. While rapid economic development of Bangladesh and India will facilitate the development of agreement on transboundary water use.

Besides the drivers on the main two axis (i.e. water variability and economic development), the scenarios will contain the other key drivers as identified during the workshop. This is displayed in figure 2.6. The scenario framework displayed in figure 2.6 was composed based on the results of the first day, and includes directions of key drivers such as: population growth, sectoral compositions, rural-urban migration patterns and trends, political and institutional conditions, technological developments, agricultural sector development and investments, and has been changed to the current framework since then.

This scenario framework has been used as a first building block and inspiration to develop the different directions of the scenario narratives, and has since then evolved based on workshop results and further analysis and research done by the core scenario team. The results of this are presented and discussed in the next chapter.

productive **Transitional economy** resilient

Development of a diversified economy
Modernization of agriculture
Stabilizing population
Continuous urbanization driven by pull factors of diversified industrial and service sector in cities
Emergence of second tier cities
Liberalization – free trade
Private sector investments
Rapid technological development
Reduction of inequality
Low climate change
International cooperation

Growing and stabilizing population
Effective institutions and governance
Increased agricultural productivity – focus on higher value added crops
More awareness and focus on natural resources
Increased resilience to natural disasters
Rapid technological development – high investments in agricultural R&D
Reduction of inequality
High autonomous upstream developments
High climate change

Stable water conditions

Differentiated world: Medium to high growth in industrialized countries, stagnating growth in developing countries including Bangladesh
High inequality: growing wealthy elite
Governance and globalization controlled by the elite
Unsustainable urban migration – encroachment of four major cities
Growing and stabilizing population by 2040
Regulatory capture
Little international cooperation
Low climate change
Slow technological diffusion

Extreme water variability

Focus on conventional growth of garment industry
Regular disaster recovery
High inequality
exponential growing population
Unlimited supply of cheap laborers migrating to urban areas
urbanization in unplanned settlements driven by push factors (agricultural poverty) – encroachment of four major cities
Little international cooperation – upstream developments continue without cooperation
Regulatory capture
Slow technology advancement
High climate change
High vulnerabilities to floods

Urban encroachment **Conventional growth** reactive

Figure 11: First draft scenario narratives as presented in the February 2015 scenario workshop

Figure 12: Participants developing impact uncertainty matrix, BDP2100 Scenario workshop

2. BDP2100 Delta scenarios

The BDP2100 scenario workshop (11-12 Feb 2015) resulted in the first building blocks for the BDP2100 Delta scenarios. The four scenarios developed in the workshop have been further substantiated and developed in the period February-April by the core scenario team and experts from several BDP baseline studies. This has resulted in four draft scenario proposals that have been validated and adjusted based on several validation workshop with key experts in May and June, 2015.

The aim of the four scenarios is to represent cornerstones of plausible developments, so they can identify different impacts of strategies under different 'what if's' and thus evaluate the robustness of proposed strategies.

The figure below displays the current scenario frameworks, derived from the building blocks and key drivers identified. Main axis are the water variability (consisting of climate change developments and upstream developments in riparian countries) and economic development and land use changes (see paragraph 1.4)

This chapter outlines the current scenario drafts and addresses the key drivers per scenario. It starts with a brief overview of the current socio-economic conditions in Bangladesh and follows with a description of the scenario narratives; the direction of the different drivers and their interconnectivity. It also outlines the impacts of land use of the different sectors, as well as the expected urban patterns. Furthermore, key water related implications are discussed per scenario and key indicators of the scenarios are quantified.

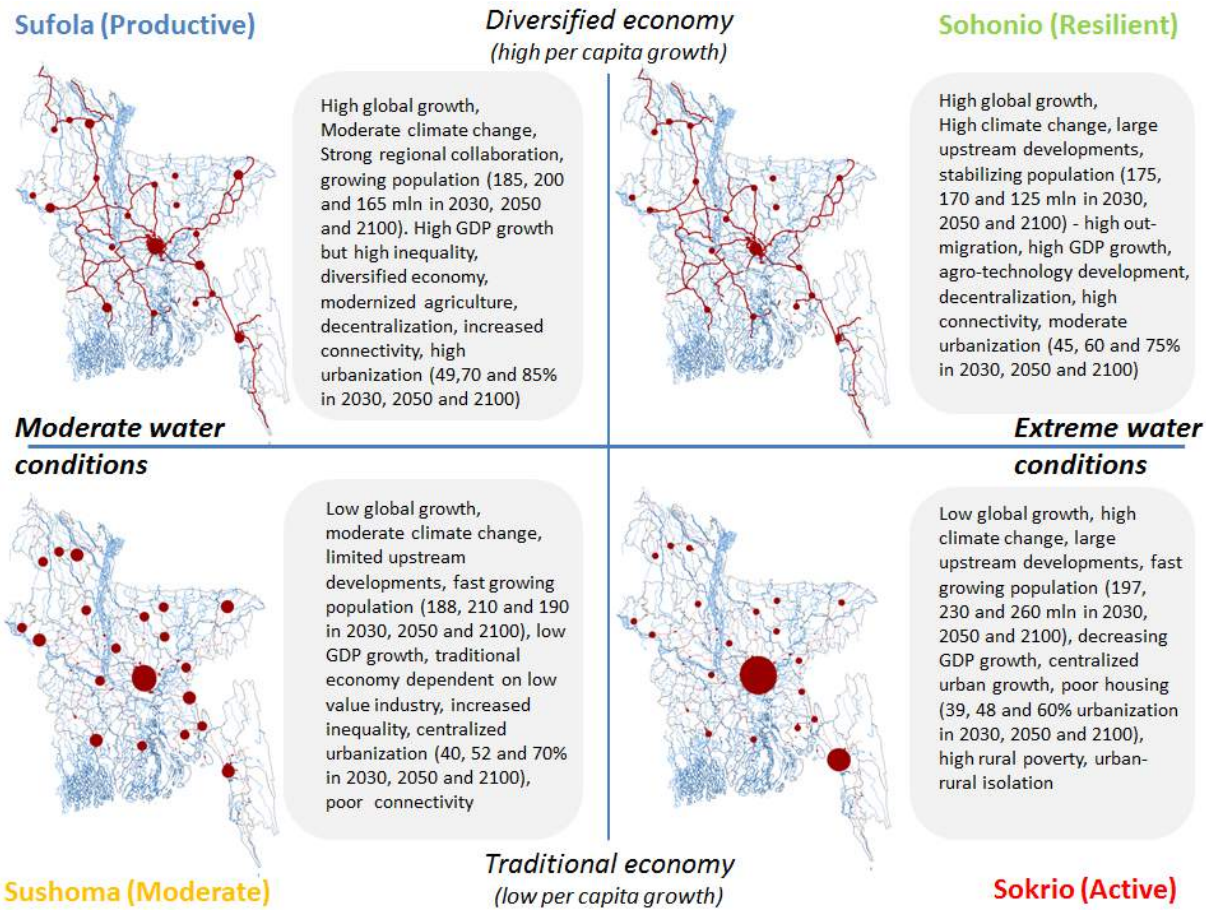

Figure 13: Summary narratives scenarios BDP2100

2.1. Current socio-economic conditions

To address the possible future conditions of Bangladesh, it is important to have an overview of the current conditions. Bangladesh has a current population of 157 million (January 2015, BBS) with a corresponding population density of more than 1,115 (BBS, 2011) persons per km^2. Bangladesh' population has grown very fast, from around 50 million in 1961 to 149 million in 2011; this represents an average growth rate of 1.98%.

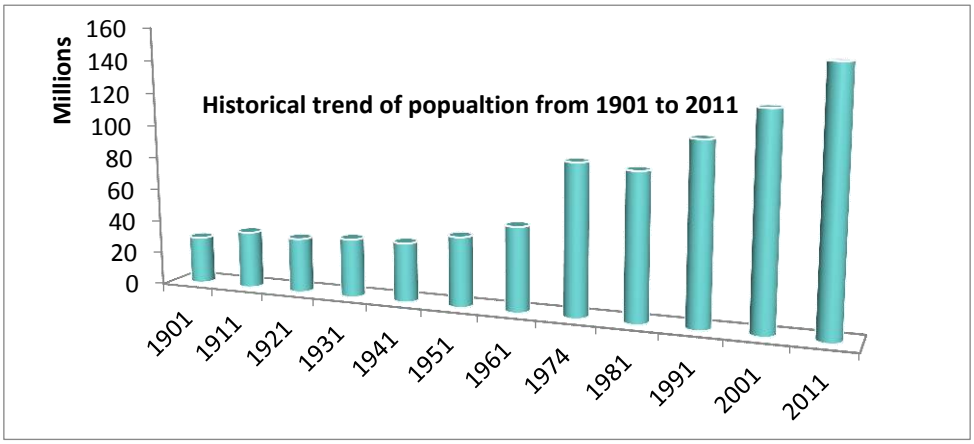

Figure 14: Historical population trend Bangladesh (BBS, 2011)

The national real GDP grew by about 77% between 1975 and 1990, an average annual rate of approximately 5.13%. In the period 1990-2013, yearly growth rates ranged between 5.2% and 6.2% (average five year period growth rates (socio-economic baseline study, 2015). The sectoral distribution shifted from a dominated agricultural value added, to a higher industrial share. This is also visible in current and historic land uses, although the urban and industrial surface area is still moderate.

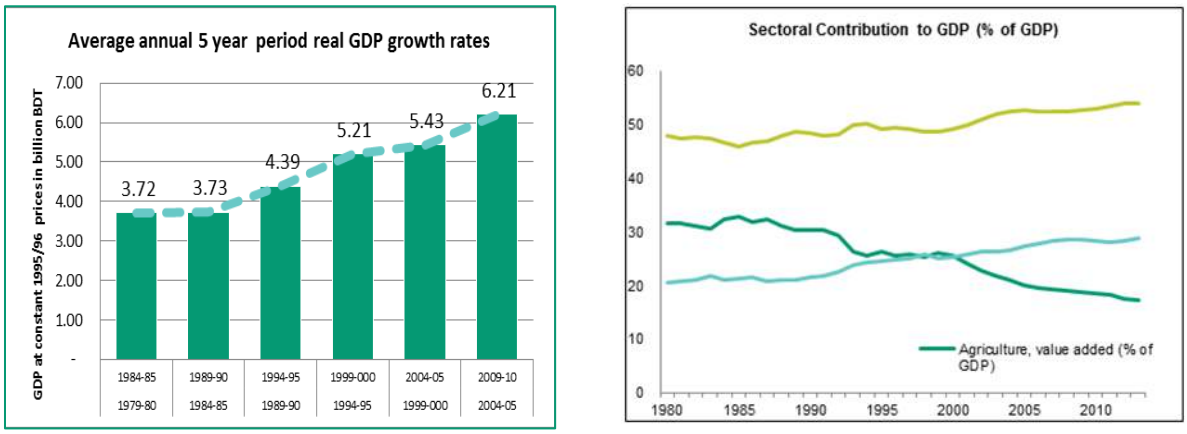

Figure 15: Average annual 5-year period GDP growth rate (left) and current and historical sectoral GDP composition (right)

(Source: Socio-economic Baseline Study Report)

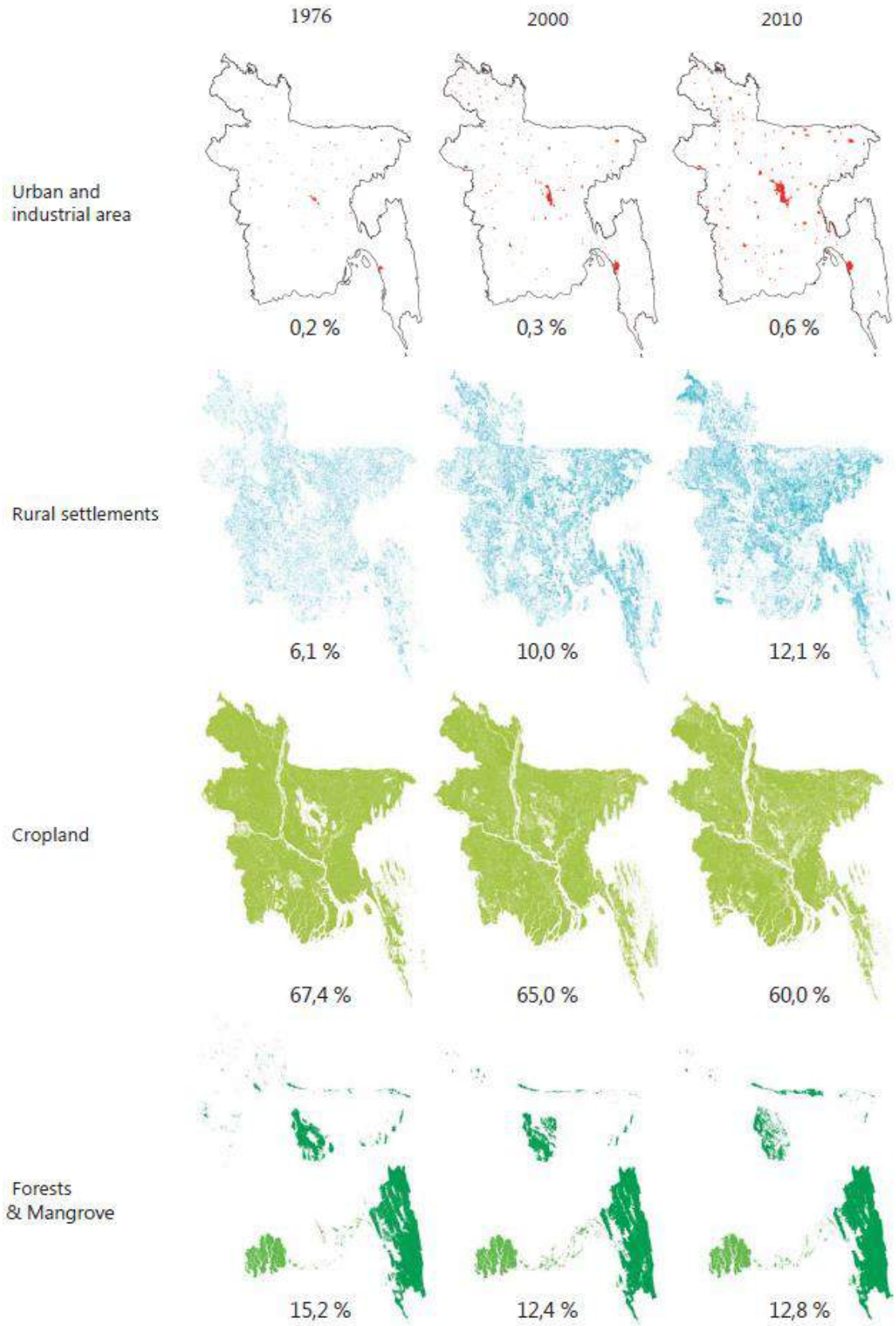

Figure 16: Selected land use types over time (Hasan et al, 2013)

2.2. Sufola (*productive*) scenario, *market driven delta*

This scenario is characterized by moderate water conditions, stabilizing population growth and an increase of per capita GDP growth as a result of fast global economic growth and a continuous transition of Bangladesh towards a diversified economy.

Key words: Market-driven economy, focus on rapid economic growth, trade liberalization, private investments, limited regulations, upstream collaboration driven by economic interests, rapid technological advancement, modernization of the agricultural sector, decentralisation, increased connectivity and economic hubs, rapid urbanization distributed all over the country.

Climate & upstream developments

Climate change in Bangladesh is relatively mild under this scenario. Temperature will only increase by about two degrees by the end of the century. There will be a slight increase (10 to 15%) in monsoon rainfall but the timing of the monsoon will not change. Dry season rainfall will stay more or less the same. Climate change will slowly reduce (up to 10% by the end of the century) the dry season inflow, while the river water levels in the monsoon period will increase by 10% in 2050 and 15% by the end of the century. Mean sea level is expected to rise moderately with 20-30 cm (in 2050) and 40-60 cm (in 2100). The number of cyclones that hit the coast of Bangladesh remains constant, although the intensity increases (baseline study Climate change). Both floods and drought frequency will increase but less severe compared to other scenarios.

Due to a booming global economy and high international trade, corridors between Bangladesh and India and between China/Myanmar are developing rapidly. Partly as a result of this increased economic prosperity and international economic activity multilateral collaboration with India and China improves. As a result there will be limited addition interventions in the upstream basin (the planned 16 dams in India are not built). The Teesta Treaty between India and Bangladesh is signed, resulting in an improved water sharing and also better use of available infrastructure to mitigate flood risk. These improved treaties and water management will make it possible to compensate for moderate climate change scenarios. Due to stable dry season rainfall, moderate sea level rise and improved collaboration with upstream countries the salt intrusion in the South-western part of Bangladesh will stabilize.

Socio-economic developments

The global economy is booming and is characterized by high trade liberalization, which pushes the external demand for manufacturing products of Bangladesh. Large international firms start to increase their investments in Bangladesh, which pushes economic activities further in the larger cities. Large private companies start to invest in modernizing the agricultural sector of Bangladesh, leading to more mechanized farms and higher productivity. High risk, high input, high return agriculture continues to increase (flowers, strawberries, broccoli etc). Agriculture processing industry continues to expand. This leads to an increase in livelihoods in the agri-industrial sector and more opportunities in the urban centres of the country.

Higher output and productivity in the agricultural and manufacturing sector lead to more food, services and products per capita. And though the overall income level rises, the gap between rich and poor also increases. The diversification of the economy increases and the internal market grows. The economic growth is hampered by soaring transportation costs, leading to more investments in specific rural and urban infrastructure that are needed to transport the high-value agricultural products to the markets. Other economic hubs start to emerge slowly, with improved urban facilities. Based on the increased connectivity with India, transportation possibilities (over road, over rail, over water) receive considerable investment.

The positive effects on the economy instigate further investments in technology, human capital and infrastructure by the wealthy elite and government, as they experience the merits of these investments. Improved transport links between the urban areas, such as the Dhaka-Chittagong corridor and India and

China, foster further access to local and international markets, in which trade barriers are largely removed. Slowly, due to a better fed and educated population, more high-skilled job opportunities in the service sector arise, and more people move towards middle-income status. By 2025 Bangladesh reaches middle income status. At the same time, many people migrate abroad for better opportunities in other growing economies.

As the middle income population increases and rural poverty decreases, food security objectives slowly shift to food variety objectives by 2035, with emphasis on a nutritious and varied offer. This reduces the rice production requirement and increases production of higher value crops and livestock for the internal market. By 2050, Bangladesh has a diversified market-driven economy in which the industry and service sector dominate, little regulation and an economy dominated by large private firms.

The tourist sector is one of the fasted growing sectors, with both domestic and foreign visitors enjoying the rich ecological landscape and biodiversity along the coast and northern Bangladesh. Thanks to fast rising eco-tourism, private sector investments have enabled habitat protection and the Bengal tiger habitat has grown, which has attracted many eco-tourists. The tourist sector development goes hand in hand with environmental protection of nature in the areas which attract tourists, like Cox's Bazar, the Sundarban and the Haor areas. Outside the tourist areas, the environment is under pressure due to industrial developments.

Towards 2100, Bangladesh develops into a high-income country, with growth driven by the market and private investments. As a result of higher wealth, fertility rates have gone down and most people live in advanced urban areas (85%). The service sector dominates the economy. The different urban areas and markets a highly connected.

Land-use changes

Due to the increase of economic activities, urbanization grows fast, putting continuous strains on the largest cities of Bangladesh. As a result of better transportation links and connectivity, other second tier cities are emerging, although the pace is slow. Thanks to technological advancement and growth of private investments, in combination with stable dry season inflows, Bangladesh is increasingly capable of building large scale human settlements.

Agriculture - Thanks to rapid technological progress, agricultural production shifts to higher value crops, such as vegetables, spices and ornamental plants. Due to increasing demand of rice, the cultivation of boro rise has also increased but depending on the availability of irrigation. On the whole, the intensity of cropping has also increased in favourable agro-ecological regions. Also due the rise of income and meeting enhanced nutritional demand, livestock production increases. As a result of agricultural up scaling, yields per hectare increase. Large scale mechanized farming displaces labour, which contributes to migration to urban areas. As a result of more industrial and urban activities, agricultural area declines significantly.

Urban areas - Second tier cities slowly emerge as an answer to relief the overcrowded cities of Dhaka and Chittagong, where the growing middle class and international companies demand improvements of urban infrastructure and city liveability. Private firms lead investments infrastructure (including port development) and access to markets, and dominate investments in urban facilities. The number of high rise building increases, while informal housing decreases. Urban liveability increases thanks to improved urban facilities and more green space.

Industrial – commercial areas increase significantly, mainly in opportune areas around the largest cities and second tier cities, and thus not necessarily at the best suited locations in terms of flood risk or highly fertile land.

Mangrove / Forests – mangrove and forest areas are under pressure due to more industrial and commercial activities. On the longer run however, habitats that have an economic value are protected by private investments earning from ecotourism.

Infrastructure – Rural and urban infrastructure is dependent on private sector investments and improves in those areas where the economic value is high. Improved transport links between the urban areas, such as the Dhaka-Chittagong corridor and India and China, foster further access to local and international markets, in which trade barriers are largely removed. Large private port activities increase.

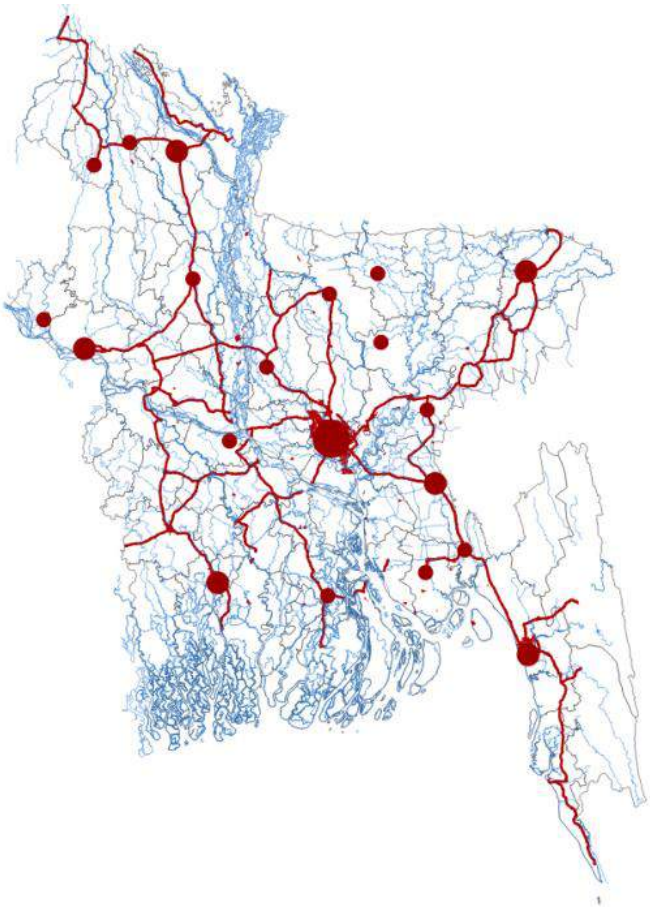

Figure 17: Visualisation urban patterns – Sufola *(productive)* scenario in 2050

Implications water use, floods and water quality

Water demand from irrigated rice agriculture will reduce due to changes to higher value crops. The water demand of these higher value crops will be lower than those of rice but a continuous and guaranteed water supply will be become more important due to the higher value of agricultural products. At the same time, to ensure food security, rice will remain the principal irrigated crop, and *overall* agriculture demand for water will increase.

The rapid development of the economy and urbanisation will increase the urban (domestic and industrial) water demand and water network. The domestic water use will shift. The average daily water use per household will increase significantly as a result of a growing wealthier population with higher consumption standards. Higher standards of drinking water quality will also increase significantly, putting higher demands on the water supply infrastructure. Fresh water supply in the dry season will be a main issue.

The need for improved **urban flood** management will increase due to the high investments in housing, infrastructure and the industry and services sector. Drainage congestion is a serious risk in the urban areas. Further, coastal polder areas will increasingly subside, leading to more waterlogging and drainage problems.

Water and environmental quality will be pressured due to more commercial and industrial activities, but the increase of commercial activities and higher income population will require better drinking water quality.

Table 3: Quantification of socio-economic developments – Sufola *(productive)* scenario

Sufola Scenario		**2015** *(reference)*	**2020**	**2030**	**2040**	**2050**	**2100**
Population	*Million inhabitants*	160	171	185	194	200	165
Urbanization	*Urban inhabitants (%)*	28	38	49	58	70	85
GDP Growth	*Average annual real GDP growth rates (%)*	6.3	7.7	8.0	7.5	6.8	3.0
GDP per capita	*Constant prices of 2010 ($)*	866	1,158	2,290	4,542	8,586	54,000
Agricultural sector share	*GDP contribution agricultural sector (%)*	16	15	13	11	8	5
Agriculture employment share	*% of people employed in agriculture sector*	47	40	30	25	20	10
Poverty	*Poverty headcount ratio at $1.25 a day (PPP) (%) Reference year: 2010*	43	32	24	18	14	1
Total freight transport	*bln ton-km*	36	51	110	229	445	2,311
Inland waterway freight transport	*bln ton-km*	5	8	23	53	108	695
Inland waterway freight transport	*Modal share (%)*	14	15	21	23	24	28
Land use developments		**2010** *(reference)*	**2020**	**2030**	**2040**	**2050**	**2100**
Agriculture land	*% surface area*	60	--	--	--	-	0
Urban / industrial land	*% surface area*	3	++	++	++	++	+
Rural settlements	*% surface area*	12	--	--	--	--	--
Mangrove / forests	*% surface area*	10	--	-	-	0	+

Source: 2015 data: Baseline reports of Bangladesh Delta Plan 2100, World Bank, CIA world Factbook. Scenario data derived from socio-economic and transportation baseline studies of BDP2100, UN population projections, IMF projections and Shared-Socioeconomic Pathways (IPCC)

Table 4: Climate change - Sufola *(productive)* scenario

Climate change Sufola scenario		2015 *(reference)*	2030	2040	2050	2100
Sea level rise	*Mean sea level rise in cm*		10-20	15-25	20-30	40-60
Temperature	*Mean max temperature degrees change (°C)*	25	+0.5	+0.75	+1	+2
Monsoon rainfall	*% change mean total monsoon (June-September) precipitation*	1,750	0	5	10	15
Dry season rainfall	*% change mean total dry season (December-February) precipitation*	36	0	0	0	0
Longest dry day period	*Increase of mean number of consecutive dry days*		0	0	0	+5
Rainfall intensity	*% change of mean total precipitation*		10	10	10	20
Cyclone intensity	*% change*		25		45	90

Source: Unnikrishnan and Shankar (2007), Hinkel et al. 2014 (IPCC, AR5), BMD, EU-Watch/Combine 2013/climate change baseline, IPCC 2013

Table 5: Peak discharges – Sufola *(productive)* scenario

Peak Discharges Sufola Scenario		2015 (reference, m3/s)	2030	2040	2050	2100
Ganges						
Peak discharge	*% change of mean annual maximum at Hardinge Bridge*	51,130	15		20	30
Brahmaputra						
Peak discharge	*% change of mean annual maximum at Bahadurabad*	67,490	5		10	15
Meghna						
Peak discharge	*% change of mean annual maximum at Bhairab bazar*	13,370	5		10	15

Source: BWDB (Yu et al. 2010), ISI-MIP & VIC (van Vliet and Ludwig, 2013)

Table 6: Upstream abstractions - Sufola *(productive)* scenario

Upstream Abstractions Sufola Scenario		2015 *(reference, m3/s)*	2030	2050	2100
Ganges					
Change Average dry season flow	*% change (minus) at Hardinge Bridge*	NA	*controlled by Ganges Water Treaty*		
Average dry season flow	*m^3/s at Hardinge Bridge*	750	*controlled by Ganges Water Treaty*		
Brahmaputra					
Change Average dry season flow	*% change (minus) at Bahadurabad*	3,000	-5%	-15%	-30%
Average dry season flow Brahmaputra	*m^3/s at Bahadurabad*	3,000	2,850	2,550	2,100

Source for Reference values: IWM, BWDB

2.3. Sohonio *(resilient)* scenario, *dynamic delta*

This scenario is characterized by a stable increase of GDP per capita, driven by favourable global economic conditions leading to a transformation to a more diversified economy, but hampered by extreme water conditions, due to climate change and adverse upstream developments.

Key words: sustainable economic growth, reduction of inequality, nature is vulnerable, modernization of agricultural sector through cooperatives, relatively rapid technological change directed towards sustainable agricultural production, limited consumption, water guides development, fast urbanisation and increased rural-urban connectivity, high migration, climate refugees, emergence of agri-business hubs.

Climate & upstream developments

In this scenario there will be rapid climate change and increased uncertainty in water availability due to upstream developments. Temperature will increase by 4 degrees until 2100. Extreme rainfall events will increase in both intensity and frequency. Also the cyclones will become more severe in intensity, though not in number. Dry season rainfall will reduce (up to -20%) and the monsoon rainfall will become much higher (up to 40%). The timing of the monsoon will become more variable and less predictable. Rapid climate change will have a severe impact on dry season flows of upstream river systems. As a result of climate change, river discharges in the dry season can be up to 50% lower by the end of the century. Wet season flows and high extremes, leading to extreme flood events will also rapidly increase. (baseline study Climate change)

To further stimulate their economic growth, riparian countries will rapidly develop new infrastructure to guarantee sufficient water supply in the dry season in their countries. Although the Teesta Treaty is signed, other dams and upstream interventions are being developed, threatening water availability in Bangladesh, especially during the dry season (low flow conditions). The river linking project will be developed and additional barrages will be developed for upstream irrigation development. Also China will develop an increasing number of hydropower plants in the upstream part of the Brahmaputra Basin. There will be an expansion of salinity in the coastal zone mainly driven by a reduced run-off from upstream and compounded by sea level rise and more frequent storm surges.

Socio-economic developments

Global economic growth is favourable. At the same time, Bangladesh is faced with severe impacts of water variability due to high upstream developments and a high climate change, which is tempering GDP growth. As a result of these climatic conditions, Bangladesh is increasingly aware of its vulnerability to nature and realises that rapid economic growth is not first priority, nor attainable. Enabled by favourable global growth conditions, priority can be placed on an equal, stable and sustainable growth, based on a 'water guides' principle. Internationally, technological changes develop relatively rapidly, and in combination with an urgency to increase agricultural productivity due to increased water scarcity, agricultural research and technology advances are considerable. By 2020, the technological progress made leads to different crop varieties (including salt tolerant crops) and a significant increase in agricultural productivity. The agricultural sector starts to modernize slowly, led by different cooperatives, with an ability to react in a resilient manner to the highly uncertain and variable water conditions.

In line with a more equal economic growth trajectory, investments in human capital are considerate, leading to a growing educated population. Growing economic activities and growing high-value agricultural products require an improvement of infrastructural conditions, to decrease transportation costs, and connectivity between urban and rural areas slowly starts to improve.

The modernization of the agricultural sector decreases agricultural employment, but increases demand in agri-food processing industries, leading to high rural to urban migration. At the same time, until 2030, the job opportunities available in the cities are insufficient to bear the huge rural to urban migration and vast growing working population and many people seek opportunities elsewhere abroad. Different Asian countries, China, Singapore, Taiwan, Japan, Thailand and South-Korea are in urgent need of a young working population, and people who can afford it move to opportunities in these countries. Also, as a larger population continues to become better educated, this also includes knowledge migration and studies abroad. The population stabilizes around 2035 to 175 million people, and by 2050 Bangladesh has around 170 million people. The population decline is mainly caused by high migration to other Asian economies and also as a result of continuing lower fertility rates.

Even though agricultural productivity increases, rural life is difficult, with lower discharges in the dry season and more severe and floods during the monsoon period. As a result, there is a large number of 'climate refugees', people that are forced to emigrate due to the lack of fertile land.

At the same time, thanks to technological advancements, drought and flood events are better monitored and predicted, resulting in a more Sohonio behaviour of the rural population. As a larger share of the population is well educated, adaptive solutions to cope with the increased water scarcity and salinity are increasing, although there is a limit to the possibilities. In the coastal zone this could result in expansion of aquaculture due to the higher profits and the increasing salinity trends. Sustainable aquaculture could increase as the better educated people understand the long term higher yields from for instance sustainable shrimp farming. By 2035 the landless/landowner system is no longer attainable due to increased resistance of the rural and urban population and this system slowly diminishes, increasing equality and agricultural cooperatives continue to be on the rise. The wealthy elite also experiences the profits from these technological advancements and puts more investments in connectivity and infrastructure, leading to agri-business clustered small cities well connected to the larger urban metropolitan areas.

As a result of limitations due to harsh climatic conditions, the agricultural sector is forced to modernize with cooperatives. But the process is slow. People in the city increasingly find higher level job opportunities and the country will slowly move to middle income, which is reached by 2030-2035. By 2050, the country has developed in a resilient country with a stable economic growth per capita (also realised by high out-migration) that is more equally distributed and well equipped to adapt to the natural hazards and climatic conditions.

Towards 2100, Bangladesh develops into a high-income country, which has mastered in technological adaptation and sustainability to cope with the harsh climatic conditions. Agro-technology and services drive the economy. As a result of harsh climatic conditions and high international mobility of people, population has gone down to 125 million people. Most people live in urban areas, which are well connected to the agri-techno hubs around the country.

Land-use changes

Driven by difficult rural conditions in combination with more industrial possibilities in the city, high rural to urban migration takes place. At the same time, high out-migration to other countries is taking place. The growth of the number of well-educated people, especially in the first 10 years, exceeds the growth of the number of jobs. Thus, better educated people both 'drive-out' the low educated people from the labour market and seek their future elsewhere. The low educated people see no other option then migration.

Agriculture – Urban area will grow at the expense of agricultural land. Although the arable agricultural land decreases significantly, due to less fertile ground and more salinity intrusion, thanks to investments in agricultural R&D and education, higher yielding varieties and more water stress tolerant crops are developed, leading to higher yields per acre with wider adaptation. Agricultural modernization leads to the appearance of small scaled clustered semi-urban hubs that facilitate food processing industries. The farmers groups, contract farming and precision agriculture enhance the resilience of farmers, as in joint action more can be achieved. Food quality is improving, as awareness of farmers on food quality increases, and resources are used to set-up a good system of enforcement of proper chemical use.

Infrastructure – Small secondary cities get increasingly better connected to the larger cities as this is required to enable the products to reach the markets.

Urban areas – High rural to urban migration due to harsh climatic conditions and water scarcity, while at the same time the urban areas act as pull factors due to a more diversified economy . There is also high out-migration to opportunities abroad. Small agro-hubs arise connected with larger cities. Connectivity and infrastructure development develops at a slower pace and GDP growth is lower than the Sufola scenario.

Industrial / commercial areas increase significantly due to less fertile land. Industrial development focussed on agro-food production

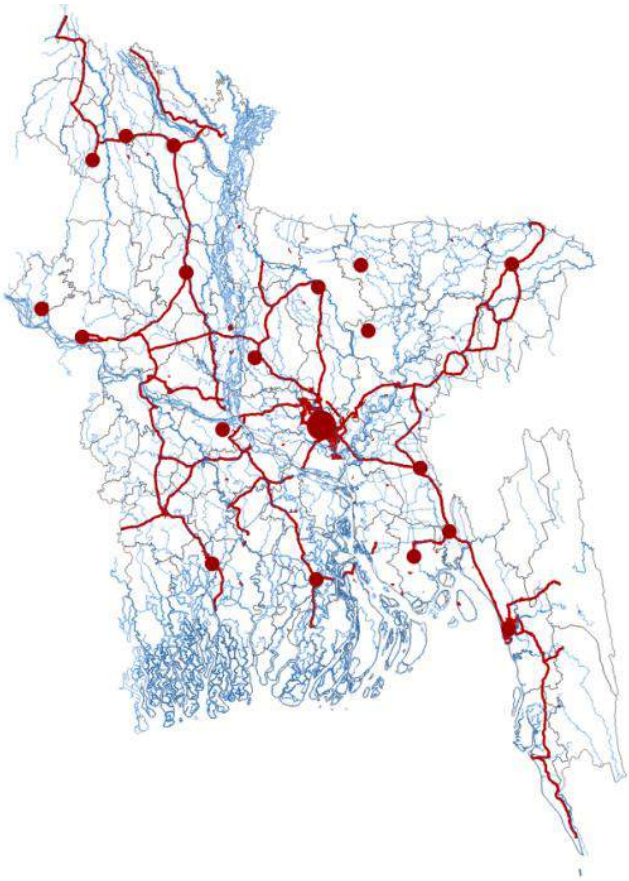

Figure 18: Visualisation of urban patterns – Sohonio *(resilient)* scenario in 2050

Implications water use, floods and water quality

Water demand - High water shortages for the agricultural sector, but thanks to technological advancements the agricultural sector will further intensify moving away from rice towards higher value agricultural crops. The more variable climate and lower dry season water availability will put a constraint on the future development of agriculture. The rising income level of the urban population will result in higher water demands from industry and households. Especially in the dry season it will become difficult to deliver this supply.

Floods There will be a large increase in flood risks due to the increase of extreme events and siltation in the major rivers as well as further expansion of urban areas. Sea level rise and more intense cyclones will further increase the flood risk in the coastal zone. Further, polder areas will increasingly subside, leading to more waterlogging and drainage problems.

Water quality will decrease due to water shortages, arsenic contamination and salinity intrusion. At the same time, sustainable use of water increases.

Table 7: Quantification of socio-economic developments - Sohonio *(resilient)* scenario

Sohonio Scenario		**2015** *(reference)*	**2020**	**2030**	**2040**	**2050**	**2100**
Population	*Million inhabitants*	160	168	175	174	170	125
Urbanization	*Urban inhabitants (%)*	34	38	45	54	60	75
GDP Growth	*Average annual real GDP growth rates (%)*	6.3	6.4	6.5	5.8	5.0	2.5
GDP per capita	*Constant prices of 2010 ($)*	866	1,125	2,008	3,469	5,723	30,000
Agricultural sector share	*GDP contribution agricultural sector (%)*	16	15	13	12	10	8
Agriculture employment share	*% of people employed in agriculture sector*	47	42	35	30	25	15
Poverty	*Poverty headcount ratio at $1.25 a day (PPP) (%) Reference year: 2010*	43	35	30	25	20	3
Total freight transport	*bln ton-km*	36	49	91	160	267	973
Inland waterway freight transport	*bln ton-km*	5	7	16	30	53	243
Inland waterway freight transport	*Modal share (%)*	14	14	18	19	20	25
Land use developments		**2010** *(reference)*	**2020**	**2030**	**2040**	**2050**	**2100**
Agriculture land	*% surface area*	60	-	-	-	0	+
Urban / industrial land	*% surface area*	3	+	+	+	+	+
Rural settlements	*% surface area*	12	-	-	-	-	--
Mangrove / forests	*% surface area*	10	-	-	0	+	+

Source: 2015 data: Baseline reports of Bangladesh Delta Plan 2100, World Bank, CIA world Factbook. Scenario data derived from socio-economic and transportation baseline studies of BDP2100, UN population projections, IMF projections and Shared-Socioeconomic Pathways (IPCC)

Table 8: Climate change – Sohonio *(resilient)* scenario

Climate change Sohonio scenario		2015 *(reference)*	2030	2040	2050	2100
Sea level rise	*Mean sea level rise in cm*		15-30	30-40	40-60	80-125
Temperature	*Mean max temperature degrees change (°C)*	25	+1.5	+1.75	+2	+4
Monsoon rainfall	*% change mean total monsoon (June-September) precipitation*	1,750	15	18	20	40
Dry season rainfall	*% change mean total dry season (December-February) precipitation*	36	-10	-10	-10	-20
Longest dry day period	*Increase of mean number of consecutive dry days*		+5	+8	+10	+20
Rainfall intensity	*% change of mean total precipitation*		20	20	20	50
Cyclone intensity	*% change*		70		90	100

Source: Unnikrishnan and Shankar (2007), Hinkel et al. 2014 (IPCC, AR5), BMD, EU-Watch/Combine 2013/climate change baseline, IPCC 2013

Table 9: Peak discharges - Sohonio *(resilient)* scenario

Peak Discharges Resilience Scenario		2015 (reference, m3/s)	2030	2040	2050	2100
Ganges						
Peak discharge	*% change of mean annual maximum at Hardinge Bridge*	51,130	30		40	70
Brahmaputra						
Peak discharge	*% change of mean annual maximum at Bahadurabad*	67,490	15		20	30
Meghna						
Peak discharge	*% change of mean annual maximum at Bhairab bazar*	13,370	15		20	30

Source: BWDB (Yu et al. 2010), ISI-MIP & VIC (van Vliet and Ludwig, 2013)

Table 10: Upstream abstractions – Sohonio *(resilient)* scenario

Upstream Abstractions Sohonio Scenario		2015 *(reference, m3/s)*	2030	2050	2100
Ganges					
Change Average dry season flow	*% change (minus) at Hardinge Bridge*	750	*controlled by Ganges Water Treaty*		
Average dry season flow	*m^3/s at Hardinge Bridge*	750	*controlled by Ganges Water Treaty*		
Brahmaputra					
Change Average dry season flow	*% change (minus) at Bahadurabad*	3,000	-15%	-30%	-50%
Average dry season flow Brahmaputra	*m^3/s at Bahadurabad*	3,000	2,550	2,100	,1500

Source references values: IWM, BWDB

2.4. Sushoma *(moderate)* scenario, *delta under pressure*

This scenario is characterised by a slower GDP per capita growth, due to moderate global economic growth with competition over labour-intensive production and a fast growing population in combination with low climate change and limited upstream developments.

Key words: Traditional growth with focus on low-value production, limited technological diffusion, top-down regulation, central economy, high inequality, growing wealthy elite, water follows development, fast growing Dhaka & Chittagong with urban sprawl, underdeveloped urban-rural connectivity.

Climate & upstream developments

Climate change in Bangladesh is relatively mild under this scenario. Temperature will only increase by about two degrees by the end of the century. There will be a slight increase (10 to 15%) in monsoon rainfall but the timing of the monsoon will not change. Dry season rainfall will stay more or less the same. Climate change will slowly reduce (up to 10% by the end of the century) the dry season inflow, while the river water levels in the monsoon period will increase by 10% in 2050 and 15% by the end of the century. Mean sea level is expected to rise moderately with 20-30 cm (in 2050) and 40-60 cm (in 2100). The number of cyclones that hit the coast of Bangladesh remains constant, although the intensity increases. Both floods and drought frequency will increase but less severe compared to other scenarios.

Under this scenario there will be limited upstream developments. Upstream countries allocate investments in other economic growth sectors and areas, which alleviates the direct need for large interventions in specific regions that could negatively affect Bangladesh. At the same time, collaboration with upstream countries is not further improved and there will not be an improved water sharing agreement. Under this scenario, changes in flood risk will be mainly driven by uncontrolled urban development and less due to climate change. Salinity in the Southwest will increase due to higher upstream water extraction in the dry seasons (both in India and Bangladesh). The slow sea level rise will also contribute to increase salinity intrusion.

Socio-economic developments

The global economic conditions are moderate, and Bangladesh economy is driven by a continuation of the traditional economic growth trajectory with a focus on low-value production. The GDP per capita continues to grow, but slows down due to an increasing supply of low-skilled labourers and a slow pace of productivity increases. Competition between Bangladesh and other developing economies over low value production is high.

Thanks to moderate climate change and limited upstream developments, there is sufficient opportunity to develop and exploit traditional economic growth and industrialization leading to high opportunities to few and lower opportunities to the majority of poor rural farmers. As a result, a fast urban migration takes place and inequality is growing. There is a growing wealthy elite that can afford good education at private schools and abroad and a growing pool of unskilled labourers. As output is not reinvested in much needed infrastructure, agricultural R&D and human capital, inequality is rising. Middle income status is not materialized in 2025 and people that can afford good education flee to overseas opportunities. As the climatic conditions are stable, the unsustainable growth trajectory can be maintained for a large number of years, however a tipping point exacerbating effects can be expected in the mid to long run, causing economic growth to stagnate. In this scenario, the environmental degradation due to overexploitation of natural resources and industrial activities is severe. Food quality is deteriorating, as farmers are increasingly using agro-chemicals to increase the shelf-life of their products.

Towards 2100, population growth slowly starts to stabilize and diminish to 190 million people. Bangladesh has not yet reached high income status and is struggling to keep pace with global advancements. Due to the long-term global economic downturn the rise of the middle income class has not sufficiently taken off and inequality has grown substantially. Both within the large urban areas and between urban and rural areas this inequality is visible.

Land-use changes

Urban areas - The trend of rapid urbanization continues. The four large cities, Dhaka, Chittagong, Sylhet and Khulna, grow unsustainably, due to a lack of good connectivity and infrastructure; other smaller cities grow at a much slower pace. They are not well connected to the bigger cities and economic activities and city facilities remain underdeveloped. As other small cities are ill-equipped with city facilities and public services, more pressure is put on the larger urban cities. The four cities transform in large megalopolis cities with a high amount of unplanned settlements. Urban land values skyrocket, leading to an uncontrolled land market with a large private sector and real estate speculations. There is a big shortage of affordable housing, hampering the middle income class to develop, and informal housing increases. There is a lack of services and overall city liveability, which stalls private and foreign companies to invest and settle in Dhaka. Congestion is high.

Income and land access inequality grows, with a growing number of landless households. The number of households that are living in informal settlements grows. The population density in the largest cities increases significantly. Quality of life deteriorates, especially due to traffic Congestion, and power and water shortage.

Infrastructure – infrastructure investments are lagging behind, leading to poor rural to urban connectivity. Dhaka grows exponentially, while growth of other cities with urban facilities stagnate as a result of poor infrastructural connections.

Agriculture – As the climate is rather stable, pressure on arable land is mainly caused by a rapidly growing population and poor urban facilities. Fertility of land will gradually reduce and problems of availability of macro and micro nutrients will severely reduce productivity. Agricultural land is mainly exploited by large scale mechanized farming. Landlord/tenure system will remain intact, growing inequality of land access, growing number of landless households. The pressure on agricultural land will remain high and next to

large-scaled farming by the elite, the rural poor will continue to focus on self-sufficient rice farming. Arable land at pressure due to unsustainable intensification. Marketing facilities are poor, due to limited transport facilities from the rural areas to the cities, especially the four large metropolitan cities. Price of agriculture commodities are high in the cities, but small farmers are not able to get good prices.

Mangrove / forest areas decrease due to more industrial and urban activities

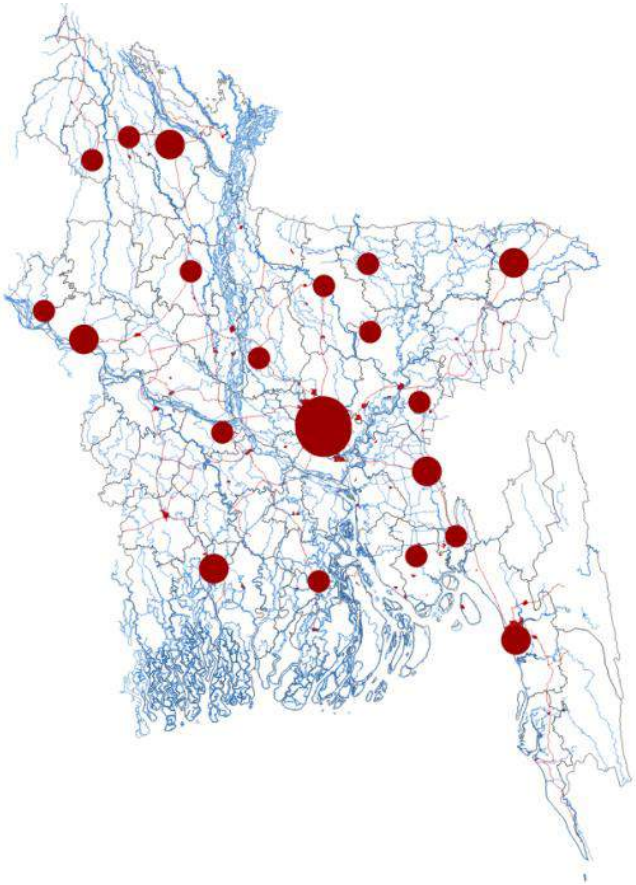

Figure 19: Visualisation urban patterns – Sushoma *(moderate)* scenario in 2050

Implications water use, floods and water quality

Water demand - The urban water demands will increase due to higher population growth but the majority of people will not be able to pay for improved water supply and sanitation. This will result in high water pollution and low **water quality** delivery increasing urban health problems due to poor water supply and sanitation. There is an increased risk of urban pollution due to massive urban areas with poor facilities.

Rural water demand is also high due to unsustainable use of water supply. As the climate change is relatively less, dry season inflow is not significantly decreasing. Water demand increases significantly due to a higher rural population and by large scale farming, resulting in unsustainable water use. Agricultural water demand will increase due to intensive farming and ensuring food security for the increased population. Groundwater is getting out of reach, increasing the costs of farming.

In this scenario there is an additional **flood** risk for of urban population and there is high risks of drainage congestion.

Table 11: Quantification socio-economic developments – Sushoma *(moderate)* scenario

Sushoma Scenario		**2015** *(reference)*	**2020**	**2030**	**2040**	**2050**	**2100**
Population	*Million inhabitants*	160	173	188	200	210	190
Urbanization	*Urban inhabitants (%)*	34	35	40	46	52	70
GDP Growth	*Average annual real GDP growth rates (%)*	6.3	6.0	5.0	4.5	4.0	1.5
GDP per capita	*Constant prices of 2010 ($)*	866	1,072	1,685	2,519	3,585	12,000
Agricultural sector share	*GDP contribution agricultural sector (%)*	16	16	15	14	13	10
Agriculture employment share	*% of people employed in agriculture sector*	47	47	46	45	45	35
Poverty	*Poverty headcount ratio at $1.25 a day (PPP) (%) Reference year: 2010*	43	38	35	32	30	15
Total freight transport	*bln ton-km*	36	48	82	131	195	590
Inland waterway freight transport	*bln ton-km*	5	6	11	20	31	112
Inland waterway freight transport	*Modal share (%)*	14	11	10	10	11	12
Land use developments		**2010** *(reference)*	**2020**	**2030**	**2040**	**2050**	**2100**
Agriculture land	*% surface area*	60	-	-	-	-	-
Urban / industrial land	*% surface area*	3	+	+	+	+	+
Rural settlements	*% surface area*	12	+	+	+	+	-
Mangrove / forests	*% surface area*	10	--	--	--	--	-

Source: 2015 data: Baseline reports of Bangladesh Delta Plan 2100, World Bank, CIA world Factbook. Scenario data derived from socio-economic and transportation baseline studies of BDP2100, UN population projections, IMF projections and Shared-Socioeconomic Pathways (IPCC)

Table 12: Climate change - Sushoma *(moderate)* scenario

Climate change Sushoma scenario		2015 *(reference)*	2030	2040	2050	2100
Sea level rise	*Mean sea level rise in cm*		10-20	15-25	20-30	40-60
Temperature	*Mean max temperature degrees change (°C)*	25	+0.5	+0.75	+1	+2
Monsoon rainfall	*% change mean total monsoon (June-September) precipitation*	1,750	0	5	10	15
Dry season rainfall	*% change mean total dry season (December-February) precipitation*	36	0	0	0	0
Longest dry day period	*Increase of mean number of consecutive dry days*		0	0	0	+5
Rainfall intensity	*% change of mean total precipitation*		10	10	10	20
Cyclone intensity	*% change*	?	25		45	90

Source: Unnikrishnan and Shankar (2007), Hinkel et al. 2014 (IPCC, AR5), BMD, EU-Watch/Combine 2013/climate change baseline, IPCC 2013

Table 13: Peak discharges - Sushoma *(moderate)* scenario

Peak Discharges Sushoma Scenario		2015 (reference, m3/s)	2030	2040	2050	2100
Ganges						
Peak discharge	*% change of mean annual maximum at Hardinge Bridge*	51,130	15	18	20	30
Brahmaputra						
Peak discharge	*% change of mean annual maximum at Bahadurabad*	67,490	5		10	15
Meghna						
Peak discharge	*% change of mean annual maximum at Bhairab bazar*	13,370	5		10	15

Source: BWDB (Yu et al. 2010), ISI-MIP & VIC (van Vliet and Ludwig, 2013)

Table 14: Upstream abstractions - Sushoma scenario

Upstream Abstractions Sushoma Scenario		2015 *(reference, m3/s)*	2030	2050	2100
Ganges					
Change Average dry season flow	*% change (minus) at Hardinge Bridge*	750	*controlled by Ganges Water Treaty*		
Average dry season flow	*m^3/s at Hardinge Bridge*	750	*controlled by Ganges Water Treaty*		
Brahmaputra					
Change Average dry season flow	*% change (minus) at Bahadurabad*	3,000	-10%	-25%	-40%
Average dry season flow Brahmaputra	*m^3/s at Bahadurabad*	3,000	2,700	2,250	1,800

Source reference values: IWM, BWDB

2.5. Sokrio *(active)* scenario, *basic needs first*

This scenario depicts a stagnation of GDP per capita growth due to unfavourable economic growth conditions and an exponential growing population, in combination with extreme water variability due to climate change and adverse upstream developments.

Key words: Traditional growth with focus on low-value production, fast growing population, fierce national and international competition, slow technological change, high informal sector, fast growing Dhaka & Chittagong and scattered rural settlements, urban-rural isolation, high urban and rural poverty, high vulnerability, climate refugees.

Climate & upstream developments

In this scenario there will be rapid climate change and increased uncertainty in water availability due to upstream developments. Temperature will increase by 4 degrees until 2100. Extreme rainfall events will increase in both intensity and frequency. Also the cyclones will become more severe in intensity, though not in number. Dry season rainfall will reduce (up to -20%) and the monsoon rainfall will become much higher (up to 40%). Further, the timing of the monsoon will become more variable and less predictable. Rapid climate change will have a severe impact on dry season flows of upstream river systems. As a result of climate change, river discharges in the dry season can be up to 50% lower by the end of the century. Wet season flows and high extremes, leading to more extreme flood events, will also rapidly increase.

Due to a stagnating global economic situation upstream countries will rapidly develop new infrastructure to ensure their water supply in order to protect their economy. The river linking project will be developed to support (irrigated) agricultural development upstream. China will also rapidly develop new infrastructure to increase hydropower production. International relations with upstream countries will not improve. The development of the river linking project will result in lower flows especially in the Brahmaputra and regional trans-boundary rivers. In the management of the dams a reduced flood risk of Bangladesh will not be taken into account, which further increases flood frequencies and risks of large scale river floods in Bangladesh. The groundwater table continues dropping, due to reduced water recharge and overuse of groundwater. The lack of technological development limits tackling the arsenic problem..

Upstream developments in combination with reduced dry season rainfall and continued wide scale irrigated rice farming will significantly reduce dry flows of the river and increase lowering of the groundwater table. The more variable and more intense monsoon rainfall will increase the variability of flows resulting into higher peaks in the wet season. Under this scenario there will be a rapid lowering of the groundwater table and an increase in salt intrusion in the south-west due to sea level rise, large reductions in dry season flows and more frequent storm surges.

Socio-economic developments

The global economic growth is stagnating, leading to a decrease of global demand in low value products, such as garments, and a fierce competition for growth between developing nations. A combination of a growing pool of low-skilled labourers and fewer opportunities in livelihoods leads to a rapid increase of unemployment and urban and rural poverty. Both the industrial and agricultural output (due to more fresh water scarcity) is under pressure, while productivity hardly increases due to slow technological changes and slow increases in human capital and infrastructure improvements. At the same time, the informal sector grows rapidly, leading to less government revenues and expenditures. Urban manufacturing and service sectors remain underdeveloped.

Due to slow global and local economic growth, international migration is limited, education levels do not move up and fertility rates decrease at a much slower pace. Many people move to Dhaka, which is growing exponentially. At the same time, due to a lack of urban opportunities and investments, a large part of the population is forced to remain in rural areas, depended on self-sufficient rice farming. The increasing salinity and more extreme events due to climate change will reduce agricultural productivity. This will further increase rural poverty and reduce food security. The number of rural landless households continues to grow and inequality continues to rise. The vulnerability to natural hazards and extreme weather events reaches an all-time high, as severe drought and flood events cause casualties and agricultural yields to decrease dramatically. City life is also harsh, with a vast majority of the urban population living in poor housing conditions and a fierce competition over very poorly-paid jobs. The number of people living below the poverty rate starts to increase again and conflicts over land and food exacerbate. Food quality is a problem, as farmers are using chemicals to increase the shelf-life of the food produced.

A vicious circle of rapid population growth, slow socio-economic development and a lack of urban and infrastructure development further limits the mobility of the poor rural population and liveability of the urban population. Simultaneously, in the struggle to survive, different creative movement arise and autonomous adaptation is high in which small-scaled cooperatives arise. Due to the harsh climatic conditions, a high number of climate refugees are forced to leave Bangladesh due to the lack of fertile land and food.

Towards 2100, population of Bangladesh continues to grow uncontrollably. Due to harsh climatic and economic conditions, the middle income class population has remained low, which has not decreased fertility rates, which in turn has had a negative effect on socio-economic advancement. Dhaka and Chittagong have grown into colossal megacities, while other areas remain highly isolated. Due to international economic stagnation, international mobility has remained low, except for climate refugees, of which Bangladesh has the highest number worldwide. There is a tremendous lack of natural resources and food.

Land-use changes

Urban areas – are characterized by a centralized development. A fast growing population leads to rapid growth of Dhaka and Chittagong with high urban sprawl. However, due to limited facilities of urban centres the rural population also remains high. There is a high degree of informal settlements and slum development around (peri) urban areas and a highly scattered rural population.

Infrastructure – There is inadequate infrastructure and connectivity between and within cities, resulting in isolated scattered rural settlements and large urban centres with poor urban infrastructure.

Agriculture - heavy pressure on arable land due to increasing rural population and decreasing arable land (due to population increases and severe climatic conditions). Significant decrease of agricultural land and increase of environmental degradation

Mangrove / Forests – significant decrease due to population pressures and hydrological effects.

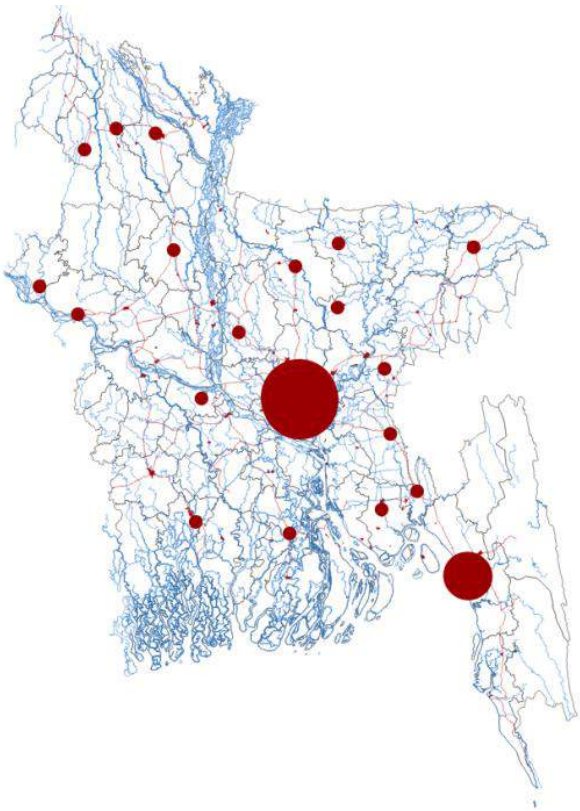

Figure 20: Visualisation urban patterns – Sokrio *(active)* scenario in 2050

Implications water use, floods and water quality

Floods - Due to severe climatic conditions and upstream developments, the agricultural output decreases and flood events cause dramatic results. Flood frequency and intensity will increase due to more severe cyclones, higher peak river flows and sea level rise. This will affect both the rural population and the growing urban population. The low economic growth will limit the investment in large scale adaptation and there is a focus on low cost community based adaptation. Many small scaled / small cooperative arise. People struggle and fight to survive. Adaptation will also depend highly on foreign assistance.

Water demand – water demand will be severe, while water supply will be seriously constrained.

Environmental degradation will be high and **water quality** will be severely stressed, both due to rural and urban pollution and salinity intrusion.

Table 15: Quantification socio-economic developments - Sokrio *(active)* scenario

Sokrio Scenario		**2015** *(reference)*	**2020**	**2030**	**2040**	**2050**	**2100**
Population	*Million inhabitants*	160	176	197	217	230	260
Urbanization	*Urban inhabitants (%)*	34	35	39	44	48	60
GDP Growth	*Average annual real GDP growth rates (%)*	6.3	4.9	4.0	3.0	2.0	2.0
GDP per capita	*Constant prices of 2010 ($)*	866	1,000	1,323	1,611	1,893	4,506
Agricultural sector share	*GDP contribution agricultural sector (%)*	16	16	16	15	15	14
Agriculture employment share	*% of people employed in agriculture sector*	47	48	50	50	47	40
Poverty	*Poverty headcount ratio at $1.25 a day (PPP) (%)* *Reference year: 2010*	43	41	39	37	35	25
Total freight transport	*bln ton-km*	36	46	68	91	113	304
Inland waterway freight transport	*bln ton-km*	5	5	7	9	12	36
Inland waterway freight transport	*Modal share (%)*	14	11	10	10	11	12
Land use developments		**2010** *(reference)*	**2020**	**2030**	**2040**	**2050**	**2100**
Agriculture land	*% surface area*	60	--	--	--	--	--
Urban / industrial land	*% surface area*	3	+	+	+	+	+
Rural settlements	*% surface area*	12	++	++	++	++	++
Mangrove / forests	*% surface area*	10	--	--	--	--	-

Source: 2015 data: Baseline reports of Bangladesh Delta Plan 2100, World Bank, CIA world Factbook. Scenario data derived from socio-economic and transportation baseline studies of BDP2100, UN population projections, IMF projections and Shared-Socioeconomic Pathways (IPCC)

Table 16: Climate change - Sokrio *(active)* scenario

Climate change Sokrio scenario		2015 *(reference)*	2030	2040	2050	2100
Sea level rise	*Mean sea level rise in cm*		15-30	30-40	40-60	80-125
Temperature	*Mean max temperature degrees change (˚C)*	25	+1.5	+1.75	+2	+4
Monsoon rainfall	*% change mean total monsoon (June-September) precipitation*	1,750	15	18	20	40
Dry season rainfall	*% change mean total dry season (December-February) precipitation*	36	-10	-10	-10	-20
Longest dry day period	*Increase of mean number of consecutive dry days*		+5	+8	+10	+20
Rainfall intensity	*% change of mean total precipitation*		20	20	20	50
Cyclone intensity	*% change*		70		90	100

Source: Unnikrishnan and Shankar (2007), Hinkel et al. 2014 (IPCC, AR5), BMD, EU-Watch/Combine 2013/climate change baseline, IPCC 2013

Table 17: Peak discharges – Sokrio *(active)* scenario

Peak Discharges Sokrio Scenario		2015 (reference, m^3/s)	2030	2040	2050	2100
Ganges						
Peak discharge	*% change of mean annual maximum at Hardinge Bridge*	51,130	30		40	70
Brahmaputra						
Peak discharge	*% change of mean annual maximum at Bahadurabad*	67,490	15		20	30
Meghna						
Peak discharge	*% change of mean annual maximum at Bhairab bazar*	13,370	15		20	30

Source: BWDB (Yu et al. 2010), ISI-MIP & VIC (van Vliet and Ludwig, 2013)

Table 18: Upstream abstractions - Sokrio *(active)* scenario

Upstream Abstractions Sokrio Scenario		2015 *(reference, m3/s)*	2030	2050	2100
Ganges					
Change Average dry season flow	*% change (minus) at Hardinge Bridge*	750	*controlled by Ganges Water Treaty*		
Average dry season flow	*m^3/s at Hardinge Bridge*	750	*controlled by Ganges Water Treaty*		
Brahmaputra					
Change Average dry season flow	*% change (minus) at Bahadurabad*	3,000	-20%	-40%	-60%
Average dry season flow Brahmaputra	*m^3/s at Bahadurabad*	3,000	2,400	1,800	1,200

Source reference values: IWM, BWDB

2.6. *Fast urban growth scenario*

This scenario is characterized by a high global economic growth, whereby both the economy and the population of Bangladesh continue to grow in combination with extreme water variability due to climate change and adverse upstream developments. As most economic activities take place in the major cities, there is a huge pull towards the major economic centres. Dhaka and Chittagong are expanding beyond precedence.

Climate & upstream developments

In this scenario there will be rapid climate change and increased uncertainty in water availability due to upstream developments. Temperature will increase by 4 degrees until 2100. Extreme rainfall events will increase in both intensity and frequency. Also the cyclones will become more severe in terms of intensity, but not in terms of frequency. Dry season rainfall will reduce (up to -20%) and the monsoon rainfall will become much higher (up to 40%). The timing of the monsoon will become more variable and less predictable. Rapid climate change will have a severe impact on dry season flows of upstream river systems. As a result of climate change, river discharges in the dry season can be up to 50% lower by the end of the century. Wet season flows and high extremes, leading to extreme flood events will also rapidly increase. (baseline study Climate change)

To further stimulate their economic growth, riparian countries will rapidly develop new infrastructure to guarantee sufficient water supply in the dry season in their countries. Although the Teesta Treaty is signed, other dams and upstream interventions are being developed, threatening water availability in Bangladesh, especially during the dry season (low flow conditions). The river linking project will be developed and additional barrages will be developed for upstream irrigation development. Also China will develop an increasing number of hydropower plants in the upstream part of the Brahmaputra Basin. There will be an expansion of salinity in the coastal zone mainly driven by a reduced run-off from upstream and compounded by sea level rise and more frequent storm surges.

Socio-economic developments

The global economy and world trade continues to grow and the economy of Bangladesh is further transformed into an industrialized and service based economy. This is mainly driven by global trade liberalization and a fast growing consumer market in China and other large Asian economies, which results in an increasing demand for energy, food and consumer products. In this scenario, the large urban areas in Bangladesh (especially Dhaka and Chittagong) benefit from the favourable growth pattern. The higher economic growth in these cities acts as a high pull factor for migration to the largest urban areas. The population continues to grow, which reaches a peak around 2050 with 225 million inhabitants, of which 70% lives in urban areas. As in most developing countries, the large cities act as centres of innovation but fail to relocate the production of mature products to secondary specialized cities. As a result, both more advanced and mature products are produced in the largest, and most expensive, areas[9]. Moreover, in these urban areas a shift is taking place to the services sectors and more industrial processing. New services will arise such as specialized consultancy, ICT services and financial services targeting new companies and the rising middle class. The informal economy also grows often with migrants from rural areas working in informal services such as catering and restaurants, household support to richer and middle class families etc. Because of the rising middle class and income level consumption of processed food, luxury consumer goods (cars, household appliances etc.) is rising. This creates new opportunities for food processing industries, luxury food retailers, production of household appliances, car manufacturing (import substitution & FDI) etc. Import substitution will also take place in other sectors where local consumer good demand is reaching higher levels, such as furniture. Because cities have a more favourable innovation climate and higher levels of education, also IT and industrial innovations take place. The increasing (but still low in an international perspective) level of income and education makes Dhaka an interesting location for foreign direct investments. Back-offices, call-centres and sales and marketing-activities, but also electronic manufacturing take up quite some (middle-income) staff. Shipbuilding industry and alternative textile processing (leather, jute, car textiles etc.) will increase employment offering to city labour force. This results in Dhaka and Chittagong growing exponentially with huge agglomeration problems such as congestion, air pollution, illegal construction, etc. Moreover, the other smaller cities grow at a much slower pace resulting in larger interregional disparities.

As a result of growing GDP, the overall income level in Bangladesh rises sharply, but the gap between the rural poor and urban rich increases. Also within cities, the differences in income level are significant. As the large cities are the engine of the economic growth in Bangladesh, the urban agglomerates also act as a major pull factor of poor rural residents, creating large hubs of urban poverty within these cities. The growth in demand for labour is not sufficient in these major cities for absorption of the increase in labour supply. Although the relative number of people living in slum conditions in the cities is decreasing, the size of the urban slum population is increasing significantly, with many of them unemployed or working in the informal sector, resulting in significant unemployment. As a result of rapid climate change and negative upstream developments, rainfall intensity and storm increases create huge pressures on the drainage capacity of the major cities. Furthermore, due to peak discharge increases, the risk of water logging & floods is severe, while at the same time the overcrowded cities have created a high risk environment for natural hazards for the most vulnerable people. Also assets such as critical infrastructure and high value economic functions and slum areas are at risk in the economic centres and in peri-urban areas.

Dry season water availability becomes a major concern, especially due to increased irrigation for large-scaled rice production for international markets, as well as other large scale private farming activities and livestock. Due to increased activities in industry, as well as huge urban population, water demand in the cities increases drastically. Due to over exploitation of groundwater and limited surface water supply in the dry season it becomes a major challenge to provide clean drinking water for the growing population of

[9] Cited from Duranton: Growing through cities in Developing Countries

Bangladesh. This results in dry periods in unstable water supply services (system failures during some hours) and an increasing level of system failures (ie. pipe breaks or dirty water due to low pressure in the water pipes). Also the water quality especially around Dhaka will continue to further deteriorate.

Towards 2100, thanks to stable GDP growth, education improvements and resulting lower fertility rates, both population and poverty levels decrease. By 2100, Bangladesh is home to 200 million inhabitants, and most people live a more comfortable (material) life with a per capita GDP of over 30.000 USD. More than 80% of the people live and work in the major urban areas and severe poverty has gone down to only 2% of the population. However, the quality of life in major cities still suffers from congestion, air pollution and lack of recreational space.

Land-use changes

Urban areas – The trend of rapid urbanization continues, combined with rapid economic growth. As economic activities are concentrated in the largest cities, congestion & environmental problems are significant. The cities are in desperate need of infrastructural and environmental improvements and better connectivity to other cities. The largest cities transform into large megalopolis cities with a huge peri-urban area and a large population living in slum conditions. Urban land prices skyrocket and there is a big shortage of affordable (formal) housing. There are large informal slum areas. As the middle income group increases, city liveability becomes increasingly important. The (especially in the first decades) unplanned urban development leads to a strange pattern of residential areas, industrial zones, still some small agricultural activities as 'green pockets' in grey areas and slums, pushing most of the agricultural activities out of the (peri-)urban areas.

Infrastructure – The largest cities are in desperate need of good city infrastructure investments, as well as inter-city connectivity to and from rural areas and smaller cities. In the cities road transport is dominant, with more environmental friendly public transport by rail being developed later. Transport over water will gradually increase.

Agriculture – Both future floods and reduced dry season water availability will put significant constraints on future agriculture. In the coastal region increased salt water intrusion will change land use from agriculture to aquaculture. Where sufficient water resources are available agricultural productivity will increase mainly by importing foreign technology and machinery. Rural areas will be dominated by larger mechanized farms, and livestock production will increase. With a growing urban middle income population, food consumption patterns change from rice to increased animal and fruit and vegetables. At the same time, as a result of a growing population, rice consumption will also increase. Up till 2030, Bangladesh is able to meet the country's increasing demand for rice and will have substantial production surpluses, which will come at environmental costs, as this will put pressure on the demand for groundwater[10].

Mangrove / forest – area will decline due to high population pressure and large scale agricultural activities and increased salt water intrusion caused by reduced dry season river flows and lower rainfall.

Implications water use, floods and water quality

Water demand –Water demand of the urban regions will increase rapidly due to population growth and increased industrial activities. As a result of a growing and wealthier urban population, food consumption patterns are changing, leading to more animal and vegetable cultivation. Large scale intensive farming will result into higher agricultural water demands, also as more surplus rice cops will be produced for the international markets. Especially in the dry season this will result in increased water scarcity and more competition between urban and rural water use. Given the emphasis on urban development in this scenarios water use will be transferred from the rural to the urban regions. As a result, especially around the lager

[10] From: Water for Food in Bangladesh: Outlook to 2030 IWMI

urban regions, water availability for agriculture will become under pressure due to high demand of the urban area.

Around the urban areas, **water quality** will come under increasing pressure due to more industrial activities and increased urban population growth. In the south west, water quality will be affected by increased salt water intrusion which is caused by a combination of sea level rise, reduced dry season river flows and lower dry season rainfall. These higher salt concentrations will make surface water unsuitable for drinking and traditional agriculture. Also increase intensification of the agricultural sector could negatively affect water quality.

Flood risks will increase due to a combination of higher peak river flows, increased rainfall intensities, stronger cyclones and sea level rise. In terms of people, especially the large urban population living in slum conditions will be affected. In term of economic assets the higher value of the developments in the large urban centre will increase the impact of possible future floods. However, also the focus on urban development could reduce the attention and thus the flood risks of people living in the rural regions.

Table 19: Quantification socio-economic developments – *Fast urban growth* scenario

Fast urban growth Scenario		**2015** *(reference)*	**2020**	**2030**	**2040**	**2050**	**2100**
Population	*Million inhabitants*	160	175	195	195	225	200
Urbanization	*Urban inhabitants (%)*	34	40	50	60	70	80
GDP Growth	*Average annual real GDP growth rates (%)*	6.3	7.0	7.8	7.2	6.5	2.5
GDP per capita	*Constant prices of 2010 ($)*	866	1,140	2,075	3,840	6,953	32,000
Agricultural sector share	*GDP contribution agricultural sector (%)*	16	15	13	11	8	6
Agriculture employment share	*% of people employed in agriculture sector*	47	41	32	28	22	12
Poverty	*Poverty headcount ratio at $1.25 a day (PPP) (%)* *Reference year: 2010*	43	35	30	25	20	2
Total freight transport	*bln ton-km*	36	50	105	213	406	1,660
Inland waterway freight transport	*bln ton-km*	5	7	19	40	81	432
Inland waterway freight transport	*Modal share (%)*	14	14	18	19	20	26
Land use developments		**2010** *(reference)*	**2020**	**2030**	**2040**	**2050**	**2100**
Agriculture land	*% surface area*	60	--	--	--	--	--
Urban / industrial land	*% surface area*	3	++	++	++	++	++
Rural settlements	*% surface area*	12	+	+	+	+	+
Mangrove / forests	*% surface area*	10	--	--	--	--	-

Source: 2015 data: Baseline reports of Bangladesh Delta Plan 2100, World Bank, CIA world Factbook. Scenario data derived from socio-economic and transportation baseline studies of BDP2100, UN population projections, IMF projections and Shared-Socioeconomic Pathways (IPCC)

Table 20: Climate change – *Fast urban growth* scenario

Climate change Fast urban growth scenario		2015 *(reference)*	2030	2040	2050	2100
Sea level rise	*Mean sea level rise in cm*		15-30	30-40	40-60	80-125
Temperature	*Mean max temperature degrees change (˚C)*	25	+1.5	+1.75	+2	+4
Monsoon rainfall	*% change mean total monsoon (June-September) precipitation*	1,750	15	18	20	40
Dry season rainfall	*% change mean total dry season (December-February) precipitation*	36	-10	-10	-10	-20
Longest dry day period	*Increase of mean number of consecutive dry days*		+5	+8	+10	+20
Rainfall intensity	*% change of mean total precipitation*		20	20	20	50
Cyclone intensity	*% change*		70		90	100

Source: Unnikrishnan and Shankar (2007), Hinkel et al. 2014 (IPCC, AR5), BMD, EU-Watch/Combine 2013/climate change baseline, IPCC 2013

Table 21: Peak discharges – *Fast urban growth* scenario

Peak Discharges Fast urban growth Scenario		2015 (reference, m^3/s)	2030	2040	2050	2100
Ganges						
Peak discharge	*% change of mean annual maximum at Hardinge Bridge*	51,130	30		40	70
Brahmaputra						
Peak discharge	*% change of mean annual maximum at Bahadurabad*	67,490	15		20	30
Meghna						
Peak discharge	*% change of mean annual maximum at Bhairab bazar*	13,370	15		20	30

Source: BWDB (Yu et al. 2010), ISI-MIP & VIC (van Vliet and Ludwig, 2013)

Table 22: Upstream abstractions – *Fast urban growth* scenario

Upstream Abstractions Fast urban growth Scenario		2015 *(reference, m3/s)*	2030	2050	2100
Ganges					
Change Average dry season flow	*% change (minus) at Hardinge Bridge*	750	*controlled by Ganges Water Treaty*		
Average dry season flow	*m^3/s at Hardinge Bridge*	750	*controlled by Ganges Water Treaty*		
Brahmaputra					
Change Average dry season flow	*% change (minus) at Bahadurabad*	3,000	-20%	-40%	-60%
Average dry season flow Brahmaputra	*m^3/s at Bahadurabad*	3,000	2,400	1,800	1,200

Source reference values: IWM, BWDB

2.7. Business as Usual scenario

This scenario reflects a business-as usual development, which assumes that there will be no significant change in policies, economics and priorities. As such, current trends and circumstances are expected to continue in an unchanged fashion. The climate change scenario is based on average future projections and upstream water extraction is assumed to be moderate.

Climate & upstream developments

In this scenario there will be moderate climate change and continuing uncertainty in water availability due to upstream developments. Temperature will increase by 3 degrees until 2100. Extreme rainfall events will increase in both intensity and frequency. Cyclones will increase in intensity, but not in frequency. Dry season rainfall will slightly reduce (up to -10%) and the monsoon rainfall will become higher (up to 20%). The timing of the monsoon will become more variable and less predictable. Climate change will reduce the dry season flows of upstream river systems by up to 20%. Wet season flows and high extremes will both increase in the future. Sea level will increase by 30-45 cm (2050) to 60-80 cm (2100).

Under this scenario there will be moderate upstream developments. To further stimulate their economic growth, riparian countries will develop some new infrastructure to guarantee sufficient water supply in the dry season in their countries. The Teesta Treaty is signed, and some other dams and upstream interventions are being developed, affecting water availability in Bangladesh, especially during the dry season (low flow conditions). The river linking project will be partly developed and some measures will be taken to moderate the impacts of water flows into Bangladesh. China will develop a number of additional hydropower plants in the upstream part of the Brahmaputra Basin. There will be an expansion of salinity in the coastal zone due to a combination of reduced run-off from upstream and sea level rise.

Socio-economic developments

The global economy is not characterized by major shocks, but is growing stable at a relatively low rate. In Bangladesh, the trend of recent decades continues, with some progress achieved in poverty alleviation and other millennium development goals. A medium pace of per capita income level growth continues, with a stable GDP growth rate of 6% per year until 2030. The global relations are relatively stable, and international markets are partially functioning and connected. Population growth remains high, as investments in education are not sufficient to rapidly slow population growth. By 2050, over 200 million people live in Bangladesh, of which more than 110 million in urban areas.

Although slight progress is made in reaching millennium development goals, still by 2050, a large population lives without access to safe water, improved sanitation and medical care. Investments in infrastructure are slow, leading to highly polluted and congested cities and badly connected rural areas. As such, transportation costs to transport agricultural products to the markets and cities remains high, creating soaring food prices in times of drought. This is especially impacting the poor urban population that does not have access to food.

In the rural areas, still a large number of people is dependent on agriculture for their livelihoods, most of which continue to grow *Boro* rice through self-subsistence farming on smaller plots of land, as an increase of large-scale farms are producing a surplus of rice and other crops for international markets. Although rice remains the staple food, the consumption of animal products and vegetables has increased. Due to the large rural and urban population and slowly improving conditions, the vulnerability to climate hazards remains high.

Sector composition gradually changes towards more services and processing industries, but at a much slower pace and more based on the current sectors compared to the scenarios productive and fast urban growth. Because of the rising incomes and middle class, some import substitution will gradually take place towards more food processing and luxury consumption goods. The textile industry will diversify towards new materials also relevant for house decoration, furniture. Food processing industries will expand their offer of processed products based upon tea, fruits, vegetables and rice. Moreover as India's IT specialists are getting more expensive, some foreign-owned IT services will increase (especially in the cities). Along with this slow but steady growth in production and population the service-industries will develop further, both in size and in terms of types of services. And there will be an increasing demand for education and health-care, creating large schools, universities, hospitals and other medical centres.

Land-use changes

Urban areas –The current trend of urban expansion continues, as economic activities are concentrated in the largest cities. As a result, congestion problems are significant. The cities need infrastructural improvements and better connectivity to other cities. Also there is a big shortage of affordable housing in the cities.

Infrastructure – The largest cities are in desperate need of good city infrastructure investments, as well as inter-city connectivity to and from rural areas and smaller cities. The dominant way of moving goods and people will be transport by road.

Agriculture – Rural areas will become a mix of large mechanized farms growing rice and other crops for the domestic urban population in combination with a large number of smaller farms producing mainly for their own family and partly for the local market. The main land use will still be rice with a continuing growth of *boro* rice growing area. Rural inhabitants will be competing over small plots of land to grow rice for their livelihoods. Up till 2030, Bangladesh is able to meet the country's increasing demand for rice[11]. The export of agricultural products will remain low. In the coastal region the increasing salt intrusion will result in a further shift from agriculture to aquaculture. There will also be some introduction of more salt tolerant crops. The focus on *boro* rice will put significant pressure on groundwater resources. In addition, dry season surface water availability will reduce increasing the dependence on groundwater in many regions. Where groundwater is depleted farmers will be forced to adapt their land use. Over time, slowly more (productivity-increasing) technology and machinery will be imported from more developed countries.

Mangrove / forest

The pressure on Mangrove and forest areas will continue to increase. Although the Sundarbans will remain protected land, the area will be affected by increasing salt intrusion, reduced dry season river flows and more extreme events. Also water pollution will increase, affecting ecosystems along the river systems.

Implications water use, floods and water quality

Water demand – The growing population and middle income class will lead to changing food consumption patterns, leading to more animal and vegetable cultivation. Also large scale farming will produce more surplus rice crops for the international market. This will significantly increase the agricultural water demand. At the same time, urban water demand will also increase due to a higher urban population, and increased activities in the industrial sector. At the same especially dry season water availability will reduce due to a combination of climate change and upstream developments. This will increase water scarcity and will increase the competition for water resources between the rural and urban regions. Due to congestion problems, the risk of water pollution and low **water quality** delivery will increase, resulting in health problems for the urban poor.

Flood risks will be high for the large urban population living in slum conditions, as well as for the higher value of the economic assets that are at stake in the large metropolis city centres. Due to increasing extreme event and higher peak river flow flood risks will increase throughout the whole country. Also flash flood frequency will increase.

[11] Amarasinghe, U. A.; Sharma, B. R.; Muthuwatta, L.; Khan, Z. H. 2014. Water for food in Bangladesh: outlook to 2030. Colombo, Sri Lanka: International Water Management Institute (IWMI). 32p. (IWMI Research Report 158).

Table 23: Quantification socio-economic developments – *Business as usual* scenario

Business as Usual Scenario		**2015** *(reference)*	**2020**	**2030**	**2040**	**2050**	**2100**
Population	*Million inhabitants*	160	172	186	197	202	170
Urbanization	*Urban inhabitants (%)*	34	38	45	51	56	70
GDP Growth	*Average annual real GDP growth rates (%)*	6.3	6.0	6.0	5.0	4.0	2.0
GDP per capita	*Constant prices of 2010 ($)*	866	1,078	1,781	2,744	4,057	14,000
Agricultural sector share	*GDP contribution agricultural sector (%)*	16	16	14	13	12	9
Agriculture employment share	*% of people employed in agriculture sector*	47	44	40	38	35	20
Poverty	*Poverty headcount ratio at $1.25 a day (PPP) (%)* *Reference year: 2010*	43	37	34	30	28	12
Total freight transport	*bln ton-km*	36	48	86	140	213	616
Inland waterway freight transport	*bln ton-km*	5	6	12	21	34	123
Inland waterway freight transport	*Modal share (%)*	14	13	14	15	16	20
Land use developments		**2010** *(reference)*	**2020**	**2030**	**2040**	**2050**	**2100**
Agriculture land	*% surface area*	60	-	-	-	-	-
Urban / industrial land	*% surface area*	3	+	+	+	+	+
Rural settlements	*% surface area*	12	+	+	+	+	-
Mangrove / forests	*% surface area*	10	--	--	--	--	-

Source: 2015 data: Baseline reports of Bangladesh Delta Plan 2100, World Bank, CIA world Factbook. Scenario data derived from socio-economic and transportation baseline studies of BDP2100, UN population projections, IMF projections and Shared-Socioeconomic Pathways (IPCC)

Table 24: Climate change – *Business as usual* scenario

Climate change Business as Usual scenario		2015 *(reference)*	2030	2040	2050	2100
Sea level rise	*Mean sea level rise in cm*		15-25	20-30	30-45	60-80
Temperature	*Mean max temperature degrees change (°C)*	25	+1.0	+1.25	+1.75	+3
Monsoon rainfall	*% change mean total monsoon (June-September) precipitation*	1,750	10	15	20	30
Dry season rainfall	*% change mean total dry season (December-February) precipitation*	36	0	-5	-5	-10
Longest dry day period	*Increase of mean number of consecutive dry days*		+2	+4	+5	+10
Rainfall intensity	*% change of mean total precipitation*		10	15	20	30
Cyclone intensity	*% change*		35		50	70

Source: Unnikrishnan and Shankar (2007), Hinkel et al. 2014 (IPCC, AR5), BMD, EU-Watch/Combine 2013/climate change baseline, IPCC 2013

Table 25: Peak discharges – *Business as Usual* scenario

Peak Discharges Business as Usual Scenario		2015 (reference, m^3/s)	2030	2040	2050	2100
Ganges						
Peak discharge	*% change of mean annual maximum at Hardinge Bridge*	51,130	20		30	50
Brahmaputra						
Peak discharge	*% change of mean annual maximum at Bahadurabad*	67,490	10		15	20
Meghna						
Peak discharge	*% change of mean annual maximum at Bhairab bazar*	13,370	10		15	20

Source: BWDB (Yu et al. 2010), ISI-MIP & VIC (van Vliet and Ludwig, 2013)

Table 26: Upstream abstractions – *Business as Usual* scenario

Upstream Abstractions Business as Usual Scenario		**2015** *(reference, m3/s)*	**2030**	**2050**	**2100**
Ganges					
Change Average dry season flow	*% change (minus) at Hardinge Bridge*	750	*controlled by Ganges Water Treaty*		
Average dry season flow	*m^3/s at Hardinge Bridge*	750	*controlled by Ganges Water Treaty*		
Brahmaputra					
Change Average dry season flow	*% change (minus) at Bahadurabad*	3,000	-15%	-30%	-50%
Average dry season flow Brahmaputra	*m^3/s at Bahadurabad*	3,000	2,550	2,100	1,500

Source reference values: IWM, BWDB

3. Summary overview scenarios

The tables and graphs in this paragraph present a summary of the quantification of the different scenarios. The data of the socio-economic scenarios is based on several sources. The population and GDP figures are derived from a combination of the quantification of the shared socio-economic pathways of the IPCC for Bangladesh, the national United Nations projections and trend analysis of different experts. Other figures are distilled from these projections and based on trends of the last 40 years.

The climate change and upstream development data is also derived from several sources, among which the climate change and water resources baseline study. The specific sources are indicated below the data tables.

The data in these tables should not be interpreted as accurate projections or forecasts; they represent a quantified backbone of the scenario narratives and are the resultant of expert judgments and existing projections and models of different climatological and socio-economic sources. The data and quantification of the scenarios is only to be used for an assessment of strategies under different possible futures (or scenarios) and for this purpose have a broad range. They are developed to represent plausible 'edges' of different possible future outcomes.

Table 27: Quantification socio-economic developments - all scenarios (sufola = productive, sohonio = resilient, sushoma = moderate, sokrio = active)

Socio-economic developments		2015 *(reference)*	2020	2030	2040	2050	2100
Population *Million inhabitants*	Sufola	160	171	185	194	200	165
	Sohonio	160	168	175	174	170	125
	Sushoma	160	173	188	200	210	190
	Sokrio	160	176	197	217	230	260
	FUG	160	175	195	214	225	200
	BAU	160	172	186	197	202	170
Urbanization *urban inhabitants (%)*	Sufola	34	38	49	58	70	85
	Sohonio	34	38	45	54	60	75
	Sushoma	34	35	40	46	52	70
	Sokrio	34	35	39	44	48	60
	FUG	34	40	50	60	70	80
	BAU	34	38	45	51	56	70
GDP Growth *Average annual real GDP growth rates (%)*	Sufola	6.3	7.4	8.0	7.5	6.8	3.0
	Sohonio	6.3	6.4	6.5	5.8	5.0	2.5
	Sushoma	6.3	6.0	5.0	4.5	4.0	1.5
	Sokrio	6.3	4.9	4.0	3.0	2.0	2.0
	FUG	6.3	7.0	7.8	7.2	6.5	2.5
	BAU	6.3	6.0	6.0	5.0	4.0	2.0
GDP per capita *Constant prices of 2010 ($)*	Sufola	866	1,158	2,290	4,542	8,586	54,000
	Sohonio	866	1,125	2,008	3,469	5,723	30,000
	Sushoma	866	1,072	1,685	2,519	3,585	12,000
	Sokrio	866	1,000	1,323	1,611	1,893	4,500
	FUG	866	1,111	2,075	3,840	6,953	32,000
	BAU	866	1,078	1,781	2,744	4,057	14,000
Agricultural share GDP *GDP contribution agricultural sector (%)* *Reference year: 2014*	Sufola	16	15	13	11	8	5
	Sohonio	16	15	13	12	10	8
	Sushoma	16	17	17	15	13	10
	Sokrio	16	16	16	15	15	14
	FUG	16	15	13	11	8	6
	BAU	15	16	14	13	12	9
Agriculture employment share *% of people employed in agriculture sector*	Sufola	47	40	30	25	20	10
	Sohonio	47	42	35	30	25	15
	Sushoma	47	47	46	45	45	35
	Sokrio	47	48	50	50	47	40
	FUG	47	41	32	28	22	12
	BAU	47	44	40	38	35	20
Poverty *Poverty headcount ratio at $1.25 a day (PPP) (%)* *Reference year: 2010*	Sufola	43	32	24	18	14	0
	Sohonio	43	35	30	25	20	2
	Sushoma	43	38	35	32	30	15
	Sokrio	43	41	39	37	35	25
	FUG	43	35	30	25	20	2
	BAU	43	37	34	30	28	12
Total freight transport	Sufola	36	51	110	229	445	2,311

bln ton-km	Sohonio	36	49	91	160	267	973
	Sushoma	36	48	82	131	195	590
	Sokrio	36	46	68	91	113	304
	FUG	36	50	105	213	406	1,660
	BAU	36	48	86	140	213	616
Inland waterway freight transport *bln ton-km*	Sufola	5	8	23	53	108	695
	Sohonio	5	7	16	30	53	243
	Sushoma	5	6	11	20	31	112
	Sokrio	5	5	7	9	12	36
	FUG	5	7	19	40	81	432
	BAU	5	6	12	21	34	123
Inland waterway freight transport *modal share (%)*	Sufola	14	15	21	23	24	28
	Sohonio	14	14	18	19	20	25
	Sushoma	14	13	14	15	16	19
	Sokrio	14	11	10	10	11	12
	FUG	14	14	18	19	20	26
	BAU	14	13	14	15	16	20

Land use developments		2010	2020	2030	2040	2050	2100
Agriculture land *% surface area*	Sufola	60	--	--	--	-	0
	Sohonio	60	-	-	-	0	+
	Sushoma	60	-	-	-	-	-
	Sokrio	60	--	--	--	--	--
	FUG	60	--	--	--	--	-
	BAU	60	-	-	-	-	0
Urban / industrial land *% surface area*	Sufola	3	++	++	++	++	+
	Sohonio	3	+	+	+	+	+
	Sushoma	3	+	+	+	+	+
	Sokrio	3	+	+	+	+	+
	FUG	3	++	++	++	++	++
	BAU	3	+	+	+	+	+
Rural settlements *% surface area*	Sufola	12	--	--	--	--	--
	Sohonio	12	-	-	-	-	--
	Sushoma	12	+	+	+	+	-
	Sokrio	12	++	++	++	++	++
	FUG	12	+	+	+	+	0
	BAU	12	+	+	+	+	-
Mangrove / forests *% surface area*	Sufola	10	--	-	-	0	+
	Sohonio	10	-	-	0	+	+
	Sushoma	10	--	--	--	--	-
	Sokrio	10	--	--	--	--	-
	FUG	10	--	--	--	--	-
	BAU	10	--	--	--	--	-

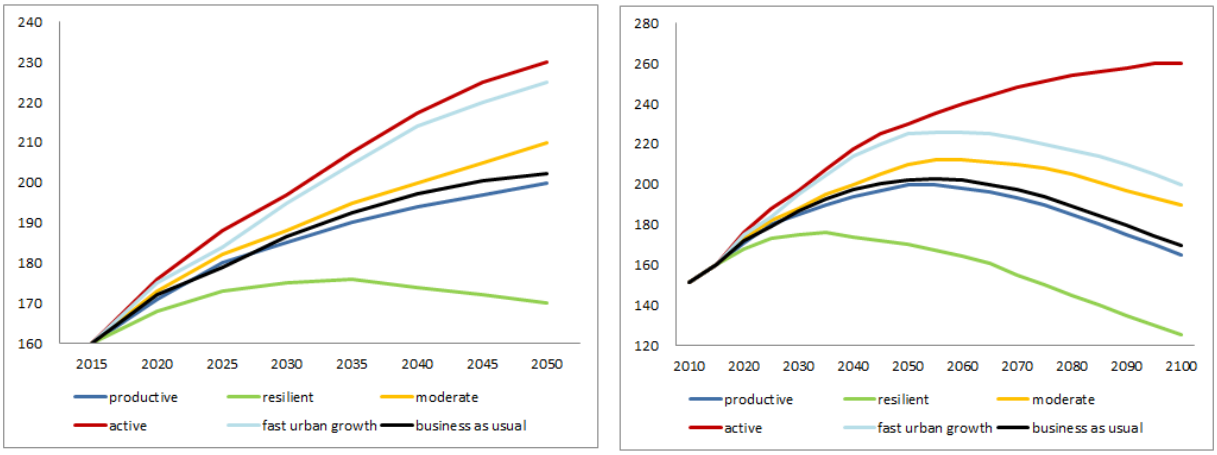

Figure 21: Population developments until 2050 and 2100 - all scenarios

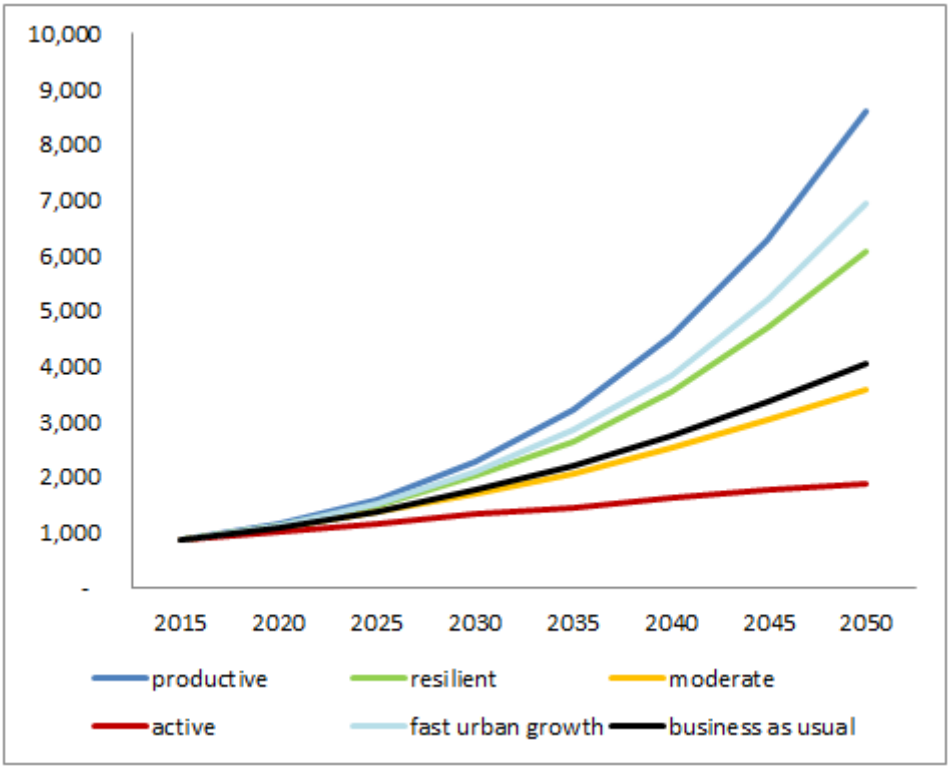

Figure 22: GDP per capita development until 2050 - all scenarios

Box: Quantification population scenarios

The Shared Socio Economic Pathways (SSPs) (http://www2.cgd.ucar.edu/research/iconics/working-groups/narratives-for-ssps) of the IPCC were combined with UN population projections (http://esa.un.org/unpd/wpp/Download/Probabilistic/Population/) to derive the population figures above; as follows: i) Productive (Sufola) – SSP5 and medium variant UN; ii) Resilient (Sohonio) – SSP1 and low variant UN; iii) Moderate (Sushoma) – SSP4 and high/medium variant UN; iv) Active (Sokrio) – SSP3 and high variant UN; v) fast urban growth – high variant UN; and vi) business-as-usual medium variant UN. Urbanization: Business as usual until 2050: UN World Urbanization prospects; figures of the other scenarios are derived from the different SSPs (see above). GDP per capita: Business as usual until 2020 – Global economic prospects

Box Quantification of climate change scenarios

The quantification of future climate change scenarios is based on the Baseline study climate change of the Bangladesh Delta Plan. Quantification is based on a thorough analysis of five different climate models. A moderate climate scenario was developed for the productive and moderate scenarios and a high end climate scenarios was developed for the resilient and active scenario. As explained in the baseline study, the main uncertainties in future climate change are caused by future greenhouse gas emission and the climate sensitivity of system earth. To quantify the uncertainty in future greenhouse gas emissions we selected two RCPs. RCP4.5 was used as realistically low scenario as RCP2.6 assumes broad scale mitigation across the world which seems unrealistic even in the medium future. RCP8.5 was used as a high end scenario. To quantify climate sensitivity five internationally tested and reputed models were used:

1) MPI-ESM-LR (http://www.mpimet.mpg.de/en/science/models/mpi-esm.html);
2) IPSL-CM5A-LR (https://verc.enes.org/models/earthsystem-models/ipsl/ipslesm);
3) HADGEM2-ES (http://www.metoffice.gov.uk/research/modelling-systems/unified-model/climate-models/hadgem2);
4) EC-EARTH (http://www.ec-earth.org/); and
5) CNRM-CM5 (http://www.cnrm-game.fr/spip.php?article126&lang=en).

These models were selected based on a range of indicators. First, it was necessary that daily output was available for all the requested variables. Models which were not able to give this information were omitted from the analyses. In addition only models of which the quality has been assessed over the last 5 to 10 years were selected. All selected models, except EC-Earth, have participated in a number of previous model inter-comparisons and have proved to be relatively good performing models. In addition, models which covered the range of future climate projected by the whole CMIP5 ensemble were selected. The most extreme models were not included. Two relatively dry models, two relatively wet models and a middle of the road model were selected. The ensemble average change of the five models was compared with the ensemble average change of the 39 CMIP5 models. As there are large biases in the results of climate models a bias correction was necessary. After downloading the data, the series were standardized. First, series of equal length were constructed. For the historical data the series comprised data from 1st January 1960 until 31st December 2005. The rcp45 and rcp85 comprised data from 1st January 2006 until 31st December 2100. Exceptions are the CMCC-CESM series, which started at the 1st January 1961 and the IPSL-CM5A-LR series which ended at the 31st of December 2099. Subsequently all data series were interpolated to a 0.5 x 0.5 degree grid size that is similar to the WATCH forcing data (centre of the first grid cell: 179.75 W and 89.75 N) (Weedon et al. 2011).

The temperature, precipitation and snowfall data series were bias corrected according methods developed by Piani et al (2010). The bias correction script (written in IDL) that was made by Piani and Haerter within the WATCH project was used. The radiation and wind speed data series were bias corrected with the method used by Haddeland et al. (2012), using a python script in combination with the CDO package. Both the bias correction methods used the Watch forcing data series (1960-1999) as a reference. For the moderate scenarios we used RCP4.5, at the twenty percentile lowest results based on an analysis of all the five climate models. For the high end scenario we used RCP8.5 in combination with the eighty percentile highest results. Especially for future rainfall changes the uncertainty is very high. To avoid the impression that this scenarios assessment result in precise future numbers of future climate change we have decided the round the numbers if the uncertainty was very high. Rounding was done to the nearest 5 or 10.

Table 28: Quantification climate change - all scenarios

Climate change		2015 *(reference)*	2030	2040	2050	2100
Sea level rise *Mean sea level rise in cm*	Sufola	7,100	10-20	15-25	20-30	40-60
	Sohonio	7,100	15-30	30-40	40-60	80-125
	Sushoma	7,100	10-20	15-25	20-30	40-60
	Sokrio	7,100	15-30	30-40	40-60	80-125
	FUG	7,100	15-30	30-40	40-60	80-125
	BAU	7,100	15-25	20-30	30-45	60-80
Temperature *Mean max temperature degrees change (°C)*	Sufola	25	+0.5	+0.75	+1	+2
	Sohonio	25	+1.5	+1.75	+2	+4
	Sushoma	25	+0.5	+0.75	+1	+2
	Sokrio	25	+1.5	+1.75	+2	+4
	FUG	25	+1.5	+1.75	+2	+4
	BAU	25	+1.0	+1.0	+1.75	+3
Monsoon rainfall *% change mean total monsoon (June-September) precipitation*	Sufola	1,750	0	5	10	15
	Sohonio	1,750	15	18	20	40
	Sushoma	1,750	0	5	10	15
	Sokrio	1,750	20	18	20	40
	FUG	1,750	15	18	20	40
	BAU	1,750	10	15	20	30
Dry season rainfall *% change mean total dry season (December-February) precipitation*	Sufola	36	0	0	0	0
	Sohonio	36	-10	-10	-10	-20
	Sushoma	36	0	0	0	0
	Sokrio	36	-10	-10	-10	-20
	FUG	36	-10	-10	-10	-20
	BAU	36	0	-5	-5	-10
Longest dry day period *Increase of mean number of consecutive dry days*	Sufola		0	0	0	+5
	Sohonio		+5	+8	+10	+20
	Sushoma		0	0	0	+5
	Sokrio		+5	+8	+10	+20
	FUG		+5	+8	+10	+20
	BAU		+2	+4	+5	+10
Rainfall intensity *% change of mean total precipitation*	Sufola		10	10	10	20
	Sohonio		20	20	20	50
	Sushoma		10	10	10	20
	Sokrio		20	20	20	50
	FUG		20	20	20	50
	BAU		10	15	20	30
Cyclone intensity *% change*	Sufola	?	25		45	90
	Sohonio	?	70		90	100
	Sushoma	?	25		45	90
	Sokrio	?	70		90	100

Source: Unnikrishnan and Shankar (2007), Hinkel et al. 2014 (IPCC, AR5), BMD, EU-Watch/Combine 2013/climate change baseline, IPCC 2013

Table 29: Quantification peak discharges - all scenarios

Peak Discharges	Scenario	2015 (reference, m^3/s)	2030	2050	2100
Ganges					
Peak discharge *% change of mean annual maximum at Hardinge Bridge*	Sufola	51,130	15	20	30
	Sohonio	51,130	30	40	70
	Sushoma	51,130	15	20	30
	Sokrio	51,130	30	40	70
	FUG	51,130	30	40	70
	BAU	51,130	20	30	50
Brahmaputra					
Peak discharge *% change of mean annual maximum at Bahadurabad*	Sufola	67,490	5	10	15
	Sohonio	67,490	15	20	30
	Sushoma	67,490	5	10	15
	Sokrio	67,490	15	20	30
	FUG	67,490	15	20	30
	BAU	67,490	10	15	20
Meghna					
Peak discharge *% change of mean annual maximum at Bhairab bazar*	Sufola	13,370	5	10	15
	Sohonio	13,370	15	20	30
	Sushoma	13,370	5	10	15
	Sokrio	13,370	15	20	30
	FUG	13,370	15	20	30
	BAU	13,370	10	15	20

Source: BWDB (Yu et al. 2010), ISI-MIP & VIC (van Vliet and Ludwig, 2013)

Table 30: Upstream abstractions - all scenarios

Upstream Abstractions	Scenario	2015 (reference, m^3/s)	2030	2050	2100
Ganges					
Change Average dry season flow *% change (minus) at Hardinge Bridge*	Sufola	750	*controlled by Ganges Water Treaty*		
	Sohonio	750			
	Sushoma	750			
	Sokrio	750			
	FUG	750			
	BAU	750			
Average dry season flow *m^3/s at Hardinge Bridge*	Sufola	750	*controlled by Ganges Water Treaty*		
	Sohonio	750			
	Sushoma	750			
	Sokrio	750			
	FUG	750			
	BAU	750			
Brahmaputra					

	Sufola	3,000	-5%	-15%	-30%
	Sohonio	3,000	-15%	-30%	-50%
Change Average dry season flow	Sushoma	3,000	-10%	-25%	-40%
% change (minus) at Bahadurabad	Sokrio	3,000	-20%	-40%	-60%
	FUG	3,000	-20%	-40%	-60%
	BAU	3,000	-15%	-30%	-50%
	Sufola	3,000	2,850	2,550	2,100
	Sohonio	3,000	2,550	2,100	1,500
Average dry season flow Brahmaputra	Sushoma	3,000	2,700	2,250	1,800
m^3/s at Bahadurabad	Sokrio	3,000	2,400	1,800	1,200
	FUG	3,000	2,400	1,800	1,200
	BAU	3,000	2,550	2,100	1,500

Source reference values: IWM, BWDB

4. Next steps

The scenarios have been drafted to enable a thorough strategy assessment and to identify which strategies are robust (fit in each scenario) and flexible (are easy to adjust if the future changes). Each scenario has its own water related implications, which have been elaborated in the different scenario sections.

The process towards the drafting of the BDP scenarios is illustrated in figure 1, describing the different process steps and outputs. This figure also incorporates the sub sequential steps, which are the impact assessment and strategy assessment.

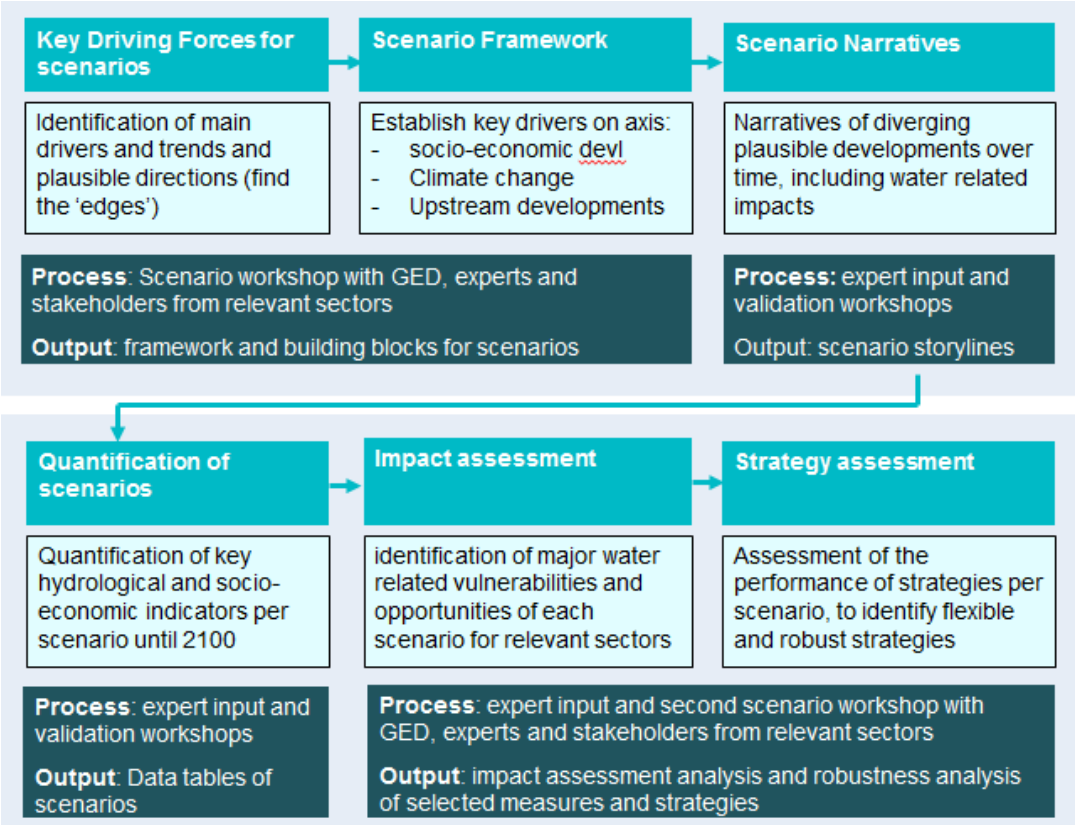

Figure 23: BDP2100 Scenario development process

4.1. Assessment of water related implications

The scenarios outline a bandwidth of possible future developments, with the aim to identify key climate and water related bottlenecks and impacts under different circumstances. The scenarios represent different 'business-as-usual' developments that do not include any policies or measures to solve these bottlenecks, so they can be used to assess the effectiveness of proposed measures or strategies.

A draft of the main water related implications for the four basic scenarios or 'extreme' edges have been summarized in the table on the next page. This overview, gives a qualitative indication of the **impact assessment** and subject to further discussion and modification, i.e. by specifying the impact for each priority economic sector. This is elaborated during strategy development in the Delta Plan.

		Sufola (productive)	Sohonio (resilient)	Sushoma (moderate)	Sokrio (active)
	Ability to invest in adaptation ($)	**$$$$ -** very high GDP growth, ample economic means	**$$$ -** high GDP growth, adequate economic means	**$$** - low GDP growth, limited economic means	**$**- very low GDP growth, severely limited economic means
Flood risk	Economic damage risk	**High:** high economic asset values / very high GDP growth, moderate CC	**Very high:** high economic value / high GDP growth, high CC	**Moderate:** moderate economic value / low GDP growth, moderate CC	**Moderate:** moderate economic value / low GDP growth, high CC
	Rural population (and their livelihood) at risk	**Low:** good connectivity and rapid development of rural areas (incl. chars), improved gender distribution and lower poverty level, moderate CC	**Moderate:** good connectivity and rapid development of rural areas (incl. chars), improved gender distribution and lower poverty level, high CC	**High**; rural isolation (incl. chars), no improvement in gender distribution and lower poverty level, moderate CC. Post flood impacts severe	**Very high**; rural isolation (incl. chars) & bad housing, no improvement in gender distribution and lower poverty level, high CC. Severe post flood impacts
	Urban population (and their livelihood) at risk	**Low**: very high GDP growth, high urbanization level and better housing, low unemployment, moderate CC	**Low:** high GDP growth, low urbanization level and better housing, low unemployment, high CC	**High:** high number of informal housing, high urbanisation level, high inequality, high unemployment, moderate CC	**Very high:** high number of informal housing, high urbanisation level, high inequality, high unemployment, high CC
	Critical infra & objects (e.g. roads, power supply, sanitation, ICT, schools, hospitals) at risk	**Moderate:** critically important infrastructure and objects in flood-prone areas at highest experienced flood/storm-surge level, moderate CC	**High:** critically important infrastructure and objects in flood-prone areas at highest experienced flood/storm-surge level, unexpected depths and areas larger through high CC	**Low:** underdeveloped infrastructure and objects in flood-prone areas at highest experienced flood/storm-surge level, moderate CC	**Moderate:** underdeveloped infrastructure and objects in flood-prone areas at highest experienced flood/storm-surge level, unexpected depths and areas larger through high CC
Water security	Water availability	**High:** Dry season water availability will be relatively high due to moderate CC and low upstream water abstraction due to international collaboration. Little increase in saline intrusion	**Low**: Dry season water availability will be low and highly erratic due to rapid climate change and moderate upstream abstractions. Moderate saline intrusion in the coastal area	**High:** Dry season water availability moderately stressed due to moderate CC and upstream water abstraction. Moderate saline intrusion in the coastal area	**Low**: Dry season water availability will be highly stressed rapid climate change and high upstream abstractions. Large increase in salt intrusion
	Rural Water security	**Low:** Agricultural water demand stabilises due to the cultivation of higher value crops and stabilising boro rice cultivation. In combination with relatively high availability resulting in moderate scarcity. The need for reliable (timely) water supply increases	**High:** Although the modernization of agriculture will over time reduce the demand, the reduction in dry season supply and increased saline intrusion will result in higher water stress	**Moderate:** Water demands will be high under this scenario due to continued demand for irrigated boro rice and the need for food self-sufficiency. Due to continued supply water stress will be moderate	**Very high:** Extensive salt water intrusion, frequent drought and high demand due to continuation of rice production leads to growing and severe water stress

	Urban water security	**Moderate:** Urban water demands will rapidly expand due to increased urbanization and rapid industrial expansion. Due to reduced competition with agriculture, moderate CC and low upstream abstraction, urban water stress will stabilize. Water quality will become increasingly limiting for industrial and domestic use	**Low:** Urban water demand will rapidly increase. It will be difficult to meet these needs especially in the dry season due to frequent droughts and high upstream water abstractions. In the wet season supply will become difficult due to floods and extreme weather events. Growing IW Transport sector severely constrained due to low water levels	**Moderate:** Demand will be moderate due to low economic and urban growth although population growth will be high. Deteriorating water quality will limit water use for domestic, agricultural and industrial use	**Very low:** Unabated water pollution and poor w water quality, in combination with frequent droughts, population increase and salt water intrusion cause severe urban water stress. Stress is mitigated due to low urbanization and industrialization rates
	Environmental pressures	**Moderate to High:** Due to rapid market driven economic development, environmental pressures will initially increase. In the long run, a richer population will demand environmental protection and the economic growth will allow investment in water treatment, reuse and water saving technologies and place a higher value on ecosystems preservation. Good cooperation with upstream neighbours will enhance water quality improvement upstream	**High:** Due to rapid market driven economic development, environment pressures will continue to increase. CC and high upstream abstraction exacerbate these pressures leading to water quality concerns; with saline intrusion as key factor The lower number of people will slightly mitigate this pressure. In the long run, a richer population will demand environmental protection; economic growth will allow investment in water treatment, reuse and water saving technologies and place a higher value on ecosystems preservation. Good cooperation with upstream neighbours will enhance water quality improvement upstream	**High** due to continued unsustainable water management, and food self-sufficiency, wetlands, rivers and coastal areas will come under increasing pressure. There is little scope for investments in environmental technologies and development	**Very high** The high number of people in combination with high CC and high upstream water abstraction will result in very low water quality especially in the dry season. The lack of public and private funding along with limited riparian collaboration lead to very high environmental pressures

5. Conclusion

Four distinctive Bangladesh Delta scenarios have been developed with the aim to offer four different, plausible stories of possible future directions important for future water management. The scenarios are used to identify key climate and water related impacts or bottlenecks that are likely to occur due to future land use developments. Each scenario is characterized by specific changes in the land use, climate and upstream development. These changes result in different challenges related to water supply, flood management and environmental protection.

In the current phase of the BDP2100, the proposed measures and strategies are assessed against different future outcomes. The scenarios developed will form the basis for this analysis, where they will be used to evaluate the effectiveness of measures and strategies under each scenario. The effectiveness of the proposed strategies will be measured by means of different decision support indicators, both qualitative and quantitative. The outcomes of the decision support indicators will be different per strategy *and* per scenario. This will create a well-informed basis for decision-makers to prioritize which strategies and measures should be implemented immediately (are '*no regret*') and which measures could be postponed until it becomes clearer how the future of Bangladesh will evolve.

To properly carry out strategy assessment, the scenarios were not designed as *projections*. Instead, they depict the 'extreme edges' of possible outcomes to identify those strategies that are well equipped and effective in *all* scenarios.

The scenarios should be treated as a 'living document' and need to be reviewed regularly. As the future unfolds it becomes clearer in which direction the economy and climate Bangladesh are developing, and the scenarios can be adjusted accordingly. This should ideally be done after 5-year periods and the different strategies and measures should be evaluated continuously. In this sense, scenario analysis can be considered an integrated part of a continuous adaptive process to create a sustainable, solid approach for Bangladesh Delta Management.

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Annex 1 Validation workshops

A number of validation sessions were held, of which the results have been used to further substantiate and validate the scenario narratives and quantification. Below an overview is presented of the results of the different validation sessions.

Validation session at CEGIS, June 2015

Factors of Comparison	Productive Scenario 2050 Good Economic, Good Climate change	Resilient Scenario 2050 Good Economic, Bad Climate change	Congestion 2050 Bad Economic, Good Climate change	Stagnant Scenario 2050 Bad Economic, Bad Climate change
Alternative names	**Productive BD delta**	**Resilient BD delta**	**Developing BD delta**	**Under developed BD delta**
Climate and Upstream Developments	**Relatively mild climate change**, water variability and hazards, less impacts on resources;	**Extreme climate change**, water variability and natural hazards; and manageable impacts due to better economic condition;	**Relatively mild climate change** and natural hazards; medium impacts of water variability and natural hazards;	**Extreme climate change,** water variability and hazard, highest impacts on resources due to poor economic condition;
	Planned and timely implementation of interventions built in GMB basin such as the river linkage project and additional barrages in the Ganges	**Additional interventions built in GMB basin** such as additional barrages in the Ganges and hydropower plants in upstream part of Brahmaputra by China;	**Slow implementation of interventions built in GMB basin** such as the river linkage project and additional barrages in the Ganges	**Reduction of water availability and salinity increase** due to water extractions upstream; Large interventions in GMB basin leading to **significant reduction of dry flows** and **increased river flood frequencies** and risks;
	Strong Regional cooperation, Strong International support, Complete implementation of regional and international treaties;	Low Regional cooperation, Strong International support, conditional /inequitable implementation of regional treaties	Limited Regional cooperation, Poor International support, moderate (50%) implementation of regional treaties	Limited Regional cooperation, Poor International support, non-compliance to regional treaties
Socio-economic developments	**High global economic growth** leading to **high demand of skilled products** of Bangladesh;	**High global growth** leading to **high demand of skilled products** of Bangladesh;	**Moderate global growth** - slowing global demand for low-value products - high urgency to	**Low global growth** – decreasing global demand of low-value products;

Factors of Comparison	Productive Scenario 2050 Good Economic, Good Climate change	Resilient Scenario 2050 Good Economic, Bad Climate change	Congestion 2050 Bad Economic, Good Climate change	Stagnant Scenario 2050 Bad Economic, Bad Climate change
Alternative names	**Productive BD delta**	**Resilient BD delta**	**Developing BD delta**	**Under developed BD delta**
			invest in agricultural productivity;	
	High investments in human capital (education) and modernized technology leading to diversified economy;	**High investments** in human capital (education) and modernized technology leading to diversified economy;	**Less investments** in human capital and technology leading to low productivity;	**Less investments** in agricultural R&D & human capital, low technological improvements leading to low productivity;
	Trade liberalization and developed infrastructure connections;	**Trade liberalization and improved infrastructure connections**;	**Limited productivity increase**, limited technological diffusion;	**Rapidly growing informal sector** – less government income – less investments in urban facilities and infrastructure;
	Diversified and integrated farming and production of high yielding variety of crops, invention of super crop through research on genome sequencing etc.	Adaptive farming and production of crops resilient to climate change and other adverse environmental effects such as drought, salinity etc.	Moderate production of crops. Low agricultural and industrial input.	Adaptive farming and production of crops resilient to climate change and other adverse environmental effects.
	From food security to food variety; Farming and food processing	**Focus on food security** –Only agriculture farming based production	**Focus on food security** –Only agriculture farming based production	**Focus on small-scale rice-farming** – increased conflicts over land and food;
	Stabilizing population – **190 million people** by 2050	Stabilizing population due to migration – **170 million people** by 2050	Fast growing population – **210 million people** by 2050;	Exponential growing population – **230 million people** by 2050;
	High **GDP growth of 10%** by 2030 – **8%** by 2050;	Moderate to high **GDP growth of 6%** by 2050;	Moderate to low **GDP growth of 6%** by 2050;	**Low GDP growth of 4% by 2050;**
Land Use Changes	Rapid urbanization **– 70% urban population** in 2050;	Medium paced urbanization – **60% urban population** in 2050;	unsustainable urbanization– 52**%** **urban population** in 2050;	urbanization slows down due to limited jobs and urban facilities – **45% urban population** in 2050;

Factors of Comparison	Productive Scenario 2050 Good Economic, Good Climate change	Resilient Scenario 2050 Good Economic, Bad Climate change	Congestion 2050 Bad Economic, Good Climate change	Stagnant Scenario 2050 Bad Economic, Bad Climate change
Alternative names	**Productive BD delta**	**Resilient BD delta**	**Developing BD delta**	**Under developed BD delta**
	Complete decentralization of economic activities and governance towards the **second tier cities** with urban facilities and good infrastructure links; Emergence of small cities and rural clusters for agro-business activities with reasonably well connectivity and infrastructure;	Development of economic activities and governance towards the **second tier cities**; Emergence of small cities and rural clusters for agro-business activities with reasonably well connectivity and infrastructure;	Unsustainable growth of four large cities with inadequate urban facilities; Medium number of informal settlements;	Unsustainable growth of four large cities with inadequate urban facilities; High number of informal settlements;
	Skyrocketing urban land prices – big shortage of affordable housing leading to high number of informal housing;	Skyrocketing urban land prices – big shortage of affordable housing leading to high number of informal housing;	Large increase of rural settlements and informal urban settlements;	Large increase of rural settlements and informal urban settlements;
	Planned spatial growth and connectivity	Planned spatial growth and connectivity	Poor infrastructure investments – poor urban to rural connectivity;	Highly scattered growth
	Urban household based farming of vegetables/roof top gardening	Urban household based farming of vegetables/roof top gardening	**Pressure on agricultural land due to congestion with large scale farming** by elite / foreign companies and self-sufficient rice farming by rural poor;	**Significant decrease of arable land** and increase of environmental degradation;
Implications of water use, floods and water quality	**Continued and guaranteed water supply** essential;	**High water shortages agricultural sector** – more resilient higher value crops; **Minimized environmental pollution risks**; **Water quality**	**High environmental pollution risks**; **Water quality will decrease** due to lack of ETPS and non implementation of environmental guidelines	**High risk of environmental degradation**; **Water quality will decrease** due to lack of ETPS and non implementation of environmental guidelines

Factors of Comparison	Productive Scenario 2050 Good Economic, Good Climate change	Resilient Scenario 2050 Good Economic, Bad Climate change	Congestion 2050 Bad Economic, Good Climate change	Stagnant Scenario 2050 Bad Economic, Bad Climate change
Alternative names	**Productive BD delta**	**Resilient BD delta**	**Developing BD delta**	**Under developed BD delta**
		will decrease due to salinization, but more **sustainable use of water increases** (such as sustainable aquaculture);		
	High urban (domestic-commercial-industrial) water demand of good quality – average daily water use per household will notably increase;	**High water demands industrial – commercial sector**;	**High rural water demand** due to unsustainable use of water;	**Severe water demand**;
	Higher flood protection levels needed due to economic activities;	**Large increase in flood risks** due to harsh climate and growing economy;	**Flood vulnerability high** due to uncontrolled urban development and informal settlements – high risk of drainage congestions;	**Increase of flood intensity and frequencies** and high vulnerability of rural and urban population - Focus on low cost community based adaptation;

Source of data:

- GDP values estimated by analyzing the trend of GDP growth in the last 40 yrs
- Population data taken from the population projection conducted by the thematic group on population
- Urbanization trend taken from projections made by Professor Nazrul Islam, an expert in Urbanization
- Climate change predictions again based on previous experience of experience major hazards

Validation session socio-economic parameters

On May 14, 2015, a validation session with key socio-economic experts was held. Key points that were mentioned during the socio-economic validation session are listed below, as well as the follow-ups of the scenario team.

- ***The scenarios currently have quite a wide focus and could focus more on what the scenarios could imply for climate-water related hazard risks and potential impacts***/damages for population, agriculture and industries in Bangladesh (the key bottlenecks in 2030, 2050 stemming from the scenarios). A combination of spatial patterns of population (housing), agricultural land, and industries and infrastructure in the 4 socio-economic scenarios and for example flood maps (for 2 scenarios 2030 and 2050) could provide more insight in this. In this sense the role of the scenario development in exploring bottlenecks for the drafting of the Delta plan and its measures itself would be strengthened.

The narratives have a wide focus, with the aim to show different possible developments in relation to a number of key uncertainties or drivers. These drivers were the outcome of the scenario workshop in February. In order to have a consistent storyline, the key drivers are described in a storyline / narrative and all have huge implications for the possible land use changes, which impact the water system.

The scenarios are on national scale, and are ideally downscaled to regions. The key water related implications have been described per scenario and summarized in table .

- *A chapter on the implications of the 4 scenarios for Bangladesh* in terms of the impacts of climate change and upstream developments (water variety/ hazards) in relation to size and spatial patterns of population, agricultural lands etc. could be added.

This has been included in paragraph 2.x

- *The axis of water variety could better have the two original drivers on it: climate change and upstream developments.*

It has been a conscious choice to combine both drivers to one axis, and to set this out against a different key driver: the economic developments. In this format, the framework remains simple and effective, while at the same time leaves opportunity to address the other key drivers. It is in line with the approach used by the IPCC. The different scenarios of climate change and upstream developments are described separately within the scenarios. It has been chosen to change the term '*variability*' to 'condition', to better represent both dimensions on the axis.

- *The names of the 4 scenarios are not very clear and appealing*. It is advised to change the names of all scenarios also in relation to the consequences of the scenarios for Bangladesh. Ideas mentioned were: Safe dynamic economy (instead of productive), Threatened traditional economy (or traditional economy at risk, instead of stagnation). The ideal Bangla or English names were not yet proposed.

These were the first preliminary names that were mentioned during the scenario workshop (February 11-12, 2015). Many other suggestions have followed. Paragraph 3.5 lists other suggestions that might be more representable. We propose to change the four scenario names to four different names, which can be found in paragraph 3.5. At the same time, ideally the names will be altered into Bangla names.

- *It is an issue to insert the assumption of more climate resiliency in the resilient scenario.* This might lower the bandwidth in terms of implications of high economic growth combined with extreme climate

change in terms of affected people and assets in Bangladesh (the bottlenecks) beforehand (it conflicts with policy poor scenarios in relation to bottleneck identification and climate&water variety policies which you want to assess later on).

This could indeed be an issue with the name 'resilience'. For this reason, paragraph 3.5 lists a number of alternative names. We suggest to use the name 'space' instead of resilient.

- *Semi urban areas could develop more strongly in agricultural areas because of rising food processing (agrihubs).* This should be elaborated more on in the narratives of scenarios (and if this is more likely in resilient or in productive). It seems to be more likely in productive related to the high agricultural growth and modernization in that scenario.

Mr. Z. Karim will be elaborating more on the agricultural part of the narratives. This will be included in the final document.

Specific remarks on quantifications:

- *The bandwidth of real GDP growth is varying over time*. It seems too small in the first years (also related to uncertainty in relation to world economy and hartals) compared to years 2050-2100. It is advised to increase 7,3% for productive 2010-2020 to 7,6 or 7,7%, Stagnation could be decreased to 4,9% (2010-2020) and later on to 2% and 1%. Mr. Adeeb Choudhury will send a proposal by latest week of 18 May.

This change has been incorporated in the current figures.

- *The population growth seems at the low side in productive scenario if labour force growth is correlated with GDP growth as in many long term growth models*. Declining fertility rates (negative correlation with GDP per capita growth) do seem to dominate increasing life expectancy (positive correlation with GDP per capita growth). Mr. Adeeb Choudhury will investigate the relation between GDP per capita growth and population (fertility rates, life expectancy) a bit more and check if the link between GDP growth and population growth is strong or broken in countries such as India (about 5 years ahead of Bangladesh) and Malaysia (15-20 years ahead). He will propose a number for population in productive based on this.

Analysis has been done and figures have been changed accordingly.

- *GDP per capita seems too high in 2100 in productive*. It would be good to compare the GDP per capital levels to some countries in different stages of development (Pakistan 1299 in 2013 could be looked at for stagnation 2030), India (5 years ahead, 1499 for productive), Malaysia (10.515 in 2013 for productive in 2030). Mr. Adeeb Choudhury will look into this.

Has been changed.

- *% Crop land and % urban land should be linked to population, industry growth and infrastructure growth in the 4 scenarios*. In all scenarios agricultural land should decrease over the whole period. Infrastructure, industrial zone development and urbanization will continue also with declining population (more space per household, more cars related to GDP growth etc.). Mr. Adeeb Choudhury will assess some other more advanced economies (India, Malaysia) and look into the % urban land and agricultural land in these economies.

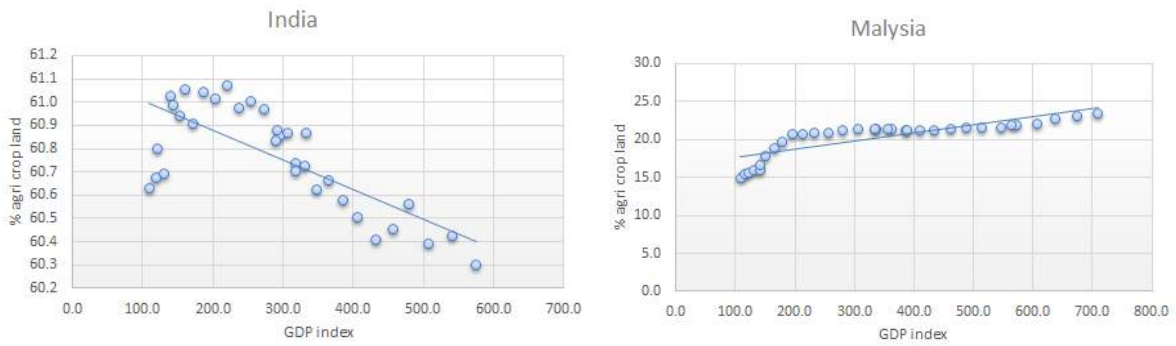
The scenarios make a distinction between the following land use categories, based on the distinction used in several baseline studies, such as the urbanization baseline study:

1. Agricultural land use
2. Urban / industrial land use
3. Rural settlements

4. Mangrove / forests

Historic and current data used originates from different baseline studies. Mr. Adeeb Choudhury has done different analysis to compare the relationship between GDP development and agricultural crop land and found a negative correlation between GDP growth and percentage crop land (Worldbank database) for the countries where the percentage share of crop land was significant (more than 50%). Based on these results, it is expected that the % of agricultural crop land will decrease with an increase of GDP for Bangladesh.

Figure Correlation between agricultural crop land and GDP for India and Malaysia



Source: World Bank Database

The Figure above gives a rough overview of the expected urban patterns per scenario. In the higher growth scenarios, more connectivity between cities and urban centres will arise, to transport goods to markets. In the scenarios with a low per capita growth, infrastructure connections between urban areas are in poor condition. Population growth is concentrated around the largest cities (which have poor urban facilities) and the limited urban-rural connectivity is hampering accessibility of economic goods.

- Freight transport tons should be correlated with GDP growth (elasticity) in this respect the pattern of congestion (sometimes falling) cannot be plausible if GDP continually grows. Mr. Hussain (infrastructure specialist) will look into this and come with a proposal for adjusted figures.

Figures have been changed accordingly.

- Poverty figures development should be consistent with GDP per capita development. In stagnation and urban and congestion they are stable over some periods, this is not consistent. In productive they should decline faster in the first periods (in India the poverty figure is 23%, and is about 5 years ahead of Bangladesh). Mr. Adeeb Choudhury will look into this and do some international comparisons with India, Malaysia, Pakistan etc. It would be better to use the most recent WB limit of $1,7.

Figures have been changed accordingly. As $1.7 was not a common indicator, the official World bank poverty ratio of $2.00 a day has been used.

- Freshwater consumption is dominated by agriculture. In order to quantify it should be reasoned if agriculture production growth is dominant over agricultural (water use) efficiency increases. It the latter is the case productive should have the highest intake growth.

Water use is currently not quantified in the scenarios. The narratives describe the qualitative direction and implications of water use for the different scenarios. Water use and allocation of water can be considered a policy option or measure and is therefore not quantified in the scenarios.

Validation session physical parameters

A scenario validation session was held on May 31st at the Delta Plan office, with key water resources and climate experts to discuss the physical parameters of the developed scenarios. As a result of the discussion, the following points were agreed upon:

ACTION TABLE:

No	Agreed Action	Lead
1	Ensure **consistency** in the storylines in the PPT, share with all	WO
2	**Check wording** and replace in PPT	WO
3	Consider adapting **time horizons to 2030 – 2040 – 2050 – 2100** rather than 2020 which could be considered a projection	MvA
4	Explain the choice for the 4 quadrant method in report and PPT	MvA, CTS
5	Find **alternative English and Bengali names for Urban Encroachment** (only Urban too narrow and also negative) and **Stagnation** (evokes negative reactions). All to suggest names to Maaike and Catharien	ALL
6	Incorporate **improvements** to Socio-Economic, Abstractions and Climate Change **indicators** and share with Experts on Socio-economy, climate and water resources. For CC include ranges rather than discrete values. Include clear **source reference for each indicator**	MvA, KS, FL, DAQ
7	Give **feedback to final list of scenario indicators**	ALL
8	**Share latest Climate change information** with CC team, incl Bay of Bengal SLR data/projections	MFAK, ZHK
9	Explore **inclusion of sedimentation** in Scenario storylines	WO-MHS
10	Check Planned (IRLP) **Abstraction figures for Brahmaputra** with WARPO	GAC
11	Check data on Abstractions by China	MB
12	For Drought include 1/5 years in indicators, for Floods also 1/100	FL, KS
13	Develop knowledge agenda list with Project, leading to strategy	SBS
14	Include Meghna peak flow reduction in scenarios (upstream development)	
15	**Finalise report** and **PPT** incorporating all feedback	MvA, CTS
16	Organise **session with GED and Focal Points** on Final Report	GAC, JH

WO = William Oliemans; MvA = Maaike van Aalst; CTS = Catharien Terwisscha Scheltinga; FL = Fulco Ludwig; KS = Kymo Slager; DAQ = Dewan Abdul Quader; MFAK = Malik Fida Abdul Khan; MHS = Maminul Haque Sarker; GAC = Giasuddin Ahmed Choudhury; MB = Michael de Boer; SBS = Shams bin Shaker; JH = Jaap de Heer

Annex 2: Suggestions for alternative scenario names

During the different validation sessions and feedbacks received, many suggestions were provided to change the names to better representatives of the scenarios. Below table gives different suggestions mentioned. The bold names are proposed by the team to use instead of the original names. If agreed, the names will be altered in this report and other documents.

Productive – alternative names: - **Market driven** - Safe dynamic economy - Productive BD delta (CEGIS)	**Resilient** – alternative names: - **Space** - Water guiding economy - Agri-hubs / Agribusiness - Resilient BD delta (CEGIS)
Urban encroachment – alternative names: - **congestion** - congested - urban isolation - rural decline - moderate - Developing BD delta (CEGIS)	**Stagnation –** alternative names: - **basic needs first** - traditional economy at risk (validation session socio-economics) - active - reactive - Underdeveloped BD delta (CEGIS)

Rationale for the names and update on the changes in the Final Version:

Although a key component of the 'Productive' scenario is the market driven component, it was decided that productive best represents the main elements of the scenario.

In January 2016, during a GED meeting and the BDP team, a proper Bengal name was suggested, which is 'Sufola' for Productive

'Resilient". During the socio-economic validation session, it was mentioned that 'Resilient' could apply the assumption of more climate resilience. This would conflicts with the aim to design policy poor scenarios in relation to bottleneck identification. Several other suggestions have been made, and it is yet to decide which name would be more suitable. It could be 'space', as this well represents a scenario with the least number of inhabitants in the future.

In January 2016, it was decided that the name 'resilient' would remain, and was translated in Bengali to 'Sohonio'

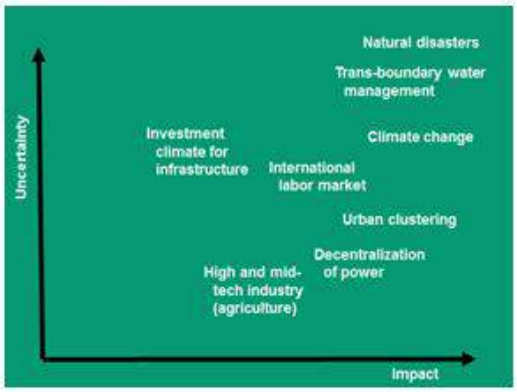
'Urban encroachment' was mentioned most often to change, as it had a negative connotation with urbanization and encroachment. It was therefore changed to 'Congestion' and later 'Moderate' as this better represented the key conditions and description of this scenario.

In January 2016, a Bengal translation was given: 'Sushoma'

'Stagnation' also has a negative connotation. Main premise of this scenario is that food security and survival have the most priority, which requires an active approach to adapt to changing external conditions. In January 2016, the name 'stagnation' was therefore changed to 'active', with the Bengal translation of 'Sokrio'

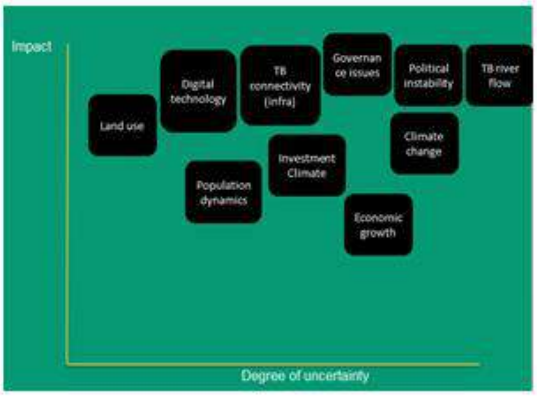
Annex 3: Output of the scenario Workshop

Group 1

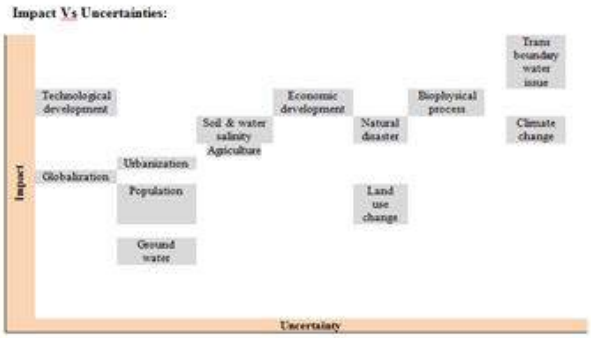


Group 3

Group 2

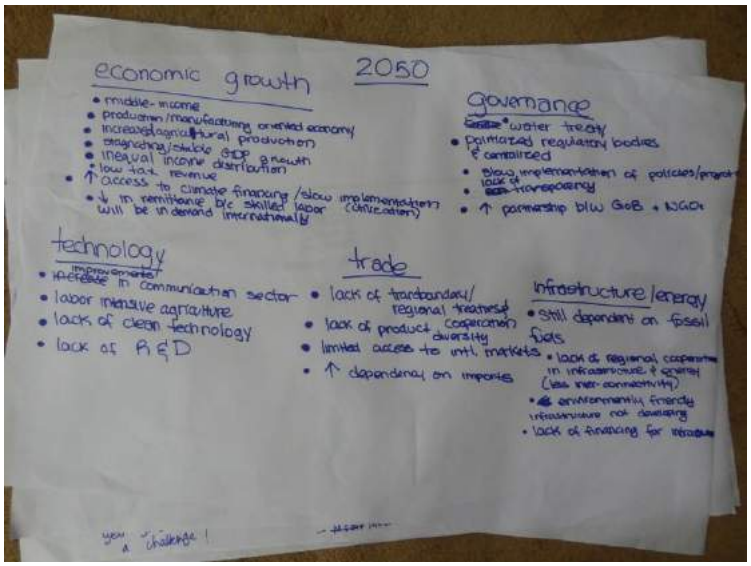


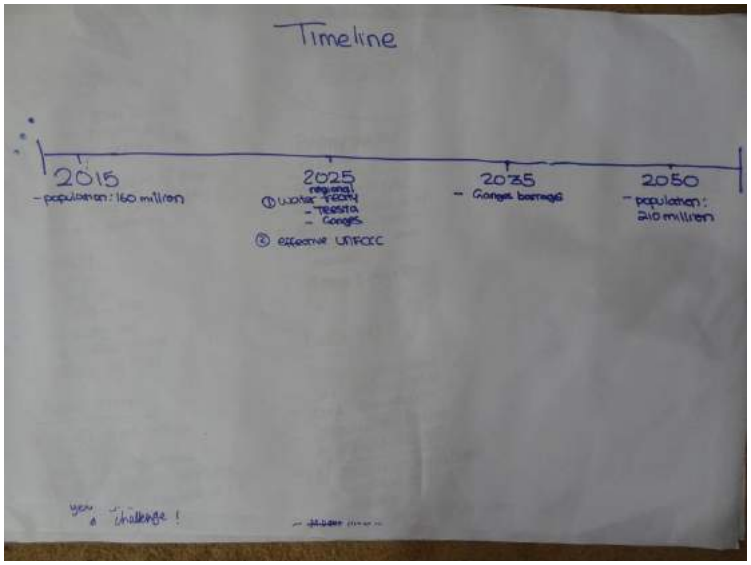
Group 4



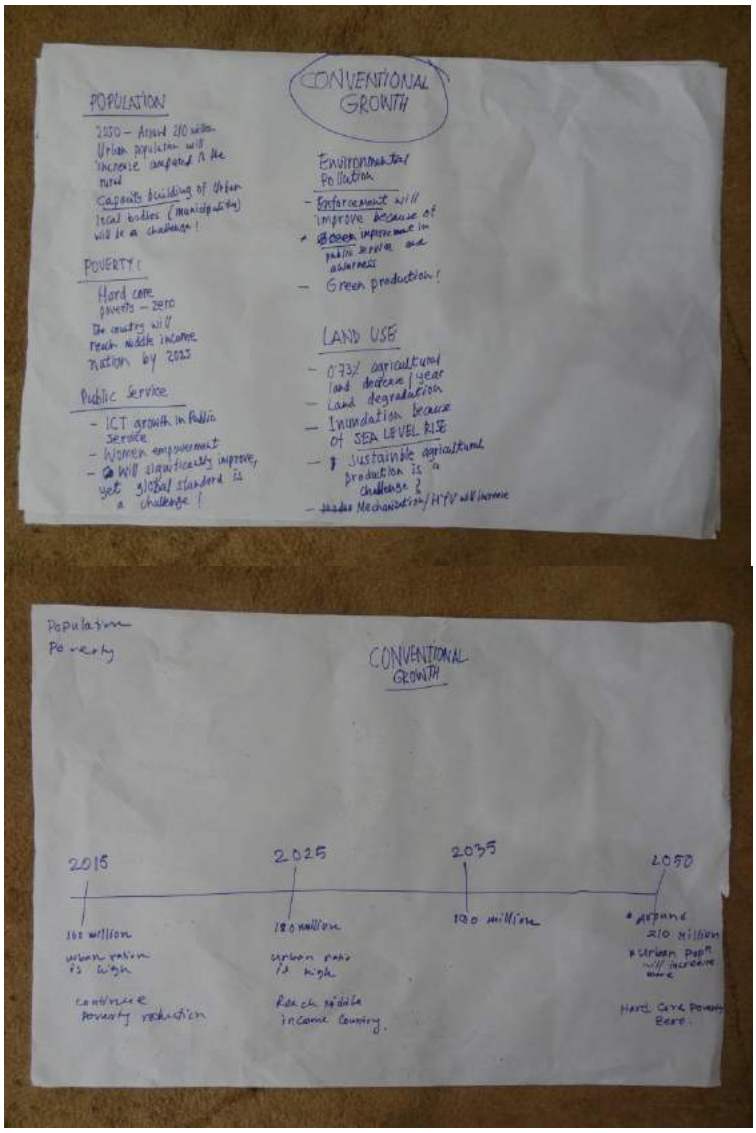
Results of Scenario Workshop Day 2: building blocks for scenario narratives

Group 1 ' congestion'

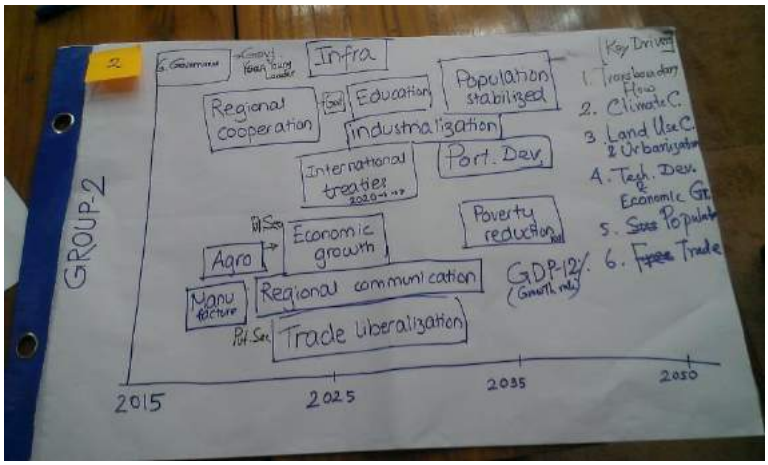




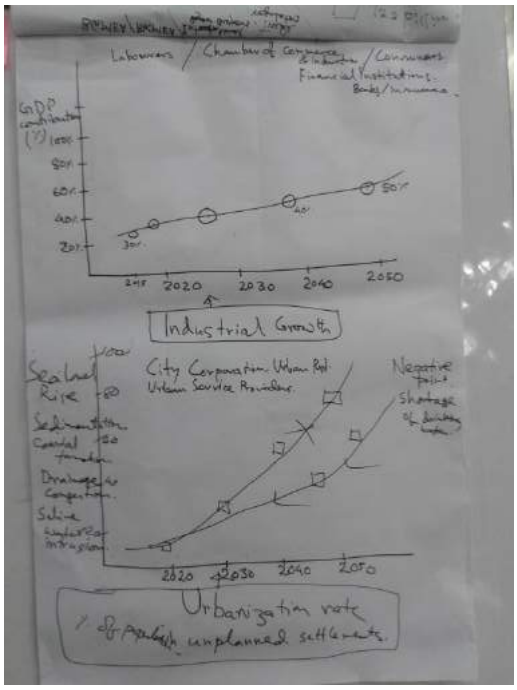
Group 2 'Congestion'

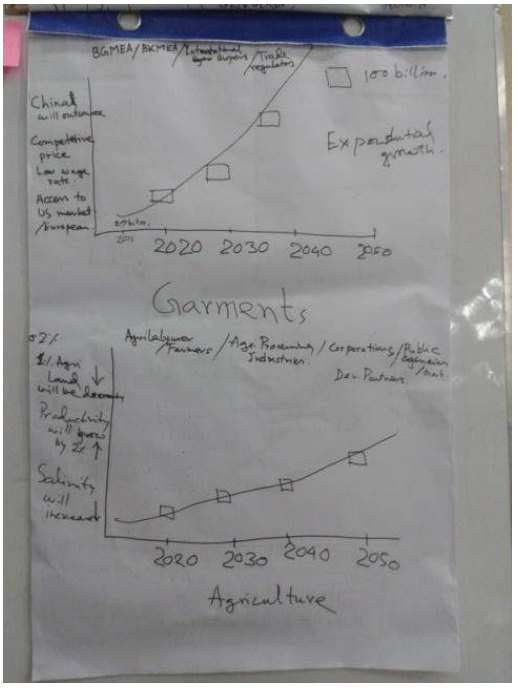


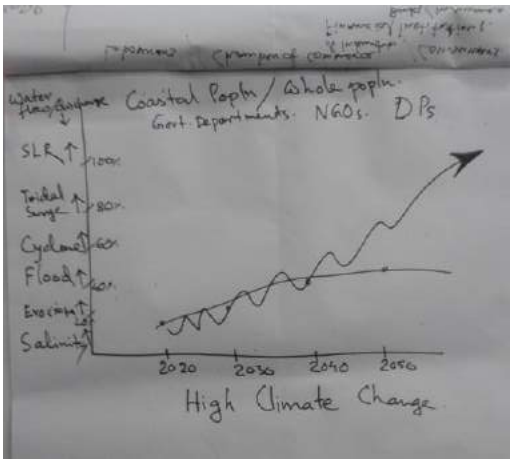
Group scenario ‘Productive’



Group scenario ‘stagnation’







Annex 4: Outputs of the September 2015 Scenario Workshop

PROGRAM 2ND SCENARIO WORKSHOP

Facilitators: William Oliemans (overall – plenary sessions), Catharien Terwisscha Scheltinga (group session)

Presentors:

- Dr. Jaap de Heer (scenarios and assessment framework as part of the formulation of the Delta Plan)
- William Oliemans: the process of scenario development in the BDP
- Fulco Ludwig: a succinct summary of the four scenarios

Hand out:

1. Presentation Fulco Ludwig
2. Executive summary Scenario Report
3. Factsheet Chalan Beel and TRM programmes, including map and list of measures
4. A3 poster with summary of the 4 scenarios
5. Summary of Indicators Assessment Framework

Program:

Time	Topic	Speaker/Facilitator
9.30	Registration	
9.45	Opening	Senior Member Prof. Dr. Shamsul Alam
10.00	Opening	Team Leader BDP2100 Dr. Jaap de Heer,
10.20	Introduction on scenarios and day program	William Oliemans, BDP2100 Water Resources
10.40	Presentation of the 4 scenarios	Dr. Fulco Ludwig, NDP2100 Climate Change
11.00	Questions	William Oliemans
11.15	Break	
11.30	Formation of and discussion in 4 sub-groups	All
12.30	Plenary presentations	Sub-group leaders,
13.00	Conclusions plenary session	Catharien Terwisscha Scheltinga
13.15	Closing	Senior Member Prof. Dr. Shamsul Alam

Main assignment:

Objective: applying the scenarios to assess the bottlenecks and robustness of a proposed program (Chalan Beel and TRM chosen as they are not yet detailed are sensitive to future developments and can benefit from multidisciplinary – integrated assessment)

Each group has three tasks:

1. Assess the bottlenecks for the problem situation in relation to each program for each scenario (eg: worsening drainage congestion, loss of fish habitats, decreasing rice production, etc) by using selected assessment indicators. Fill in table/matrix for each bottleneck with ++, +, 0, -, --
2. Assess robustness of measures, by comparing/adding up scores for each of the two scenarios
3. Reflect on the scenarios, focussing on at least: i) distinctiveness; and ii) consistency

Group distribution:

2 main groups – in parallel:

Group 1: Chalan Beel Group with 2 sub-groups, in parallel:

1a: Applying scenarios 'Productive' and 'Stagnation'

1b: Applying scenarios 'Resilient' and 'Congestion'

*Group 2: TRM Group, with 2 sub-groups, in paralel*2a: Applying scenarios 'Productive' and 'Stagnation'

2b: Applying scenarios 'Resilient' and 'Congestion'

HAND OUT 1: SUMMARY DESCRIPTION OF TWO HOT SPOTS FOR SCENARIO APPLICATION

To ensure structured implementation of the delta plan in the form of different strategies, a total number of six delta Hotspots have been identified for the BDP 2100 (Figure 1). The Hotspots focus on the 'problems, challenges and knowledge gaps' as identified in the thematic Baseline Studies, with each Hotspot having common water related concerns and similar development potentials. In the Scenario workshop, the focus will be on two hotspots: i) the Coastal zone; and ii) Barind and Drought Prone Areas**.**

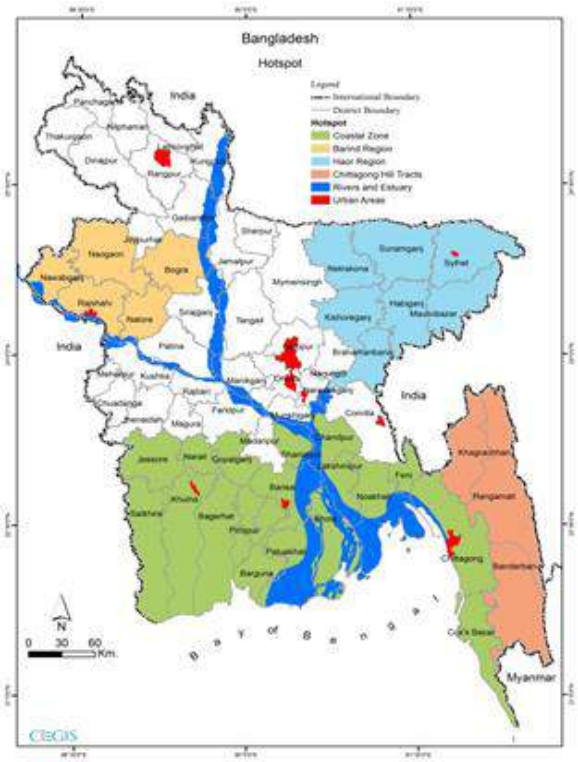


Figure 24: Identified Hotspots under Bangladesh Delta Plan 2100

HOTSPOT 1: COASTAL ZONE

The coastal zone covers the south-west, south-central and south-east areas of Bangladesh, which, in its natural state, are subjected to regular inundation by high tides, *saltwater intrusion*, *cyclonic storms* and associated *tidal surges*, *coastal flooding* and the natural process of *sedimentation and erosion*. Most of the coastal areas are protected by coastal polders, which have induced a long term vulnerability towards climate change hazards, along with persistent *Operation & Maintenance challenges*, making them a prime development domain within the delta plan. *Water supply* for domestic and other purposes is constrained due to *salinity and arsenic* prevalence. *Sanitation coverage* is below national average. *Waterlogging* is a problem in large parts of the coast, especially in the southwest and southeast, with differing causes. In addition to natural sedimentation, the reduction of dry season flow and construction of polders reduced the tidal prism and lengthened the drainage path, leading to reduced drainage capacities.

Outlook and long term challenges

Sea level rise is likely to cause significant changes in *river salinity* in the southwest coastal area of Bangladesh during the dry season (October to May) by 2050, which will likely to lead to significant shortages of drinking water in the coastal urban areas and *scarcity of dry season irrigation water*. The impacts of climate change for this area are most critical because of its high population density and poverty level, and the reliance of many livelihoods on climate-sensitive sectors, such as agriculture and fisheries. Equally important is land *subsidence*. The lower deltaic area of Bangladesh is located on two active troughs, which are subsiding at an accelerated rate. Upstream developments will lead to significant changes in river flows and dynamics that will change the seasonal availability of freshwater in the coastal zones. Key on-going projects in the hot spot area include the Char Development and Settlement Project (CDSP), the Emergency Cyclone Recovery and Restoration Project (ECRRP), the Southwest Area Integrated Water Resource Planning and Management, Noakhali Drainage improvement, Sundarbans Biodiversity Conservation Plan, Cyclone Preparedness Program (CPP) and Deep Sea Port Development Plans (Sonadia

and Payra Port), the Coastal Embankment Improvement Program (CEIP), as well as a number of river plans. The Ganges barrage is in the advanced planning stage.

In summary, the *key bottlenecks* in the Coastal hot spot include

i) saltwater intrusion and coastal flooding
ii) cyclonic storms and tidal surges
iii) costal and river bank erosion
iv) waterlogging
v) siltation of regional rivers
vi) operation & maintenance
vii) water supply (salinity and arsenic)and sanitation coverage
viii) drought
ix) subsidence and sea level rise

Proposed new Programs and Measures for the Coast, as included in the Draft 7th Five Year Plan, which will be completed and assessed in more detail as part of the Delta Plan, include:

Construction of Ganges Barrage and Ancillary Works
Coastal Embankment Improvement Programme
Char Development and Settlement Project- V
Integrated Management of Drainage Congestion for Greater Noakhali
Tidal River Management
Estuary Land Development Programme
Integrated Land Reclamation Project of Hatiya-Dhamar Char-Nijhum Dwip
Urirchar Noakhali Cross Dam Project

HOTSPOT 2: BARIND AND DROUGHT PRONE AREAS

The Barind region with the Barind tracts falls in the north-west region of Bangladesh, and includes 12 districts. It covers roughly an area of some 7,770 sq km. About 5,4 million people live in the hot sport area. The Pleistocene terraces of the Barind Tracts experience frequent droughts and water scarcity, which hamper dry season irrigation initiatives. Drought is especially severe in the High Barind (Natore, Bogra, Thakurgoan Districts). The area receives some 1300 mm of rain on an annual basis and is considered the driest region of the country. Rainfall is particularly scarce in the 4-month dry winter period, in which, if water supply can be secured, optimal conditions exist for intensive agriculture. Groundwater development has been extensive over the past 30 years, driven by both public and private sector initiatives. Intensive development, exceeding recharge from rainfall, has led to a declining groundwater table, shrinking wetlands and subsequent threats to ecosystems, irrigation and water supply sources.

The hotspot further includes Meander floodplains as the High Ganges River Floodplain and the Lower Atrai Basin. These floodplains normally receive enough freshwater for multiple cropping within one season. Due to the intense monsoon rainfall, and the interruption of drainage routes by roads, embankments and other infrastructure and high monsoon river levels, drainage congestion is a key issue in eastern part of the hotspot area, leading to a delayed planting of boro crops. An additional issue is the disconnection of the floodplain from the regional and national river system, related to the development of the Chalan Beel FCD(I) system. A decline of fisheries habitats, biodiversity and livelihoods dependent upon fisheries as well as siltation of regional rivers has been the result.

In summary, the *key bottlenecks* in the Barind hot spot include

i) agricultural droughts and groundwater depletion;
ii) clean and safe drinking water supply and sanitation;
iii) drainage congestion and floods;
iv) increasing water pollution;
v) floodplain connectivity and wetland decline; and
vi) siltation of regional rivers.

Increased competition for freshwater supplies constitute a further hazard to the environment, in addition to climate change and increasing water pollution, all of which threaten the adequate future development of domestic and agricultural fresh water supply in the region.

Proposed Programs and Measures for the Drought Prone Areas of the North West (extract from draft 7th Five Year Plan, draft version to be completed during Delta Plan) include:

North Rajshahi Irrigation Project
Revitalization and Restoration of water bodies of Chalan Beel, including Beel Halti
Revitalization and Restoration of Hurasagar and Atrai rivers
Enhanced Managed Aquifer Recharge in the Barind

HAND OUT 2: KEY CRITERIA FOR ASSESSMENT

To assess the future situation for the two specific areas chosen; i) the Drought Prone Hot Spot (North West) and ii) the Coastal Zone, a number of key criteria for assessment are included. These criteria are presently being developed in the Bangladesh Delta Plan as part of the Assessment Framework and derived from key Policy Goals and Frameworks[12]. In the group session, the criteria are used to:

1. Assess the development of Hot Spots under different Scenarios;
2. Assess the robustness of proposed measures and interventions

For the purpose of the workshop, the criteria will be scored from ++ (highly positive trend/impact) to + (positive), 0 (neutral), - (negative) and -- (highly negative trend/impact). The criteria are outlined and briefly described here below:

1. Economic Productivity & Loss

The criterion Economic Productivity & Loss is related to changes in *Sector Productivity* of the key sectors Agriculture, Livestock, Fisheries, Industry, Transport, Human Resources and Energy and *Economic Loss* related to the above sectors as well as Housing, (Critical) Infrastructure and Health.

2. Livelihood Security

The criterion Livelihood Security consists of two main categories: *i) Food Security*; and *ii) Water Security*. Whereas Food security is mostly related to caloric sufficiency as well as food variety, water security is related to safe drinking water and sanitation as well as security from disasters such as floods, droughts and erosion.

3. Equity & Gender

Equity & Gender are crosscutting assessment criteria related to Income Distribution and the Livelihood Security criterion described above. The difference with the second criterion is that these are considered Gender and Poverty specific.

4. Environmental Sustainability

Environmental Sustainability is a key criterion to assess the impact on ecosystem sustainability, both in protected areas and in the ecosystem services provided through wetlands, floodplains, soils, rivers and intertidal areas.

[12] The assessment framework details these broad criteria into specific 'state' and 'decision support indicators'

Applying Scenarios: Bottleneck Analysis

	Productive	Resilient	Congestion	Stagnation
Bottleneck 1	++	+	-	--
Bottleneck 2	0	0	--	-
Bottleneck 3	-	-	--	--
Bottleneck …				

Applying Scenarios: Robustness Analysis

	Productive	Resilient	Congestion	Stagnation
Measure 1 *Robust*	+	+	+	+
Measure 2 *Delay*	+/-	-	+	+
Measure 3 *Delete*	-	-	+/-	-