JOINT COOPERATION PROGRAMME BANGLADESH – THE NETHERLANDS

Intermediate Report 2019

Water Food Nexus - Make it real

JOINT COOPERATION PROGRAMME

Bangladesh Netherlands

Knowledge development for a prosperous delta

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Developing the partnership for applied research by

Deltares CEGIS Center for Environmental and Geographic Information Services WAGENINGEN UNIVERSITY & RESEARCH IWM Water Environment & Climate Kingdom of the Netherlands

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Summary

In the previous report we have realized an integral approach with different stakeholders on factors that influence the question will Bangladesh have sufficient food in the future. In this report the aim is to gain more insights in quantifying the factors and insights. Quantification in this sense means the use of models to create output that helps answering the question. One must realize that quantification of processes does not always show the reality on the ground. However, it does help structuring the thought process and inform policy makers on possibilities. As we understand that the question is a complex question, we focus in this report on the quantification on the water need in relation to agricultural crops on different scales and different areas with different challenges (e.g. North-West and coast).

Reflecting with literature on first insights regarding the quantification it is stated that the overall impact of climate change could be small in 2030, this can be explained by the strong positive C02 fertilization. In 2050 however, these impacts might become bigger. Rice and wheat production drop between 8-32 %. Demand for irrigation water for maintaining food self-sufficiency could rise between 40-50% This could have big impacts on the domestic and commercial water supply, fisheries, ecosystems, navigation, and salinity management (Faisal et al.,2004). These findings help showing the urgency of starting the thought process and support policy makers now. Without attempts of quantification it will become harder to take action and action is something we need to take now in order to make a difference in the future.

Contents

Abbreviations

JCP	Joint Collaboration Program
BBS	Bangladesh Bureau of Statistics
BDP2100	Bangladesh Delta Plan 2100
BUET	Bangladesh University of Engineering and Technology
CEGIS	Center for Environment and Geographical Information Systems
EKN	Embassy of the Kingdom of the Netherlands
IWM	Institute of Water Modelling
IWRM	Integrated Water Resources Management
OMT	Operational Management Team
SIBDP	Support to the Implementation of the Bangladesh Delta Plan
SMT	Strategic Management Team
TL	Team Leader
WARPO	Water Resources Planning Organization
WB	World Bank
WMKIP	Water Management Knowledge and Innovation Programme
WP	Work Package
WUR	Wageningen University and Research

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1. INTRODUCTION

There is a growing global concern of the world food program that food security (and nutritional value of foods) will decrease as an effect of climate change and changing socio-economic circumstances (WFP, 2016). One of the changes in socio-economic circumstances is the increase in GDP, this is linked to a higher intake of protein. The higher intake of protein requires more input of (scarce resources). Bangladesh also fits within the trend of growing GDP and is affected by climate change. Although the country has made huge steps the last decades in increasing the food security and the food self-sufficiency of the country (Bishwajit et al.,2013), it is a country with a fast-growing population with a fast-increasing need for more and protein rich food. This increase in need is mainly because of dietary changes (more welfare is linked to increased demand for protein) and a growing population (Mathijs, 2015). This results in a high pressure on agriculture to produce more food. As agriculture consumes around the 90% of the water use in Bangladesh (FAO Aquastat, 2012) the water demand is also increasing. Moreover, the increase of welfare is also linked to a high-water consumption pattern (Alcamo et al.,2007). Congregating these water and food developments in a water security assessment for agriculture, one can see that it is low in comparison to other countries in Asia (AWDO, 2016). One thing that explains a low water security score for Bangladesh is the changing climate; water resources are becoming more unpredictable under the current climate change scenarios (ADB,2016). This means that the amount of water may not change, but the distribution of the water could change. For the future, this means a more unpredictable water situation for the country. Combining the unpredictable water situation with the growing population show a potential problem for the food supply for this population. However, it is unclear how big the gap between the food demand and supply will be in the future. Some qualitative methods show a trend towards water and food shortage (Zhou et al.,2019). However, a quantitative approach for identifying how big the gap is, is not done yet in an integral way.

Therefore, the focus will be on finding out, quantifying how much food is needed, and how much water is needed for this growing population.

To determine this gap, the supply side must be considered. On the supply side, to feed the population, agriculture must produce more crops and livestock under increasingly challenging circumstances due to climate change. On the food supply side, food demand is related with food production, which in its turn is related to agriculture's demand for water. Current agricultural production will need to transform to future food demand, and in line with future water availability. On the water demand side, there is also more competition for water by industry, citizens and environment, expansion of the cities, their increasing need for water, reduction of the agricultural area, and transformation of the food need towards higher protein intake.

In summary, more water is needed for a growing and more prosperous population; reliability of the water resources is declining, how is Bangladesh going to meet the food demand of the future with the current water resources in the context of climate change (Gerbens-Leenes et al., 2010).

In this report we are presenting a valid approach on how to approach quantifying the gap for the future water and food demand. Moreover, it aims for a shared understanding of the food security and nutrition situation in the country. To

align with the nation goals of leaving no one behind and empowering women our report also includes these overall goals. Therefore, our report calls for a more diversified agricultural sector and enhanced social protection system that leaves no one behind and points out the empowering of women is key to achieving sustain food and nutrition sector.

2. SUMMARY AND PROBLEM ANALYSIS

For the understanding of the plans and the approach, the problem analysis is briefly summarized in this chapter. In the project plan, the problem analysis is extensively described (The project plan is added as an Annex xx) The analysis can be summed up in three main points:

- **Integration of water and food modelling**

As highlighted in the introduction, models are a tool for decision makers to structure to their policy and make informed choice. The future is uncertain and this makes it difficult for policy makers to decide. In order to make well-informed choices on the water and food developments, there is a need to assess future water and food situation (and thus assess the current situation as well). The complexity of the future water and food situation is mostly in the integration of the scale (local and national) and the integration of topics (water and food). To get a reliable insight on the future of the components, it is needed to connect multiple scale levels of a model in an integral model for water and food modelling. Most current models are focussed on either water or food and on one scale (global or local). Integral multilevel modelling of both water and food remain a challenge

- **Integration (on local level) of the different authorities related to water and agriculture**

It has been highlighted by (in) formal interviews that both the authorities on water and agriculture (BWDB, BADC, BMDA, LGED and DAE) are involved in projects that concern the water and food (agriculture) sector. As the introduction describes and the expert interviews later on in this report, it is a primary focus that not only the topics are integrated on the content but also on the institutional level. This is needed to address the integral component of the water and food assessments. An example of the integration of collaboration is Blue Gold, CDSP, HILIP project where the organizations worked together on project-base.

- **Implementation model outcomes at different institutional level (scales)**

This challenge requires integrated models and integrated authorities in order to implement the outcomes of the model at different scales. After a successful model and authority integration, it becomes a challenge to translate global/district/local to a different scale and implement the outcomes efficiently into policy for each level. As an example, BDP2100 could be thought of as an integrated approach established by multiple integrated models and integrated authorities. This national approach needs to be applied at local level. This poses a challenge.

OBJECTIVE REPORT

In the introduction the need for quantification of the food& water demand gap is described. To meet the described need, the objective of this project is*: To quantify with models the (possible) gap between the demand and supply of water and food in Bangladesh.* To reach the main objective, sub-goals are formulated:

- Describe and explain factors influencing the water and food supply and demand
- Give an insight on the approach for the future influencing the water and food supply and demand
- Give an in-depth analysis of the current collected data related to the water and food context of Bangladesh

As the objectives will be reached in this project, there will be output. This output gives insights on possibilities for the future and supports therefore informed decision making. That is why the output is useful for policy related uses and planners.

3. APPROACH

First the problem analysis from the project plan is presented briefly in three points. Afterwards the focus of the research is explained.

3.1 Summary problem analysis & delimitation

The focus of the research is on the integration of water and food modelling (point 1). This because the client and the interviewed experts have highlighted this a main priority. The second and third point (point 2 and 3) described here, are important to keep in mind but are not included in this research. Therefore, the second and third point are only described in this section and not further elaborated elsewhere.

1. **Integration of water and food gap**

Models are a tool for decision makers to structure to their policy and make informed choice. The future is uncertain, and this makes it difficult for policy makers to decide. To make well-informed choices on the water and food developments, there is a need to assess future water and food situation (and thus assess the current situation as well). The complexity of the future water and food situation is mostly in the integration of the scale (local and national) and the integration of topics (water and food). To get a reliable insight on the future of the components, it is needed to connect multiple scale levels of a model in an integral model for water and food modelling. Most current models are focussed on either water or food and on one scale (global, national and local). According to several experts (Annex) Integral multilevel modelling of both water and food remain a challenge.

2. **Implementation challenges (on local level) of the different authorities related to water and agriculture**

The challenge of integration between the different authorities has been highlighted in formal interviews that both the authorities on water as well as agriculture (BWDB, BADC, BMDA, LGED and DAE). All authorities are involved in projects that concern the water and food (agriculture) sector.

As the introduction describes and the expert interviews later in this report, it is a primary focus that not only the topics are integrated on the content but also on the institutional level. This is needed to address the integral component of the water and food assessments. An example of the integration of collaboration is Blue Gold, CDSP, HILIP project where the organizations worked together on project base.

3. **Implementation model outcomes at different institutional level (scales)**

The challenge lies here in the outcomes of the models for implementation at different institutional levels. This requires integrated models and integrated authorities to implement the outcomes of the model at different scales. After a successful model and authority integration, it becomes a challenge to translate global/district/local to a different scale and implement the outcomes efficiently into policy for each level. As an example, BDP2100 could be thought of as an integrated approach established by multiple integrated models and integrated authorities. However,

this approach only applies at bigger scales (national and hydrological). This approach needs to be applied at local level as well.

3.2 Explanation factors

This part explains all determined factors with the experts as described in part 3.2.

Climate Change

As it is an overarching theme for all factors, climate change is considered in a different way than the other factors for the approach. It is different as it seen as a driving force of change for every factor. Climate change makes all the factors outcomes for the future more uncertain, that is why it is not included as a separate factor. For this research project, climate change scenarios are considered until 2050.

Population growth

Explanation term in project context: On a global scale, the population more than doubled between 1960 and 2012, from 3 billion to over 7.3 billion. Various projections indicate that by 2050, the population will grow to between 8.3 and 10.9 billion people (UN, 2012b), with a predicted medium figure being 9.6 billion by 2050. Overpopulation has many consequences for food demand and food availability. It often leads to overexploitation of the (food) resources (Washington, 2015). Also in Bangladesh this trend is seen. The population is growing and has been growing the last years. This leads to higher pressures on the resources.

Our definition in this report: The change in amount of people from the years 1971 until 2050.

Why considered in approach: A growing population requires more food. A higher demand for food requires more water for agriculture. Looking at the Bangladesh context, the population also becomes more prosperous. This entails that the diet changes towards more protein-based diet. A higher protein diet requires more water. In summary both, the food demand and the water demand will be affected.

Diet Change

Explanation term in project context: More income means a shift of dietary pattern. This entails mostly an increase of the protein intake (Huang and Bouis, 1996). As Bangladesh experiences an increase in the average income per person, it also leads to a shift in the dietary pattern. This affects the food demand; the population creates a higher demand for protein. A higher demand for protein requires more water (see water availability part for explanation why protein requires more water).

Our definition in this report: The change in the dietary pattern of an average Bangladesh person from 1971 until 2050.

Why considered in approach:

As mentioned before, the people of Bangladesh are becoming more prosperous. This includes that they have more means to buy food. Assuming that the people will buy more food, the food demand will increase. Moreover, increase in prosperity generally leads to an increase in protein intake. A higher protein intake is linked to high water demand. This is why the water demand is also affected by this development (Mekonnen and Hoekstra, 2011).

Land-use Change

Explanation term in project context: Land use is here considered as the urbanization trend. It is one of leading causes for loss of arable land and thus less lead available for food availability. The rate of this trend is bigger than ever. Although urban areas cover only 3% of the world surface, the impact of the urbanization is widespread. It affects environment on a local and as well as a global scale (Rana, 2011). In Bangladesh it can also been seen, many people are moving to the cities and the cities itself are growing as well.

Our definition in this report: As described, urbanization is also general trend in Bangladesh. More people are moving and living in cities. This is because of the growing population and the moving of the population to the city. This urbanization trend leads to less available cropland

Our understanding of factor: The change of land-use from cropland area to urban area from 1971 until 2050.

Crop change

Explanation term in project context: Changes in the global production of major crops are important drivers of food prices, food security and land use decisions. The calculation of the crop production is done by the amount of area x the type of crop. This results in a certain production number. Average global yields for these commodities are determined by the performance of crops in millions of fields distributed across a range of management, soil and climate regimes. Research shows that since 1981 there is a negative response to temperature increase of wheat, maize and barley (Lobell and Field, 2007). Looking at the staple crop of Bangladesh (rice) one can notice that including climate change in the predictions, leads to a shortening of the rice maturity period of 8% and yield increase by 12% (Saseendran et al.,2000)

Our definition in this report: The crop change consist of two components:

- Cropping pattern change from 1971 until 2050 (type of crop)
- Crop area change(amount of crop)

Why considered in approach: Crop area change is an indicator for the possible food availability. Together with the cropping pattern it shows how much of a certain crop is produced for the food availability.

Water availability

Explanation term in project context: Water availability related to agriculture. This is translated to the water available for agriculture. For Bangladesh, three water sources are important to consider. This is because all three are being applied and have being applied for several years. This concerns groundwater sources, surface water sources and precipitation. The availability of all water sources varies throughout the year. It is expected with climate change that the availability will vary more than before, making the water availability for agriculture and thus food supply more uncertain.

Moreover, the supply of the water depends on the facilities to withdraw the water (Brouwer et al., 1992). However, this is not the scope of this research project. This is because climate change will have more impact on the variation of water availability throughout the year

Our understanding of factor: The available water for food production consists of three components;

- Groundwater availability
- Surface water availability
- Precipitation

Our definition in this report: This is the available water the crops can use for the demanded food production.

4. METHODOLOGY

The Joint collaboration program has started officially with the kick-off meeting in February 2019 and thus the water-food nexus project has officially started. From February 2019, onwards several activities have taken place in the context of the project. These are summarized in table xx. In broader sense, the project has three major activities:

-Need assessment and validation of methodology

-Modelling for future projections

-Training and knowledge sharing.

The project needs assessment and methodology validation is already completed at present. The process of the needs assessment was done in two separate phases. Firstly, one to one interview with local relevant resource persons were conducted. Secondly, a validation workshop was conducted based on the initial findings in the Dhaka Water Knowledge Days (DWKD) – a weeklong event held in Dhaka. One of observations of this event was that stakeholders realize the need and are interested to be part of such a research project. They feel obliged to give their support to the JCP project if they have direct stake or facilities are provided e.g. local travel cost, daily allowance etc. Some key experts were present who gave their feedback on how to develop this project further.

Moreover, Deltares and IWM organized a training of trainers (ToT). In this training a training plan and work plan for each of the sub project was constructed. Modelling activities are expected to be carried out within 2020. An action plan on communication strategy was developed in a training programme on JCP Research Communication Training organized by Wageningen University. According to the action plan, regional Level workshops and a national workshop, addressing BDP 2100 is planned to be conducted by 2022. A brief disclosure of findings will be presented through a workshop in first quarter of 2021. The data will be adjusted in accordance with the feedback.

At the initial stage, experts of Center for Environmental and Geographic Information Services (CEGIS) and Wageningen University and Research (WUR) make a plan to facilitate the interviews and selection of the experts. During this meeting, it was decided to ask the experts about a single scenario (e.g. Barind tract) for better understanding.

Table 1 *Process 2019 presented in chronological order*

Activities	Elaboration	Timeline
Project definition	Many experts from Netherlands and Bangladesh supported the project definition period. These experts supported the topics of: modelling on global and local scale, water and food challenges in Bangladesh, modelling in Bangladesh, using GIS in Bangladesh etc.	February 2019- September 2019
Factor developments Bangladesh	Internal brainstorm on which factors are most important when considering the future water and food demand. This was done in context of the Barind area in Bangladesh. The area was used as a tool to make our assumptions explicit about the future and extrapolate the assumptions to national scale.	September 2019- October 2019
Future scenarios factors Bangladesh	Discussed with the project team what we assumed as logical developments for the future.	October 2019
Interview factors with experts	Discussed our expectations with the support of the Barind case with 9 stakeholders.	October 2019
Discussion factors with participants	Presented the factors on the Dhaka Water Knowledge Days. Let the participants decide where they think the focus should be on. Moreover, the data exercise was fulfilled where the data for the factors should come from.	October 2019
Discussion data factors with participants	Presented the factors on the Dhaka Water Knowledge Days. Let the participants decide where they think the focus should be on. Moreover, the data exercise was	October 2019

	fulfilled where the data for the factors should come from.	
(Basic calculation development)	With the presented factors, basic calculations were made in an excel file. This in order to get an insight in the numbers for the factors. From here, it shows which numbers are interesting and expected and which are not. These calculations will be used to support the model choices.	

To execute these activities, several methods are applied. The method was selected most appropriate to the goal of the activity. The first method is brainstorming. This was applied to the initial project definition. The second method is in-depth interviewing. This was used for the nine expert interviews in Bangladesh. The second method that was used is the participatory group approach. This was used in the discussion with the participants on the factors and data at the Dhaka Water Knowledge days.

The interviews are analysed by organizing the comments to the five factors. Also, the amount of comments is counted for every factor. This could give an impression on how much the professionals are talking about it. However, it is not a direct relation to the importance of the comment. It could be that if a factor is not well mentioned that all the professionals accept that is a fact.

5. RESULTS

5.1 Maps and data

In the maps and data section, the gathered data of 2019 is displayed and explained. Moreover, the source is mentioned and the format of the data.

Population growth

The population of Bangladesh has been increased rapidly. In 1974, the population of Bangladesh was 71.5 million. The current population of Bangladesh is 163 million. In the course of time, population has been almost doubled. The population of Bangladesh is expected to become 216 million by 2050. The total population of Bangladesh from 1901 to 2051 is presented in Graph xx and district wise population in Annex xx.

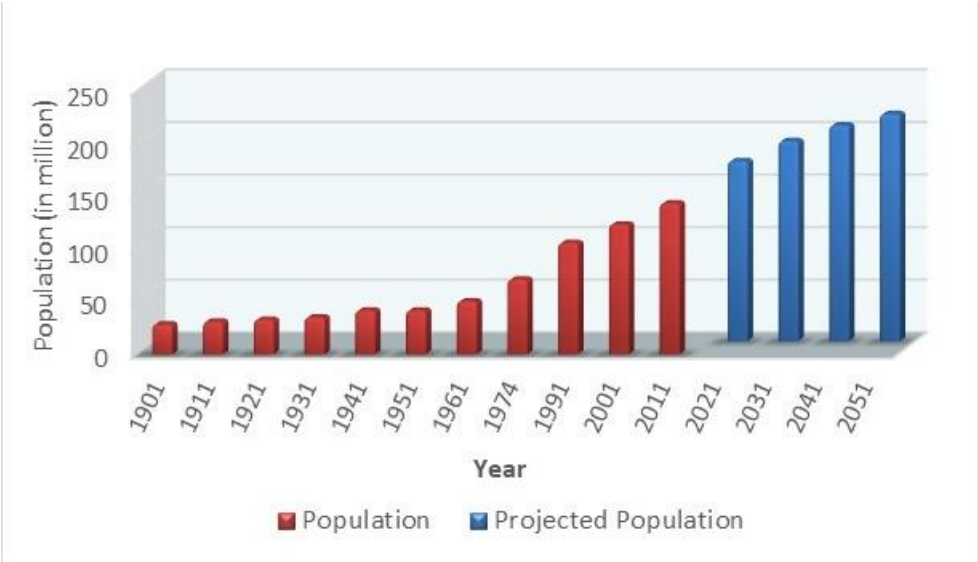

Figure 1 Population distribution,1901-2051

Population data is collected from population census done by Bangladesh Bureau of Statistics. In total five population census was done in Bangladesh. The first census was conducted at 1974 after the independence of Bangladesh. Second census was carried out at 1981. After that all census was done in an interval of ten years (1991, 2001, 2011). The lowest level of data set is Upazila (sub-district). The table presented census data from 1991 to 2011 by district. The future population projection was carried out by the United Nations Population Fund (UNFPA 2014a) carried out a population projection for Bangladesh for the period 2011-2061. Based on the assumptions regarding the future course of fertility, three projection scenarios are considered, which are labelled as 'high', 'medium' and 'low' variants. The synthesized data published in population projection of Bangladesh: dynamics and trends 2011-2061, Bangladesh Bureau of Statistics. The lowest level of data set are available in district (sub-division).

Diet Change

Dietary pattern of Bangladesh people was observed from 1991-2016. According to household income and expenditure survey (HIES), in 1991 the total food consumption was 886 which increased to 975 g/capita in 2012. Still total

consumption is below the desirable intake (1280 g/capita). The noticeable thing is the staple food consumption is reducing while other food consumption is increasing.

The data is obtained from household income and expenditure survey (HIES) published by BBS. The dataset scale is national which further subdivided into rural and urban. The desirable intake data is collected from Desirable Dietary Pattern for Bangladesh published by Bangladesh Institute of Research and Rehabilitation in Diabetes, Endocrine and Metabolic Disorders (BIRDEM) in 2013.

Table 1 Change in per capita food consumption (in gram) of Bangladesh

Food	Consumption (Gram per capita per day) as per HIES				Desirable intake (Gram per capita per day) as per DDP
	1991	2000	2010	2016	
TOTAL	886.2	893.1	1000	975.5	1280
CEREALS	516.2	486.7	463.9	406.5	400
Rice	472.7	458.5	416	367.2	350
Wheat and Others	43.5	28.2	47.9	39.3	50
POTATO	43.7	55	70.3	64.8	100
VEGETABLES	137.4	140.5	166.1	167.3	300
PULSES	17.9	15.6	14.3	15.7	50
MILK/MILK PRODUCTION	19.1	29.7	33.7	27.3	130
EDIBLE OILS	10.1	12.8	20.5	26.8	30
MEAT, POULTRY, EGG	12.9	18.5	26.2	39	70
FISH	34.5	38.5	49.5	62.6	60
CONDI. & SPICES	43.5	50	66	74.1	20
FRUITS	16.9	28.4	44.7	35.8	100
SUGAR/GUR	8.8	6.9	8.4	6.9	20
MISCELLANEOUS*	25.2	10	36.5	42.29	

Land-use Change

The area under agricultural land was 13.30 million ha which was about 91.83% of the country in 1976. This agricultural land has been decreased to 12.74 million ha with the annual loss of 13,413 ha in 2000. It reached to 12.18 million ha in 2010 with annual loss of 68,760 ha. The annual loss of agricultural land during the study period (1976-2010) was 29,692

ha. This indicates that the availability of agricultural land was in decreasing trend with much faster during the period from 2000 to 2010. The graph shows the change of land use from 2000 to 2010 and the table shows the detail land cover of Bangladesh in past years (1976, 2000, 2010).

The land use data was collected from Trends in the availability of agricultural land in Bangladesh by Soil Resource Development Institute (SRDI). The study has been conducted through (i) digital interpretation of satellite imagery (ii) secondary information and (iii) ground truthing in selected locations of Bangladesh. A total of 16 scenes of Landsat MSS and TM/ETM imagery from path 135-139 and row 42-46 covered the entire Bangladesh have been analysed digitally. Space-borne satellite imageries (Landsat, MSS/TM/ETM) available between 1976, 2000 and 2010 were used to identify the types of land available in different locations of the country and quantify the changes with geographical distribution of arable agricultural land. The base-year of satellite image analysis was 1976. Spatial data of land cover for previous years are available in SRDI but they did not disclose it to other institutes. However, division level data are available in the report.

Besides this, land cover map of 2018 is available in CEGIS. BBS also published land use data as a tabular format by district as a part of their statistical yearbook. However, the data of these two organizations varies due to methodology implemented and time requirement for full cycle completion.

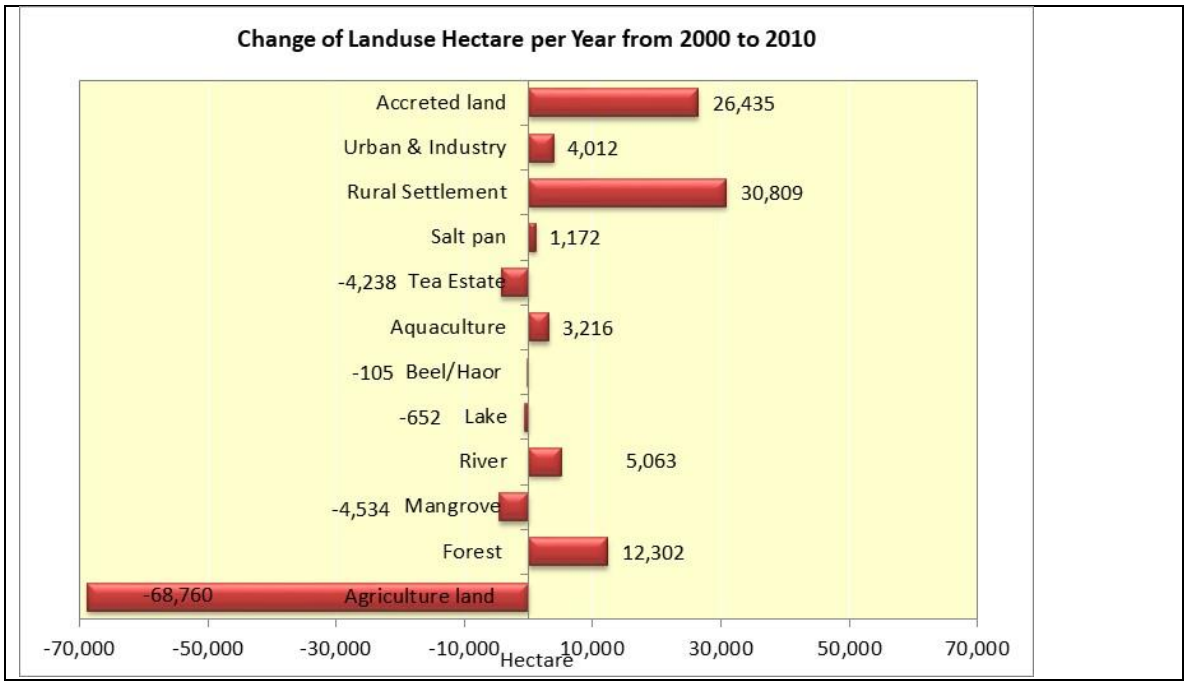

Figure 3 Change of Landuse from 2000-2010 (in hectare per year)

Table 2: Total area of different land cover

Land cover type	1976	2000	2010
Agricultural land:	**13.30**	**12.74**	**12.18**
Crop land	9.76	9.44	8.75
Forest	1.75	1.31	1.43
Mangrove forest	0.45	0.49	0.44
River	0.91	0.89	0.94
Lake	0.05	0.06	0.05
Beel and Haor	0.24	0.25	0.25
Aquaculture	0.00	0.14	0.18
Tea estate	0.12	0.14	0.10
Salt pan	0.01	0.02	0.04
Non-agricultural land:	**1.18**	**1.79**	**2.40**
Rural settlement	0.89	1.46	1.77
Urban & Industrial	0.03	0.05	0.09
Accreted land	0.27	0.28	0.55
Total	**14.49**	**14.53**	**14.58**

Source: SRDI, 2013

Crop change

In 1972 the total rice area was 9.6 million ha which is presently increased to 11.3 million ha. During 1973 AUs, Aman and Boro rice cultivation area were 2.9, 5.7 and 1 million ha respectively. Currently the figure stands at 1.1, 5.6 and 4.7 million ha. In the course of time total rice area has increased 18% of which Aus production area reduced to nearly half, no significant change is observed in Aman cultivated area while drastically increase is found in Boro cultivated area.

The data is collected from yearbook of BBS by 64 districts from 2011-2018 as tabular format. Besides this, crop area data are available from 1972-2010 which lowest level dataset is greater district (24 districts) as tabular format.

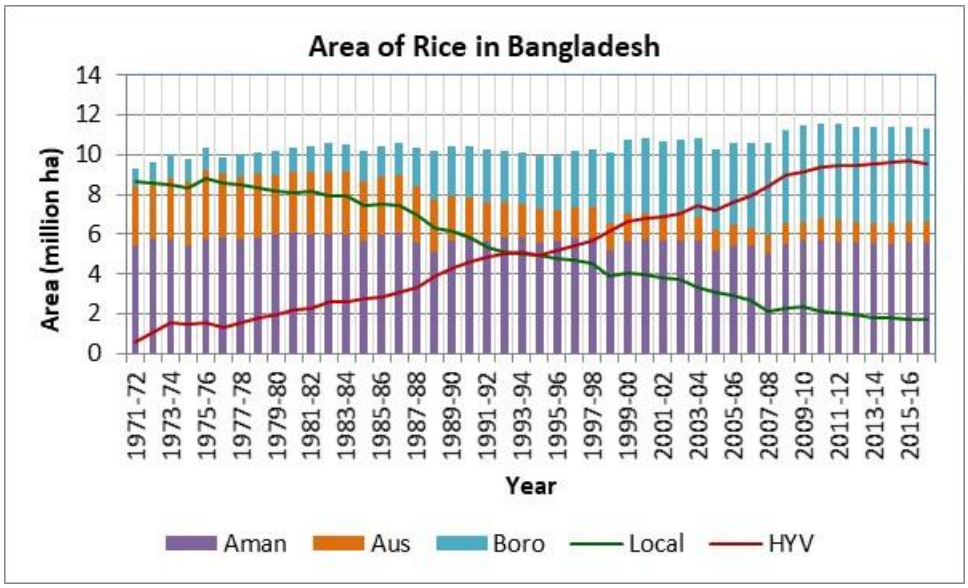

Figure 4: Area of rice in Bangladesh 1971-2016 (million ha)

Table 4: Crop area in million hectare

Sl	Crop Name	1972-73	1990-91	2000-01	2017-18	% Change
1	Local Aus	2.9	1.7	0.9	0.3	-89
2	HYV Aus	0.1	0.4	0.5	0.8	1036
	Total Aus	***2.9***	***2.1***	***1.3***	***1.1***	-64
3	LT Aman	3.3	2.9	2.1	0.3	-90
4	HYV Aman	0.6	2.0	2.8	1.1	94
5	Broadcast Aman	1.9	0.9	0.8	4.2	123
	Total Aman	***5.7***	***5.8***	***5.7***	***5.6***	-2
6	Local Boro	0.5	0.3	0.2	0.0	-94
7	HYV Boro	0.4	2.3	3.6	4.6	954
	Total Boro	***1.0***	***2.5***	***3.8***	***4.7***	375
	Total Rice Area	**9.6**	**10.4**	**10.8**	**11.3**	**18**
8	Other Cereals	0.2	0.6	0.8	0.8	271
9	Fiber	0.9	0.6	0.5	0.1	-84
10	Tobacco	0.0	0.0	0.0	0.0	-3

Sl	Crop Name	1972-73	1990-91	2000-01	2017-18	% Change
11	Sugarcane	0.1	0.2	0.2	0.1	-27
12	Potato	0.1	0.1	0.2	0.5	525
13	Oilseed	0.3	0.6	0.4	0.5	75
14	Pulses	0.3	0.7	0.5	0.4	21
15	Spices	0.1	0.1	0.3	0.3	113
16	Vegetables	0.2	0.2	0.3	0.4	147
17	Fruit	0.2	0.2	0.3	0.2	-25
	Total Non Rice Area	**2.5**	**3.5**	**3.4**	**3.3**	**34**
	Total Area	**12.1**	**13.9**	**14.2**	**14.6**	**21**

Water availability

Looking at one of the important resources, groundwater it can be seen that the level is declining day by day. In 1973 some areas of northwest region and a very few areas of north central region were found to be above 7m groundwater level. This situation is drastically changed in last six decades. At present, most of the areas of northwest and north central with some areas of south west in found where the groundwater level is above 7m.

The groundwater level data was collected from Bangladesh water development board (BWDB) from 1973-2012. The rest of the data, up to 2018, is on the process of collection. Besides this, Bangladesh Agricultural Development Corporation (BADC) and Department of Public Health Engineering (DPHE) has some data regarding groundwater level. The groundwater-zoning map shows the historical change in groundwater level of Bangladesh from 1973-2012.

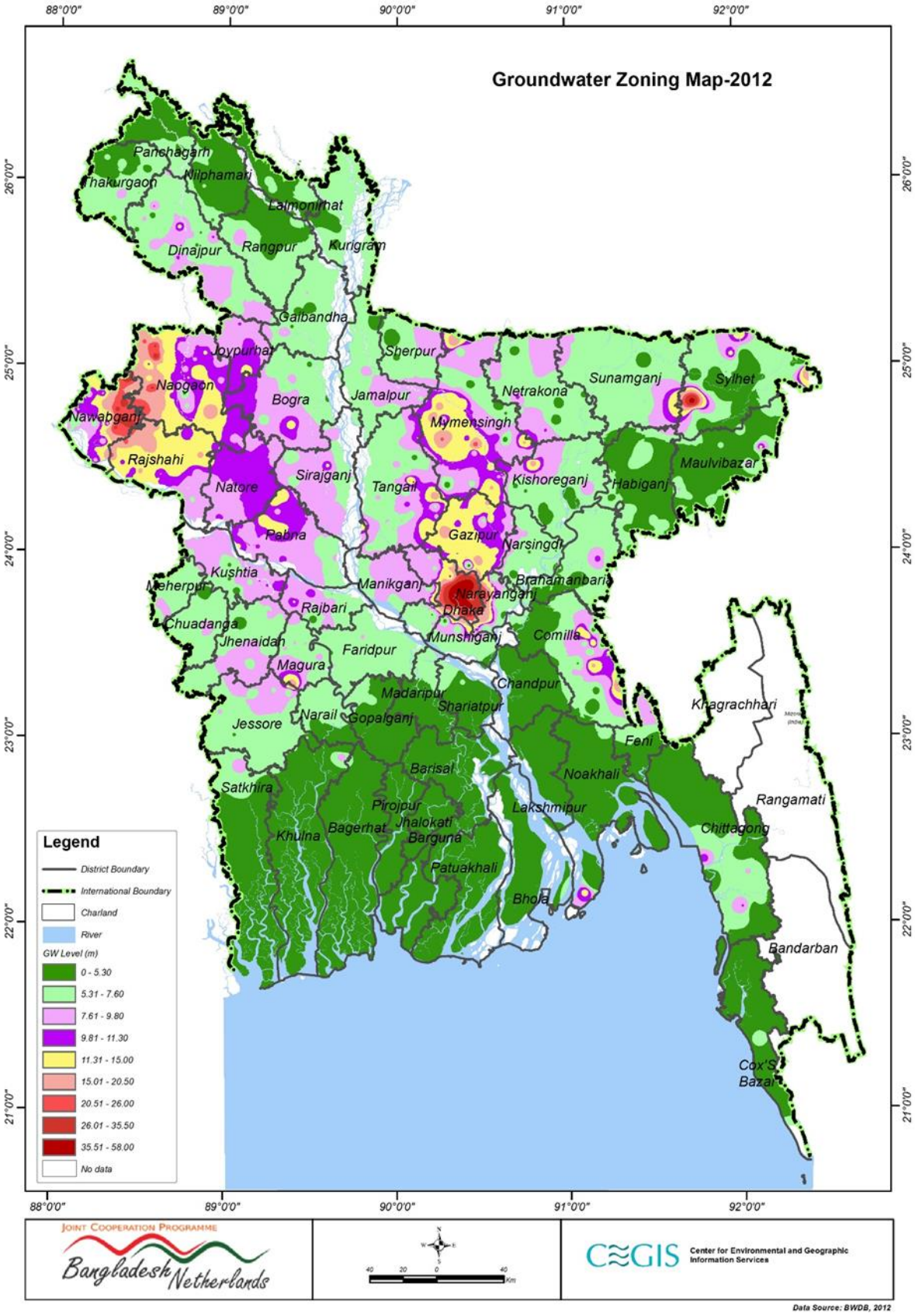

Figure 5 Groundwater zoning map 2012

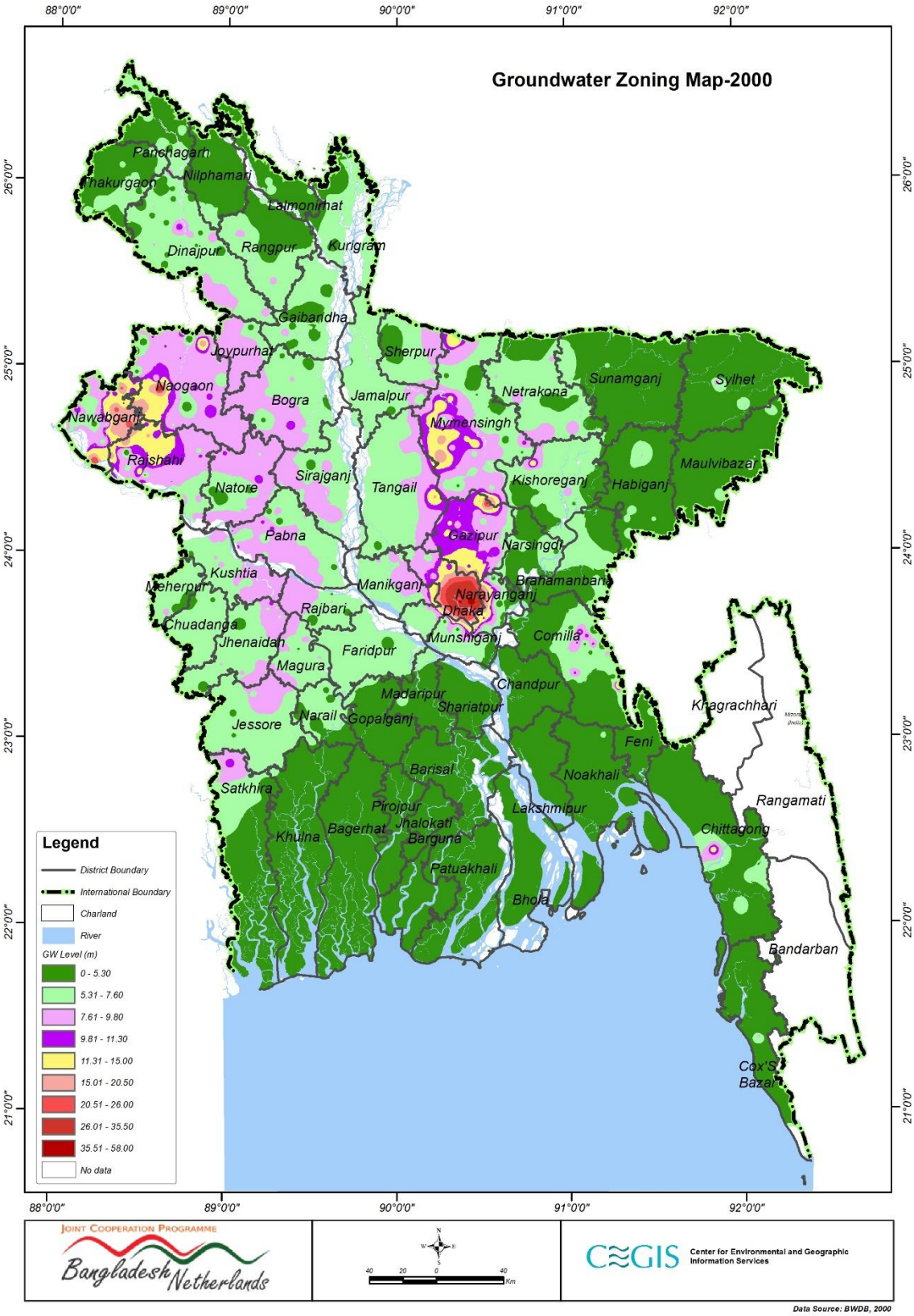

Figure 6 Groundwater zoning map 2000

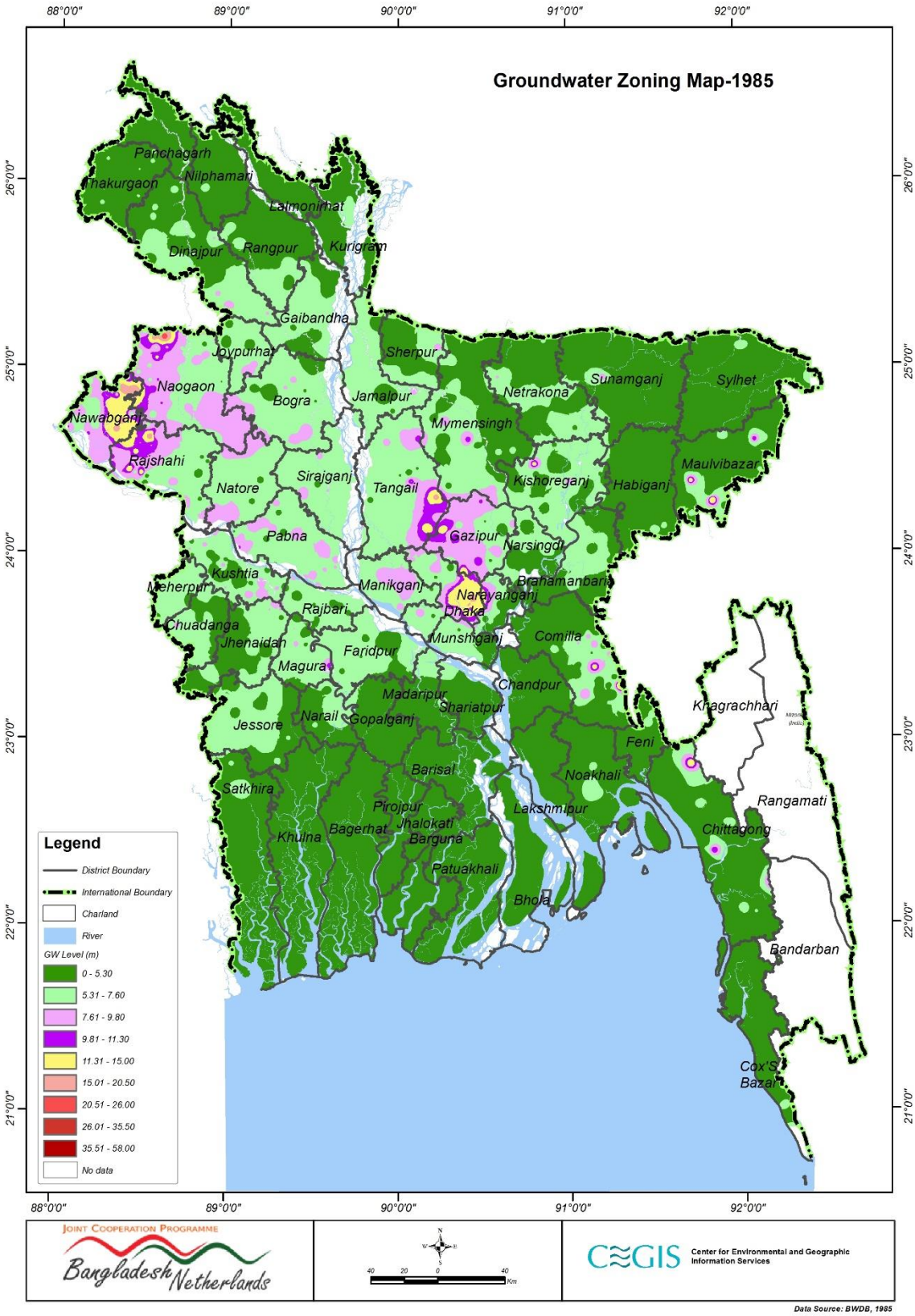

Figure 7 Groundwater zoning map 1998

5.2 Expert interviews factors

At the beginning of the project, a needs assessment was done. It was required to validate the methodology and determine the data availability. In this respect, one to one interviews were conducted with relevant experts. During these interviews, on the five major factors were mainly focused.

These are-

- Availability of water
- Change in crop choice
- Population growth
- Change of land use
- Dietary change pattern

The specific outcomes of the interviews are added as annex. In the annex the comments are arranged to the five factors. In this report the outcomes of the interviews are arranged to the five factors mentioned above. The table per factor shows the comments that were made by the experts. This is done give context to their comments. Moreover, the added comments of the experts that not fitted with one of the five factors are presented as it is valuable information. The comments are structured by first presenting the keyword of the comment and then the whole comment is added.

First the experts are presented followed by the outcomes sorted per factor than the extra comments are presented. and a summary of the interviews as closing.

The interview with experts was conducted from 12th September 2019 to 17th September, 2019. During this period total nine interviews was conducted with different sector experts. The list of experts with organization is presented below-

Table 1 *List of experts*

Sl No.	Name with Designation	Organization	Designation
01.	Dr. Md. Akram Hossain Chowdhury	Department of Agricultural Extension	Project Director (BARI innovated four cropping pattern technology extension)
02.	Engr. Md. Ferdousur Rahman	Bangladesh Agricultural development Corporation	Chief Engineer (Construction)
03.	Dr. Md. Munsur Rahman,	Institute of Water and Flood Management (IWFM), Bangladesh	Professor

		University of Engineering and Technology	
04.	Dr. G M Tarekul Islam	Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and Technology	Professor
05.	Dr. Kazi Matin U Ahmed	Department of Geology, University of Dhaka	Professor
06.	Dr. Wais Kabir	Krishi Gobeshona Foundation, Dhaka	Executive Director
07.	A. S. M. Shahidul Haque	Blue gold program, Bangladesh water development board	SVC Group leader, private sector development expert
08.	Dr. Nazmun Nahar Karim	Bangladesh Agricultural Research Council (BARC)	Principle Scientist
09.	Md. Amirul Hossain	Bangladesh Water Development Board (BWDB)	Director (Planning-III) & Program Coordinating Director (Blue Gold)

Table 2 Amount of comments related to the five factors

Factor	Number of interviews mentioning the factor (total 9 interviews)	Organizations answered
Population growth	1/9	DAE
Diet change	6/9	Department of Agricultural Extension Bangladesh Agricultural development Corporation Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and TechnologyKrishi Gobeshona Foundation, Dhaka Blue gold program, Bangladesh water development board Bangladesh Water Development Board (BWDB).
Crop change	5/9	Department of Agricultural Extension Bangladesh Agricultural development Corporation Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and TechnologyKrishi Gobeshona Foundation, Dhaka Blue gold program, Bangladesh water development board
Water availability	8/9	Department of Agricultural Extension Bangladesh Agricultural development Corporation Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and Technology

		Department of Geology, University of Dhaka Krishi Gobeshona Foundation, Dhaka Blue gold program, Bangladesh water development board Bangladesh Agricultural Research Council (BARC) Bangladesh Water Development Board (BWDB)
Land use change	5/9	Department of Agricultural Extension Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and Technology Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and TechnologyKrishi Gobeshona Foundation, Dhaka Blue gold program, Bangladesh water development board

As can be seen from table 2, the water availability has comments from most of the experts. This can be explained by the fact that the water factor consists out of 3 categories to comment on (grounwater,surface water and precipitation). The most professionals that we have been speaking to have affinity to one of the categories from water. The only one that did not answer on the water part was proffessor Tarekul Islam. The reason for this is not a clear one, it might be that the topic of the interview was more related to the nexus as this is his specialism.

The lowest mentioned factor is the population growth. This is only commented on by DAE. An explanation could be that the fact is well known to all the professionals that the population is growing and there are sufficient numbers to assume this fact.

Table 3 Outcome interviews for the factor population growth

	1	2	3	4	5	6	7	8	9
Population Growth	The population of the country is increasing day by day. Under this situation both, agricultural land and labour force is reduced. Farm mechanization and introduction of climate resistant adaptive varieties will be a concern of coming days	X	X	X	X	X	X	X	x

Table 4 Outcome interviews for the factor Diet change

	1	2	3	4	5	6	7	8	9
Diet change	Staple food of the country is rice. The water requirement of rice is high. Therefore, the government is trying to shift the crop choice and cropping time. First calculate the national food demand through diet analysis.	Bangladesh is self-sufficient for food in terms of quantity but not in terms of quality or nutritional value.	x	There is a change in the dietary pattern. Especially in urban and semi urban areas. As purchase power increased, people used to have more meat, egg, fish for their daily meal instead of rice	X	Increase of welfare and income leads to decrease of rice consumption. Therefore, the rice production will be scaled down in the coming years. People used to have more meat and vegetables in their daily diet. To feed more cattle and fowl, farmers have to grow more fodder (e.g. maize). This crop has long life span, which covers more than one season in cropping pattern.	Diet changes as income increased. Rice consumption is reduced whereas vegetable, meat and fish consumption increase.	x	The diet changes because of income increase. People used to take more fruit, fish and meats rather than rice. As a result, rice consumption is decreasing.

Table 5 Outcome interviews for the factor Crop change

	1	2	3	4	5	6	7	8	9
Crop change	Post monsoon little or no rain. This leads to dependence	Rice demand is 3.7 million m3 tons whereas we produce 3.9	x	There is also change in crop choices. For example in Gowainghat	x	Cropping pattern is changing because farmers are more desperate to	Water melon is becoming popular in the coastal area due its high return. But its water requirement	x	x

	on groundwater This shift of crop choice entails the shift to Aman rice (rainwater irrigation).	m3 metric tons. Potato demand and production is 0.47 million m3 tons and 1.1 million m3 tons respectively. Food demand will be 4.5 million metric tons in 2050 To adapt to the water availability a strategy could be to diversity crop varieties. For example. grow potatoes instead of Boro rice. Also, grow more orchard crops in hilly areas and high lands.		Upazila nearly 5000 ha land is taken under vegetable cultivation which is previously used for Boro rice cultivation. Besides this, fruits are also introduced in this area. Fruits are mainly grown for local consumption but vegetables have much export potential		maximize their production out of minimum land. Demand for non-rice crop is increasing as economic benefit is more of those crops. Instead of long life span rice crop mung bean, oil seeds and vegetables are more popular in recent days. But uncertainty of production, insufficient storage capacity, profit margin and proper market linkage for selling these crops farmers will remain on paddy production if water is available There are already short season and stress tolerant rice crops available. However, their yield is lower making them less attractive.	is high and very vulnerable. There are also high investment costs. Therefore, potential losses can be high. At this point farmers are still cultivating paddy rice. However changes are coming as people started to think economically and commercially.		

Table 6 Outcome interviews for the factor Water availability

	1	2	3	4	5	6	7	8
Water availability	Water availability high in monsoon season Climate will become more unpredictable. This is mainly because of the timing of the rain. Irrigation water losses are a problem in the North because of earth canals. This leads to high infiltration of the water. The gov. is supporting the switch to other type of irrigation (spinkler, buried pipe etc.)	Government tries to improve water efficiency through: 1.Low water demand crops (fruits, vegetables highland and maize in char areas) 2.Conveying system upgradation (more pipes and cementing open canals) 3.Awareness of water use For increasing water availability, water recycling is another concept. In Ashuganj and Palash, leftover power plant water is used for irrigation. This water is initially used for cooling purpose. However, in all cases, water pollution must be considered	x	Groundwater extraction increases due to solar power. This provides the farmers with free energy. Moreover, the government encourages the use of solar power. The groundwater becomes scarcer by the day. Therefore, the rivers and beels should increase the dependency of surface water.	Groundwater table is depleting in the Barind area. The government banned all use of deep tube wells. However, it is not enforced yet. Therefore, private installation is still happening. To manage the problems two immediate measure should be taken: - Consumptive use- maximum surface water and optimum ground water -Artificial recharge Underground taming of flood for irrigation (UTFI) might be introduced in the Barind area. As direct/natural recharge rate is low in that area. However, artificial recharge creates clog in the system, which makes harder to maintain.	When water availability will be sufficient, the farmers will still grow rice to ensure their food security. The water availability is decreasing new water technologies must be introduced, like rainwater harvesting. Groundwater depletion is not in the near future. Ground water might be replenished during monsoon every year or every alter year. Besides this, water demand for all aspects (industrial, domestic and crop production) should be calculated.	Water requirement is increasing and scarcity as well. Farmers are adapting by excavating ponds in rice fields which provide irrigation water during dry(Rabi) season. The same land is used for fish cultivation during monsoon. Vegetable is grown in the dykes of the ponds in monsoon.	Water use and deman might be reduced in two ways. Firstly, new technologie could be introduced (e.g. rain water harvesting, introductio of large pond in cro field etc); secondly, less water demand crops (pulse, oilseed, wheat, vegetables etc) might be cultivated instead of rice production

		for all management. Groundwater availability is 55,000 billion m3. 50% could be withdrawn without depleting the aquifers according to WARPO. At present "only" 18,000 billion m3 is withdrawn. From year to year it might seem that the groundwater is depleting, however on a larger time-scale it is stable. However if Industry will grow, there might be depletion of the groundwater resources Sufficient water available in monsoon season. Problems occur in dry season. Irrigation requirement is high 3-4 months a year (15th December until 30th of April). During this time, the groundwater is the only source.			Chemical properties of ground water is already changed in Barind area due to pollution and over exploitation.			

Table 7 Outcome interviews for the factor Land-use change

	1	2	3	4	5	6
Land-use change	Industrialization is also creating pressure on the agricultural land	X	Land tenure system creates problem in distributing the policies. Large farmers do not stay near to their lands. Therefore, their involvement is less than the small and marginal farmers that do live close to their lands. As a result, overall improvement slows down. May be land zoning will be a solution of this problem. Crop land, industrial zone and housing zone should be marked on it. Land ownership (per capita) limit might also be restricted by law.	At present, every year Bangladesh is losing nearly 1% of our agriculture land. Government already put restriction to protect the agriculture land. However, they should regulate with a strict hand.	X	Land tenure sy creates problem Barind area. La farmers and landowners us not engaged w farming. They somehow lease land to other p Therefore, adaptation and improvement o technologies a much difficult

Extra meeting minutes with Dr. Md. Akram Hossain Chowdhury:

- *Current developments:* Department of Agricultural Extension (DAE), Bangladesh meteorological department (BMD) and Bangladesh water development board (BWDB) combined preparing an agro meteorological forecasting app. Farmers will have the forecast for coming 7 days from this app. It will highly help them to make decision for sowing, transplanting and set time for irrigation.

Extra meeting minutes with Dr. Munsur Rahman:

- *Adaptation*: In Bangladesh, government relies on planned adaptation whereas local people rely on autonomous adaptation. The last one is quicker, less costly and more efficient (sometimes). Therefore, we must gather as much local knowledge as possible. Community based solution should be taken under consideration during planning for any policy or project.
- *Water quality*:In Barind area, groundwater level is low. Chemicals used in agriculture also pollute it. Alternative or artificial recharge of ground water might be a choice to resolve the problem. However, in this way pollution risk will be high.

- *Solutions:* A single solution might not satisfy water management of the whole country. Because Bangladesh has different water availability zone (e.g. Barind, Coastal area, Haors etc).

Extra Meeting minutes with G M Tarekul Islam:

- *Livestock:* Livestock sector is also increasing in the country as meat and milk products consumption is increased. Most of the dairy farms are growing their own fodder. Napier grass is very much popular in that community. Benefit of growing this grass is much better than growing paddy.

- In haor areas, harvesting of Boro rice is mostly depend on flash flood. In 2017, almost 220,000 ha readily harvested Boro crop is damaged due to early flash flood. To avoid this loss, scientists are introduce short lived rice varieties

Extra Meeting minutes with Dr Wais Kabir:

Government involvement: Government should provide support on storage, seeds and disease protection and quarantine. So that farmers will be attracted more to grow non-rice crop.

Extra Meeting minutes with A. S. M. Shahidul Haque:

- *Trade-off agriculture*: Agriculture-fish conflict/trade-off is very much visible in this area. Most of the cases, trade of controlled by local powerful person. Small farmers and women prefer agriculture for their security. Agriculture provides them food, cattle rearing area etc. Big farmer and landlords prefer fish culture due to its profit margin
- *Disasters:* In coastal area, frequency of disaster is very common. So small farmers are still rely on local varieties as its production cost is low and less labour is required. However, Government and NGO's promote HYV with improve varieties. They also create market linkage for farmers. So their profit margin is increased.
- *Seasonal migration:* Seasonal migration is very common in coastal area due to
    - Salinity intrusion
    - Commercial agricultural practice

Extra meeting minutes with Md. Amirul Hossain:

- *Polders:* Poldarization creates opportunities for coastal areas population. Farmers used to grow various type of crops inside the polders (e.g. tomato, sunflower, onion, ladies finger etc). Their main emphasis on watermelon production (one of their main cash crop in recent days). Besides this, mung bean and sesame are now considered as export crop. However, due to insufficient storage capacity crop choice variation is limited which ultimately reduces economy and production.
- *Canals blue gold project*: Water height and amount of silt is increasing. This way the canals become clogged and overflow of salt water sometimes occurred. Under the blue gold project, 119,000 ha land will come under cultivation under 22 polders of 4 district. Their main objective is to excavate the canals to maintain regular flow of water. This project will also help to replenish the ground water table.
- *Development coastal area:* On the other hand, coastal area is developed fast. Communication system and living condition are improving. Therefore, urbanization is occurred within the rural area. However there still might be some seasonal migration which is not noticeable yet.

Summary discussions:

The discussion might be summarized as there is plenty of water in monsoon in Bangladesh. During Kharif-I (post monsoon) and rabi (pre-monsoon) water requirement is high. More specifically water crisis is crated in three months from February to April. To overcome this situation, judicial water use is required. This might be done in two ways- introduction of low water required crops and installing new water efficient technologies. Besides this, rice production should be shifted to northwest to southern zone to reduce pressure on ground water. However, before that exact national rice consumption demand should be assumed by calculating dietary patterns with keeping in mind the future water availability and demand, population change and available agricultural land.

Lessons learned from interviews:

- Sufficient water in Bangladesh for the crops in Monsoon time
- During Kharif I and Rabi season water requirements are high, specifically February-April
- Rice production areas should be moved North West to reduce pressure on groundwater
- The start of the research should be calculating how much is needed for the population of Bangladesh

5.3 Discussion factors/data with participants

Dhaka water knowledge day was the main platform to discuss about the plans, methodology and data availability for modelling. The overall discussion was divided in two sessions-

Session-1:

After the inauguration, Mr. Rashid presented the present status of agriculture, diet change and related situations of Bangladesh. He also talked about the data availability and brief methodology of the project. After that Judit, present about the project. It covers plans, objective and scope of work.

Concluding to the first presentation the participants were asked to prioritize the factors where the most important focus was to quantify the water and food demand of the future population of Bangladesh. The participants divided in to two groups and each of them have three stickers to mark the highlight their priorities. The participants were asked to put the stickers which what they thought had the most importance regarding determining the water and food demand for the future.

The outcome of the prioritization is given in table 8. As can be seen the highest population growth (which was the lowest amount of comments in the interviews). However this was a different exercise than the interviews and therefore it might match the same outcomes, as it both points in the direction in a given fact that the population is growing. The lowest priority was given to the diet change. However, looking at our approach for calculating the demand, it is together with the population equally important for a starting point the calculations. The water availability matches the high amount of comments in the interviews and our approach for calculating the possible gap between demand and supply of the water.

Table 8 Sticker distribution factors

Factor	Number of stickers
Population growth	14
Water availability	13
Land use change	12
Cropping pattern change	10
Diet change	2

After the session a discussion was conducted. The participants mentioned they found it a complex situation in terms of future water-food nexus. Population growth is the major concern of the Bangladesh as it creates pressure on almost everything. It is also responsible for increasing food and water demand under decreasing agricultural lands. Dr. Akram argued that we should give more emphasis on crop choice and cropping time to conserve water. Dr. Karim give more importance on judicial use of water.

After the priority exercise, exercise two was conducted. This excise focussed on data collection. During this exercise, the participants are divided into five groups. Each group had three members. They are consulting about the data availability of five major concerns. After the discussion they percent their findings and suggestions for data availability. The outcomes are presented in table 9.

Table 9 Summary Data exercise

Question	Population Growth	Diet Change	Water Availability	Land Use Change	Crop Change
Source Data	1. Bangladesh Bureau of Statistics (BBS) 2. Bangladesh Institute of Development Studies (BIDS)	1. Household Income and Expenditure Survey (HIES) by BBS	1. Barind Multipurpose Development Authority (BMDA) 2. Bangladesh Agricultural Development Corporation (BADC) 3. Bangladesh Water Development Board (BWDB) 5. Bangladesh Meteorological Department (BMD) 6. Department of Agricultural Extension (DAE) 7. Water Resource Planning Organization (WARPO)	1. Food and Agriculture Organization (FAO) 2. Bangladesh Bureau of Statistics (BBS) 3. Soil Resources Development Institute (SRDI)	1. Bangladesh Bureau of Statistics (BBS) 2. Department of Agricultural Extension (DAE)
Scale Data	1. Upazila Level 2. District Level	1. BBS- National Level	National and District scale	FAO- Regional BBS and SRDI- Upazila	National to Upazila Level
Recorded Timeline of the data	1. The data available from 1974 to 2011. 2. Only population Projection (2014 report-upto 2050)	from 1991 to 2018	1990-2018	FAO-1961 to till date BBS- 1994-2018 (Online), 1973-1997 (Hard Copy)	1980-2016
Accessibility	Yes (data online from 1991)	Yes (online from 2010)	All data are not available in online. Some has to be purchased	FAO- Need to Buy BBS-PDF (online Version)	yeas

Quality of the data	Good	census data without giving any numerical value like percentage	Good to medium	Good	Reliable and Valid

As can be seen from table 9, the data varies in multiple ways. Again, the water availability has the highest number of sources of the data. This could be explained that the water availability includes three facets, groundwater, surface water and precipitation. Or another explanation is that most of our participants are water experts. The most detailed scale level is Upazila level and this data can be found for three factors: land use change, population growth and crop change. The biggest span of time is covered for land use change. This makes less sense then the second largest timespan factor which is population statistics. Population statistics are easy

A general lesson that can be learned is that the data varies in every way from scale until accessibility etc. When processing this data, it is important that the data is of high quality. To do so, the definition of high quality needs to be set by the team of experts. Therefore, it is necessary we develop for every factor a data requirement.

Session-2 Dhaka Water Knowledge days.

Session two was mainly organized to share the findings of two experts which will be helpful for our project. This session had as goal to reflect on our research in a broader context. The first professor shared his insights. He gave some insights on his work within the water-food-energy nexus. These can be summarized as the following:

In first presentation was taken by Dr. Tareq. The presentation is about water-food-energy nexus of Bangladesh. In this presentation, he tried to align water-food-energy with sustainable development targets. He argued that most of the time development is done on the cost of the environment. The mentioned three sectors have some tread off relations along with some common areas. The method of his study focussed on laws regarding water-food policies of Bangladesh and he tried to find out the gaps. They have done some questionnaires survey along with some future prediction through modelling. After that they done a network analysis where they tried to find out the inter-relationships between the sectors.

In second part of the same session, Dr. Samima Afroz presented her view on the blue gold implementation in the coastal region. In this session she presented the change of the coastal region due to blue gold implementation. This area was once unproductive due to salinity and water scarcity. But after the implementation of blue gold, farmers used to grow more than one crop in most of the areas. Even in some areas, cash crops (e.g. water melon, sunflower

etc) are introduced. In short, good market linkage, availability of water, fertilizer and seeds bring the fortune to these farmers, which is the visible effect of this project.

6 PLANNING 2020

To give a more complete overview what will be achieved on longer term, a year plan has been developed. The year plan is summarized in table xx.

Table 1 *Output 2020*

Output	Elaboration	Status	Deadline
Basic calculation of 2(or more) scenarios with excel	Provide basic calculations for the five selected factors with reliable data sources.	On-going	16th of January 2020
Underpinning model approach based on excel outcomes	Based on the outcomes of the excel file, the model choice will be explained. Moreover, the focus of the research and calculations will be explained with the selected model.	On-gong	23rd of January 2020
Running model with selected scenarios and review LPJml runs for Bangladesh	The modelling process will be started early 2020 and is expected to deliver some results before April 2020. Moreover, the available LPJml scenarios will be analysed during this time.	Not started	Before April 2020
Presentation of visuals basic calculations/ Progress project/feedback modelling scenarios		Not started	Second annual meeting JCP/ICSD4, February 2020
Local level consultations with farmers to assess the scenarios and validate outcomes modelling		Not started	April 2020
SWAP-WOFOST training in Wageningen (and possible interaction with LPJml)		Not started	June/July 2020
Training or Regional level assessment (top and mid-level professionals, at maximum 5 regional level workshops addressing BDP 2100 in all the hydrological regions.		Not started	September/October 2020
Intermediate report year 2020		Not started	25 December 2020

For the years, 2021 and 2022 are also activities planned. However, these are very much dependent on the outcomes of the year 2020. These are presented in the project plans.

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ANNEX I

Table 10 Table: Population of Bangladesh by district from 1991 to 2051

SL	Division	District Code	District	Census Population (million)			Projected Population (Million)			
				1991	2001	2011	2021	2031	2041	2051
1	Barisal	1004	Barguna	0.78	0.85	0.89	1.01	1.08	1.12	1.12
2	Barisal	1006	Barisal	2.21	2.35	2.32	2.78	3.09	3.35	3.54
3	Barisal	1009	Bhola	1.48	1.70	1.78	2.06	2.27	2.40	2.47
4	Barisal	1042	Jhalokati	0.67	0.69	0.68	0.78	0.84	0.87	0.88
5	Barisal	1078	Patuakhali	1.27	1.46	1.54	1.82	2.03	2.19	2.32
6	Barisal	1079	Pirojpur	1.06	1.10	1.11	1.27	1.36	1.40	1.41
7	Chittagong	2003	Bandarban	0.23	0.30	0.39	0.47	0.53	0.58	0.62
8	Chittagong	2012	Brahmanbaria	2.14	2.38	2.84	3.62	4.31	5.00	5.68
9	Chittagong	2013	Chandpur	2.03	2.24	2.42	2.93	3.30	3.61	3.86
10	Chittagong	2015	Chittagong	5.30	6.54	7.62	8.99	9.81	10.30	10.47
11	Chittagong	2019	Comilla	4.03	4.59	5.39	6.56	7.44	8.18	8.77
12	Chittagong	2022	Cox's Bazar	1.42	1.76	2.29	2.98	3.58	4.16	4.73
13	Chittagong	2030	Feni	1.10	1.21	1.44	1.75	1.97	2.15	2.30
14	Chittagong	2046	Khagrachhari	0.34	0.52	0.61	0.74	0.83	0.91	0.96
15	Chittagong	2051	Lakshmipur	1.31	1.49	1.73	2.22	2.63	3.02	3.42
16	Chittagong	2075	Noakhali	2.22	2.57	3.11	3.80	4.35	4.80	5.18
17	Chittagong	2084	Rangamati	0.40	0.53	0.60	0.69	0.75	0.78	0.79
18	Dhaka	3026	Dhaka	5.84	8.62	12.04	13.80	14.78	15.29	15.32
19	Dhaka	3029	Faridpur	1.51	1.74	1.91	2.20	2.38	2.48	2.52
20	Dhaka	3033	Gazipur	1.62	2.02	3.40	4.05	4.36	4.53	4.56
21	Dhaka	3035	Gopalganj	1.06	1.15	1.17	1.35	1.46	1.53	1.56
22	Dhaka	3048	Kishoregonj	2.31	2.56	2.91	3.65	4.30	4.92	5.54

SL	Division	District Code	District	Census Population (million)			Projected Population (Million)			
				1991	2001	2011	2021	2031	2041	2051
23	Dhaka	3054	Madaripur	1.07	1.13	1.17	1.39	1.56	1.69	1.80
24	Dhaka	3056	Manikganj	1.18	1.30	1.39	1.64	1.79	1.92	2.00
25	Dhaka	3059	Munshiganj	1.19	1.29	1.45	1.67	1.80	1.87	1.89
26	Dhaka	3067	Narayanganj	1.75	2.17	2.95	3.49	3.79	3.96	4.00
27	Dhaka	3068	Narsingdi	1.65	1.90	2.22	2.69	3.02	3.29	3.50
28	Dhaka	3082	Rajbari	0.84	0.95	1.05	1.20	1.29	1.34	1.35
29	Dhaka	3086	Shariatpur	0.95	1.08	1.16	1.39	1.56	1.71	1.83
30	Dhaka	3093	Tangail	3.00	3.26	3.61	4.11	4.38	4.52	4.53
31	Khulna	4001	Bagerhat	1.43	1.52	1.48	1.68	1.78	1.83	1.84
32	Khulna	4018	Chuadanga	0.81	1.01	1.13	1.30	1.38	1.42	1.42
33	Khulna	4041	Jessore	2.11	2.47	2.76	3.18	3.39	3.49	3.49
34	Khulna	4044	Jhenaidah	1.36	1.57	1.77	2.11	2.31	2.47	2.58
35	Khulna	4047	Khulna	2.01	2.36	2.32	2.65	2.82	2.90	2.89
36	Khulna	4050	Kushtia	1.50	1.74	1.95	2.32	2.54	2.71	2.82
37	Khulna	4055	Magura	0.72	0.82	0.92	1.09	1.21	1.29	1.36
38	Khulna	4057	Meherpur	0.49	0.59	0.66	0.75	0.79	0.81	0.81

ANNEX II INTERVIEWS

Interview I

Dr Akram:

In Bangladesh, plenty of water is available during monsoon (cropping season, Kharif-II). However, in Rabi season (post monsoon) little or no rain is occurred. Under this situation, a vast area required irrigation, which is mostly dependent on ground water. As the staple food of the country is rice, which water requirement is very high, government of Bangladesh is trying to shift the crop choice and cropping time. It means national rice demand will mostly be meet up by Aman rice, which is mainly produced by rainwater irrigation.

Moreover, GOB is also planned to shift the rice producing zone from north-west (barind area) to south (coastal zone) to reduce pressure on ground water.

To execute the plan, national demand should be calculated first through dietary pattern analysis. After estimating the exact amount. Maximum Boro rice production limit would be set. In this wayt Boro rice cultivation area will be reduced and water consumption will scale down. The left over lands in Rabi season might be used for other crops.

Climate become more unpredictable in Bangladesh. Although total rainfall amount is not changed but the timing is uncertain. Therefore, vulnerability increases. Due to less water availability, impact of climate change and less return from rice; orchard crops gaining popularity among the farmers of northern (barind) area in recent days. New orchard crops (dragon fruits, capsicum etc) is introduced with traditional orchard crops (mango, litchi, guava etc).

Irrigation water loss is a major concern in northern area. Most of the distribution canals area made up of earth where water is very high. To reduce the loss new water efficient irrigation technologies (sprinkler, buried pipe, farrow etc) might be introduced to farmer level for precise use of water. Initial cost for these kind of irrigation technologies are much higher. So that farmers are less attracted to these. However, in long run the overall cost is less. Government is subsidizing to some extent.

Department of Agricultural Extension (DAE), Bangladesh meteorological department (BMD) and Bangladesh water development board (BWDB) combined preparing an agro meteorological forecasting app. Farmers will have the forecast for coming 7 days from this app. It will highly help them to make decision for sowing, transplanting and set time for irrigation. However, predicting for more than a month or for a whole season is difficult due to involvement of a number of different factors.

The population of the country is increasing day by day. On the other hand, industrialization is also creating pressure on the agricultural land. Under this situation both, agricultural land and labour force is reduced. So farm mechanization and introduction of climate resistant adaptive varieties will be a concern of coming days.

Interview II

Meeting minutes with Engr. Md. Ferdousur Rahman

Bangladesh is self-sufficient for food in terms of quantity but not in terms of quality or nutritional value. At present, rice demand is 3.7 million Metric tons whereas we produce 3.9 million metric tons. Potato demand and production is 0.47 million metric tons and 1.1 million metric tons respectively.

Food demand will be 4.5 million metric tons in 2050. At present, more than 1.4 million irrigation equipment is running in Bangladesh. Government is trying to improve water use efficiency through-

- Introducing low water demand crop (fruit and vegetables in highlands, maize in char areas)
- Conveying system upgradation (introduce more underground pipes and cementing open canals)
- Awareness (farmers has a tendency to reduce irrigation cost. more irrigation means more consumption of electricity or diesel which ultimately use more cost)

Annual rainfall of Bangladesh is around 2250 mm. Besides this, we have 230 rivers. So there is plenty of water available in the country for Kharif-I and Kharif-II. The problem stands for Rabi season. Irrigation requirement is high for 3 to 4 months (15th December to 30th April). Among these months, February to April is the driest part with high crop water requirement. In this time ground water is this only source of irrigation in most of the areas. Water management might be done by diversifying crop varieties. In Rabi season, we can introduce low water demand vegetables instead of potato and boro rice. Besides this, orchard crops (mango, banana, strawberry, dragon fruits etc) might be introduced in hilly areas and high lands.

According to WARPO (1990), Bangladesh has roughly 55,000 billion cubic meter water reserve in its aquifers of which 50% might be withdrawaled every year without hampering the system. At present, total water withdrawal for irrigation purpose is nearly 18000 billion cubic meter. Which is well below the marked zone.

Every year ground water table data says that water table is somehow depleting. But this data might be misleading. If we see the time series data overall water table stays in similar condition. Basically we have enough water for present and future irrigation but if we consider the industrial growth the scenario will be changed.

But some water scarcity is already starts in some areas (Sapahar, Gomostapur, Nachole, Porsha) during dry season. This might be because of over extraction of ground water. But this situation is changed in monsoon and pre monsoon season. Water scarcity is also familiar in city areas (e.g. Dhaka, Chattogram, Narayanganj, Narsingdi, Gazipur etc). Ground water is scarce day by day. To resolve this problem, government has a plan to divert regional rivers (Jamuna and Meghna) water to cities.

As our water availability is fixed we must have to go for more efficient water use by introducing new technologies and low demand water crop varieties. Water recycling is another concept. In Ashuganj and Palash, leftover power plant water is used for irrigation. This water is initially used for cooling purpose. However, in all cases, water pollution must be taken into account for all kind of management.

Interview III

Meeting minutes with Dr. Munsur Rahman:

In Bangladesh, government rely on planned adaptation whereas local people rely on autonomous adaptation. The last one is quicker, less costly and more efficient (sometimes). So we have to gather as much local knowledge as possible.

Local adaptation has number of alternatives by their indigenous knowledge which is increase with time. Community based solution should be taken under consideration during planning for any policy or project.

In Barind area, ground water level is not only down it is also contaminated by chemicals used in agriculture. Alternative or artificial recharge of ground water might be a choice to resolve the problem. But in this way pollution risk will be high.

Our dietary pattern is changed so rice requirement will be decreased in coming days. So crop choice and water demand will be changed. A single solution might not satisfy water management of the whole country. Because Bangladesh has different water availability zone (e.g. Barind, Coastal area, Haors etc)

Land tenure system creates problem in distributing the policies. Large farmers are not stay near to land. They are not willing to spend money to improve the situation. Small and marginal farmers have not enough money to support new technologies. As a result, overall improvement slows down. May be land zoning will be a solution of this problem. Crop land, industrial zone and housing zone should be marked on it. Land ownership (per capita) limit might also be restricted by law.

Interview IV

Meeting minutes with G M Tarekul Islam:

New dimension of ground water extraction is started with the introduction of solar power. As farmers has not to pay for this and solar power is encouraged by the government. So this water extraction is not considered yet. As Ground water is scarce day by day, so dependency on surface water should be increased. Surface water storage could be increased by excavating the rivers and beels.

In haor areas, harvesting of Boro rice is mostly depend on flash flood. In 2017, almost 220,000 ha readily harvested Boro crop is damaged due to early flash flood. To avoid this loss, scientists are introduce short lived rice varieties. Change is crop choice is also occurred in some places. In Gowainghat Upazila nearly 5000 ha land is taken under vegetable cultivation which is previously used for Boro rice cultivation. Besides this, fruits are also introduced in this area. Fruits are mainly grown for local consumption but vegetables have much export potential.

Dietary pattern change all through the country. Especially in urban and semi urban areas. As purchase power increased, people used to have more meat, egg, fish for their daily meal instead of rice. Livestock sector is also increasing in the country as meat and milk products consumption is increased. Most of the dairy farms are growing their own fodder. Napier grass is very much popular in that community. Benefit of growing this grass is much better than growing paddy.

At present, every year we are losing nearly 1% of our agriculture land. Government is already put restriction to protect agriculture land. But this should maintain strictly

Meeting minutes with Dr. Kazi Matin Uddin Ahmed:

Ground water table is surely depleting in barind area. Government ban all kind of DTW installation in that area through policy. But still not enforcing it. So private installation is still going on. In earlier days, no rules were followed to install DTW which creates tremendous pressure on water table. To manage this problem two immediate measures should be taken-

- Consumptive use- maximum surface water and optimum ground water
- Artificial recharge.

Underground taming of flood for irrigation (UTFI) might be introduced in the barind area. As direct/natural recharge rate is low in that area. But artificial recharge creates clog in the system which makes harder to maintain.

Chemical properties of ground water is already changed in barind area due to pollution and over exploitation.

Interview V

Meeting minutes with A. S. M. Shahidul Haque:

Mr. Haque is also an expert of coastal zone of Bangladesh. According to him, agriculture-fish conflict/tradeoff is very much visible in this area.Most of the cases, trade of controlled by local powerful person. Small farmer and women prefer agriculture for their security. Agriculture provides them food, cattle rearing area and so on. Big farmer and landlords prefer fish culture due to its profit margin.

In coastal area, frequency of disaster is very common. So small farmers are still rely on local varieties as it's production cost is low and less labour is required. But Government and NGO's promote HYV with improve varieties. They also create market linkage for farmers. So their profit margin is increased.

Water melon is becoming popular in the coastal area due its high return. But its water requirement is high and very much prone to disaster. Cost involvement is also very high. So loss is also high. But still farmers will go for paddy cultivation if enough water is available. But changes are coming as people started to think economically and commercially.

As water requirement is increasing and water become scarce day by day, farmers are started to adapt with the situation. They started to excavate pond in rice fields which provide irrigation water during rabi season. The same land is used for fish cultivation during monsoon. Vegetable is grown in the dykes of the ponds in monsoon.

Land tenure creates another problem. Most of the cases, big farmer and landlords are not stay in the area due to frequent disaster. Small farmers and leftover guys show less interest to take risk to introduce new varieties and technologies. Cost involvement is also a big issue in this case.

Seasonal migration is very common in coastal area due to

- Salinity intrusion
- Commercial agricultural practice

Dietary change is occurred as income increased. Rice consumption is reduced whereas vegetable, meat and fish consumption increases.

Interview VI

Meeting minutes with Dr. Nazmun Nahar Karim:

Dr. Karim mainly emphasize on the judicial use of water. Water use and demand might be reduced in two ways. Firstly, new technologies could be introduced (e.g. rain water harvesting, introduction of large pond in crop field etc); secondly, less water demand crops (pulse, oilseed, wheat, vegetables etc) might be cultivated instead of rice production.

Interview VII

Meeting minutes with Md. Amirul Hossain:

Mr. Hossain is the PD of blue gold project implemented in coastal areas of Bangladesh. His main emphasis on the change in water-food balance in coastal areas of Bangladesh.

Poldarization creates opportunities for coastal areas population. Farmers used to grow various type of crops inside the polders (e.g. tomato, sunflower, onion, ladies finger etc). Their main emphasis on water melon production (one of their main cash crop in recent days). Besides this, mung bean and sesame are now considered as export crop. But due to insufficient storage capacity crop choice variation is limited which ultimately reduces economy and production.

Climate change creates problem in coastal area. Irregular pattern of rainfall creates problem in cultivation. Last year water melon productivity is reduced due to untimed rainfall. Besides this, water height and amount of silt is increasing. So that the canals become clogged and overflow of salt water sometimes occurred. Under the blue gold project, 119,000 ha land will come under cultivation under 22 polders of 4 district. Their main objective is to excavate the canals to maintain regular flow of water. This project will also help to replenish the ground water table.

Due to income generation dietary pattern is change in coastal area. People used to take more fruit, fish and meats rather than rice. As a result, rice consumption is decreasing. On the other hand coastal area is developed fast. Communication system and living condition is improved. So that urbanization is occurred within the rural area. But still there might be some seasonal migration which is not noticeable yet.

The discussion might be summarized as there is plenty of water in monsoon in Bangladesh. During Kharif-I (post monsoon) and rabi (pre-monsoon) water requirement is high. More specifically water crisis is crated in three months from February to April. To overcome this situation, judicial water use is required. This might be done in two ways- introduction of low water required crops and installing new water efficient technologies. Besides this, rice production should be shifted to northwest to southern zone to reduce pressure on ground water. But before that exact national rice consumption demand should be assumed by calculating dietary patterns with keeping in mind the future water availability and demand, population change and available agricultural land.

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Annex 1 Titel bijlage