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Agricultural interventions and investment options for climate change in drought and saline-flood prone regions of Bangladesh

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Summary:
 Rice is the staple food in Bangladesh and crucial for the food security in the country. The alluvial soil deposits, through an extensive river network across Bangladesh, have contributed to a fertile land with high rice productivity potential. However, the frequent occurrence of floods, salinity and drought has repeatedly threatened the food security especially in the rural areas. Climate change is anticipated to aggravate the frequency and intensity of extreme weather events in Bangladesh by significantly impacting rice production. Noteworthy studies have proposed potential responsive measures by concentrating either on the technical or economic efficiency of the suggested interventions. To this end, the current report presents an outranking multicriteria approach enriched with a Geometrical Analysis for Interactive Assistance for a better reflection of the appropriate interventions to improve rice production on a farm basis. Further, the investment options needed to implement these interventions are explored. The drought prone areas of Rajshahi and saline prone areas of Barisal regions were chosen for the study. The results indicated that water storage systems were prioritized in Rajshahi whereas the introduction of improved varieties in Barisal was of the highest importance. Also, the training seminars for farmers were deemed as a rather significant intervention for both regions.

<i>Land/Country:</i> <i>Fylke/County:</i>	Bangladesh Rajshahi Barisal Regions
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1. Introduction

Recent studies indicate that Bangladesh is undergoing a rapid economic growth, which is mainly attributed to the manufacturing sector (FAO, 2012) by setting aside the economic significance of agriculture. However, 80% of rural population in the country is heavily dependent on agriculture while rice is the staple crop particularly for marginal and small farmers (Islam, 2008). It is estimated that rice occupies almost 77% of the cropped areas, employs 65% of the country's labor force and provides around 95% of the whole food grain production and consumption. The continuous technological and institutional advancements in rice cultivation have contributed to almost a threefold increase in the production during the last four decades (BBS, 2011).

Rice production has been repeatedly threatened by natural disasters like flood, salinity and droughts mainly influenced by the country's unique geophysical and climatic conditions (Nienke et al. 2006). The mountainous ranging of the Tibetan Plateau is drained through a massive river network spreading all over Bangladesh and finally ending up in the Bay of Bengal. The occurrence of intense monsoonal periods often augments the drainage effects leading to floods mainly in the southern lowland areas (World Bank, 2010). Additionally, saline intrusions are noticed in the south downstream areas, which are attributed to the higher sea level elevation in the coastlands. On the other hand, less rainfall along with its uneven distribution and high evaporating losses in the northwest Bangladesh have entailed seasonal drought events with severe impacts on marginal rice farmers (Ramamasy and Bass, 2007).

The extreme events are anticipated to get aggravated by climate change as repeatedly noted in the literature (Nguyen, 2006; Biswas et al. 2009; Winston et al. 2010). The snow melting in the mountainous areas of the Tibetan Plateau coupled with erratic and intense monsoons are expected to constitute the driver for increased flooding. Also, the delayed monsoon conditions and the higher sea level intrusion are probable to lead in more frequent drought and salinization effects (MoEF, 2009; Winston et al, 2010). The rice production will inevitably incur significant losses from the extreme weather by threatening the food security status of the country.

The responsive measures for the sustenance of sufficient rice production are mainly technical or economic in nature (Wassman et al. 2009; Sidker, 2010). The technical studies are mostly focused on the introduction of water storage practices, land mechanization and conservation techniques to increase agricultural productivity (FAO, 2010; Basak, 2011). On the other hand, the economic analyses are concentrated on the cost-effective allocation of agricultural inputs for the maximization of the net revenues (profit) from rice production (Pandey et al. 2007; Islam and Mechler, 2007; Islam 2011). Both approaches though, adopt single technical or economic criteria, which assess through complete-trade off conditions, different interventions for the attaining of the most efficient solution (Huq et al. 2003; Ranjan, 2010). A similar

assumption is also applied in more sophisticated modeling tools based on general equilibrium analysis and multi-objective programming principles (Debertin, 2012).

It is however anticipated that a considerable loss of information occurs when a single-criterion assessment is employed to solve the multi-dimensional problem of rice production sustenance, which essentially reflects the food security of Bangladesh (World Bank, 2000). To this end, the current study proposes a multi-criteria outranking based approach for the assessment of agricultural interventions to tackle climate change effects in Bangladesh. Further, the implementation and up-scaling of the assessed interventions is scrutinized. The assessment process was applied through an on-line survey to experts in the rice farming of Bangladesh with familiarity to the climate change effects in the country. The study sites of Rajshahi and Barisal divisions were selected as representatives of drought and saline prone conditions, respectively.

2. Methodology

2.1 Interventions and Criteria

The proposed methodology initially classifies the most significant interventions according to the relevant literature, local experts and field visits in the study areas¹. The interventions suggested were based on already applied measures, which were deemed to improve agricultural productivity against climate change in Bangladesh when adopted at the farm level. Six different groups of interventions were classified as namely the land and water mechanization, the introduction of water storage schemes, improved/hybrid varieties, pest and disease control systems and training seminars. Each group represented various individual interventions, which could however suggest different performance when applied. All the interventions were equally assessed for both the Rajshahi and Barisal divisions except for the case of the improved/hybrid varieties. For this group, different types of varieties were indicated for the saline and drought conditions of the two areas. Below in Table 1, the following six categories are presented:

Table 1. Groups and attributes of the Suggested Interventions

Intervention Groups						
Water Mech.	Land Mech.	Water Stor.Sch.	Pest and Dis. Contr. Systems	Improved/Hybrid Seeds		Training Seminars
				Barisal	Rajshahi	
Individual Interventions						
Sprinkle irrigation	Power Tiller (hand tractor)	Deep Tubewell	Physical Pest and Disease Control	BR22	BINA dhan 7	Transplanting and Direct Sowing
Drip Irrigation			Biological Pest and Disease Control	BRR1 dhan40	BRR1 dhan49	Surface and Groundwater management
High lift mechanical pump	Thresher	Shallow Tubewell	Chemical Pest and Disease Control	BRR1 dhan41	BRR1 dhan56	
	Weeding Machine			Blocked Canal*	BRR1 dhan44	BRR1 dhan57
Low lift mechanical pump	Seeding Machine	Blocked Canal*	Integrated Pest and Disease Management		BRR1 dhan46	Sawrna
	Transplanting machine			Pond	BRR1 dhan53	Guti Sawrna
Hand-Pump					BRR1 dhan54	

*Blocked canal is the practice where farmers attempt to store fresh water (either rain or river depending on time suitability) for irrigation in dry periods. The canal blocking is made through natural items (i.e. soil, wood, rocks etc.). Note: Water Mech.=Water Mechanization Systems, Land Mech.=Land Mechanization Systems, Water Stor.Sch.=Water Storage Schemes, Pest and Dis. Contr. Systems= Pest and Diseases Control Systems, Impr./hyb.= Improved/Hybrid varieties

¹ The authors have conducted a field visit to selected saline prone districts in Barisal Division in February 2012, while another field visit was arranged in October 2012 to Rajshahi division in drought prone districts.

Then, a number of agronomic and socio-economic criteria were established. The adopted criteria were traced in the relevant technical and economic studies (Wassman et al. 2009) while the contact with local farmers along the field visits better clarified the appropriateness of each criterion. Namely, the marginal net revenues (marginal profit), the marginal water and land productivity and the sense of food security of farmers for their production were the four criteria for assessment. The marginal factor was adopted instead of the average or total measurements as dominantly occur when seeking technical or economic efficiency options (Debertin, 2012). The criteria to assess the aforementioned interventions were presented together to the surveyed respondents with an explanatory note as below:

Table 2. Criteria for the assessment of the suggested interventions

Criteria	Explanatory Note
Marginal Profits per kilo of rice (Tk/kg)	The marginal profit is the additional amount of net revenues earned by a farmer for one more kilo of rice production, e.g. USD 0.25 \$ / kg
Marginal Water Productivity (kg/m ³)	The marginal water productivity is the additional amount of rice produced by one more cubic meter of water e.g. 0.3 kg/m ³
Marginal Land Productivity (kg/ha)	The marginal land productivity is the additional amount of rice produced by one more hectare of land e.g. 3,500 kg/ha
Sense of food security	The sense of food security is interpreted as that the farmer can earn at least daily income equal to the poverty threshold in Bangladesh (USD 1.25\$/day) through the use of the suggested farming intervention

A number of experts were invited to participate in an online survey, where they were asked to evaluate the group of interventions on each of the criteria selected. Before entering the survey, representative farming features for rice farms in Barisal and Rajshahi divisions were presented as stated by the Bangladesh Bureau of Statistics for the year 2010 (Figure 1). These features were deemed to help in a better judgment of the proposed measures.

Experts' views for Climate change adaptation measures in rice farming



Dear Expert,

Before entering the survey, we present the **representative farming features** for rice farms in Barisal and Rajshahi Divisions as stated by the **Bangladesh Bureau of Statistics** for the year 2010 which may help you to better judge the **proposed measures** of the survey.

Rice Farm Features	Barisal Division	Rajshahi Division
Land Farm (in acres)	1,23	1,38
Irrigated area (% of land)	20%	83%
Cropping Intensity (in %)	180%	191%
Total Rice cultivated (% in farm)	Aus 22%, Aman 51%, Boro 27%	Aus 18%, Aman 39%, Boro 43%
Total seeds (% in farm)	Local 71%, HYV 16%, Hybrid 13%	Local 21%, HYV 68%, Hybrid 11%
Total Fertilizers (in kg/ha)	UREA 132kg/ha, TSP 92 kg/ha, MP 56 kg/ha	UREA 149kg/ha, TSP 99 kg/ha, MP 62 kg/ha
Land Machinery Used (% of land)	1%	2%
Soil Types	Acid sulphate-Clay Loam	Silty Clay Loam

Please **proceed** with the survey by clicking the "Next" button below

Load unfinished survey

Next ▶

Exit and clear survey

Figure 1. Data provided to experts in the on-line survey

For each criterion, the respondents were asked to make a dual selection. First, the most suitable intervention group to improve the relevant criterion was chosen. Once the group was selected, a follow-up question appeared in which the respondents should rank the particular interventions within the chosen group to improve each criterion's performance. An example of the Improved/Hybrid Seeds group and Water Productivity criterion is presented in Figure 2 for the drought prone Rajshahi region.

*** 4. Which of the following group of measures could better improve the Marginal Water Productivity (kg/m^3) for a farmer in Rajshahi Division for the year 2012?**

Choose one of the following answers

Improved and Hybrid Seeds (Sawma, Bina dhan 7, etc.)

? The marginal water productivity of rice cultivation is the highest amount of rice produced by an additional cubic meter of water e.g. $0.5 \text{ kg}/\text{m}^3$

You have chosen Improved and Hybrid Seed Varieties! Now please rank the importance of the specific interventions as below:

Double-click or drag-and-drop items in the left list to move them to the right - your highest ranking item should be on the top right, moving through to your lowest ranking item.

Please select at least 2 answers

Your choices	Your ranking
Other	Bina dhan 7
None of the recommended	BRRi dhan 56
	Guti Sawma
	BRRi dhan 57
	BRRi dhan 49
	Sawma

Resume later Previous Next Exit and clear survey

Figure 2. Example of agricultural intervention selection for Rajshahi region

2.2 Visual Promethee structure

The assessment of the suggested interventions was conducted through the Visual Promethee software which constitutes a combination of PROMETHEE outranking method with Geometrical Analysis for Interactive Assistance (GAIA).

The outranking methods have been proposed as an alternative to single-criterion economic tools like Cost-Benefit Analysis (Roy, 1996) or to Multi-Attribute Utility theory (MAUT) approaches (Roy, 1991). The outranking methods still seek for the Pareto-optimality condition where a dominant and efficient solution should be identified as dictated in the Cost Benefit Analysis and utility based approaches (Roy, 1996; Brans and Mareschal, 2005; Diakoulaki and Karangelis, 2007). However, the introduction of preference conditions through a pairwise comparison between interventions attempts to avoid the complete trade-offs among a set of different criteria.

The Visual Promethee encourages the introduction of weighting coefficient for a better attribution of the significance of each criterion. In the current analysis, the weights are introduced by the respondents through the on-line survey. We suppose that the weights are normalized in such a way that their sum is equal to 1 (100%) as occurs in Promethee outranking methods (Mareschal, 2013). The introduction of GAIA in Visual Promethee was added as a diagrammatic component for the identification of potential conflicts and alliances between criteria. The GAIA is based on the Principal Component Analysis, which is a mathematical tool from applied linear algebra (Shlens, 2003; Farag and Elhabian, 2009). The analysis is a relatively simple non-parametric method for extracting relevant information from complicated data sets. The approach followed is the simplification of the data to a lower dimension analysis through a covariance or correlation computation depending on the nature of the data sets. The GAIA is based on covariance analysis for the identification of the relations between the criteria and the interventions selected in each case.

2.3 Data and Surveying process

The data for the assessment of the selected interventions were elicited through an on-line survey to experts on rice farming in Bangladesh with considerable knowledge on the anticipated climate change effects in the country. The selection process was based on the publication record of the experts, the involvement in relevant research or development projects and the recommendations from local partners.

An invitation letter was initially sent to 100 experts from international organizations & NGOs, national research institutes & NGOs, national-international universities and Bangladeshi public administration bodies. Throughout the selection process it was ascertained that the highest amount of invitations was sent the international organizations and national research institutes due to the higher publication record and involvement in relevant projects. A reminder of the invitation letter was sent out about a week later.

3. Results

3.1 Response Rate

The amount of 41 responses was collected in total while the average response time was estimated at 28 minutes per survey. A classification of the respondents' professional background was shaped as below:

Table 3. Professional background of Survey respondents (about here)

Respondents	Percent (%)	Respondents	Percent (%)
International Organizations & NGOs	31	National - International Universities	22
National Research Institutes & NGOs	34	National Administration Public	13

As presented in Table 3, an almost equally high share of respondents was originated from international organization and NGOs (e.g. World Bank, Food Agricultural Organizations, International Rice Research Institute) and sound Bangladeshi research institutes. This was moderately expected because of the higher amount of invitations delivered to these two groups.

3.2 Weights, Performance matrix and Ranking results

The weights attributed to each criterion by the surveyed respondents point out the higher significance of the marginal profits for rice farm as presented in Figure 3. Moderately behind lays the sense of food security for the rice farmer together with the marginal productivity criterion. The least significance was ascribed to the marginal water productivity criterion while although of major concern for high yields it was not voted as that crucial for the suggested interventions.

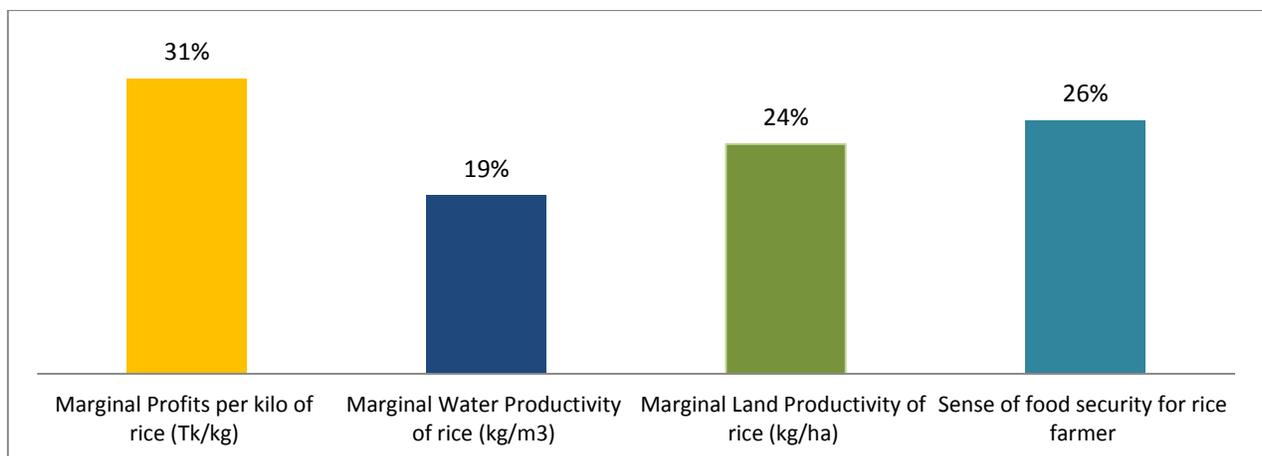
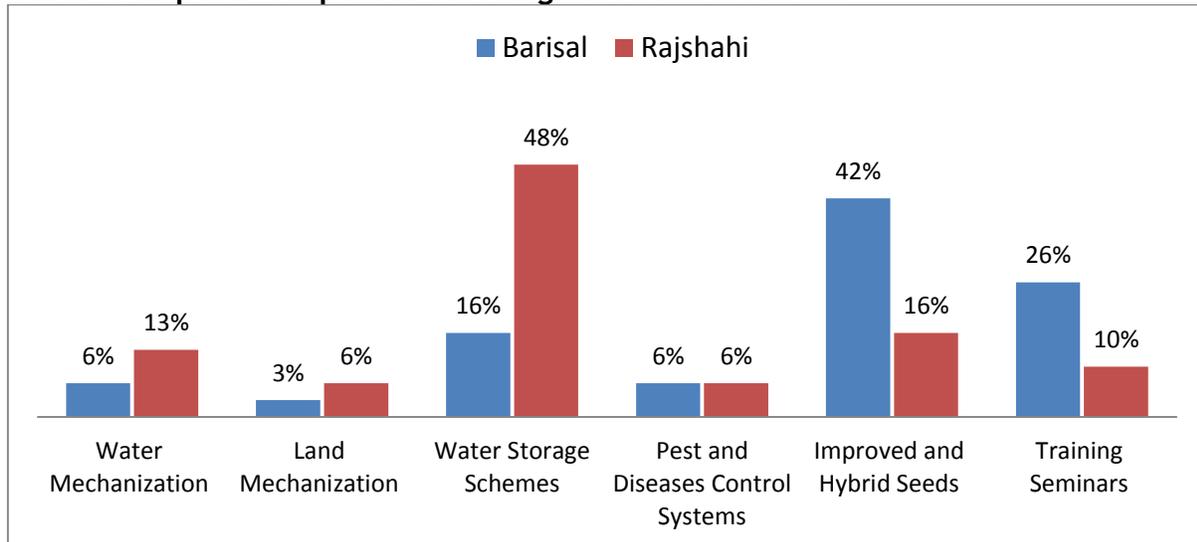


Figure 3. Suggested weighting coefficients for the four criteria

3.3 The Experts' preferences for the four criteria

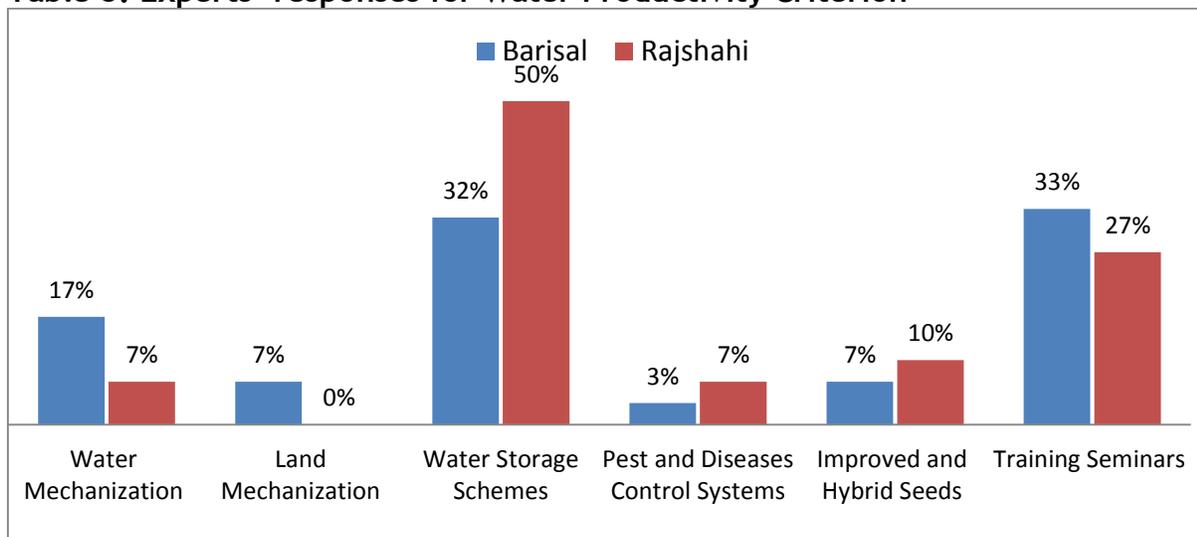
Some descriptive statistics on experts' preferences are further presented for each criterion respectively. As indicated in Table 4, in the case of marginal profit criterion, the experts are highly supportive of Water Storage group for Rajshahi region while the Improved/Hybrid Seeds are taking the lead in Barisal.

Table 4. Experts' responses for Marginal Profit Criterion



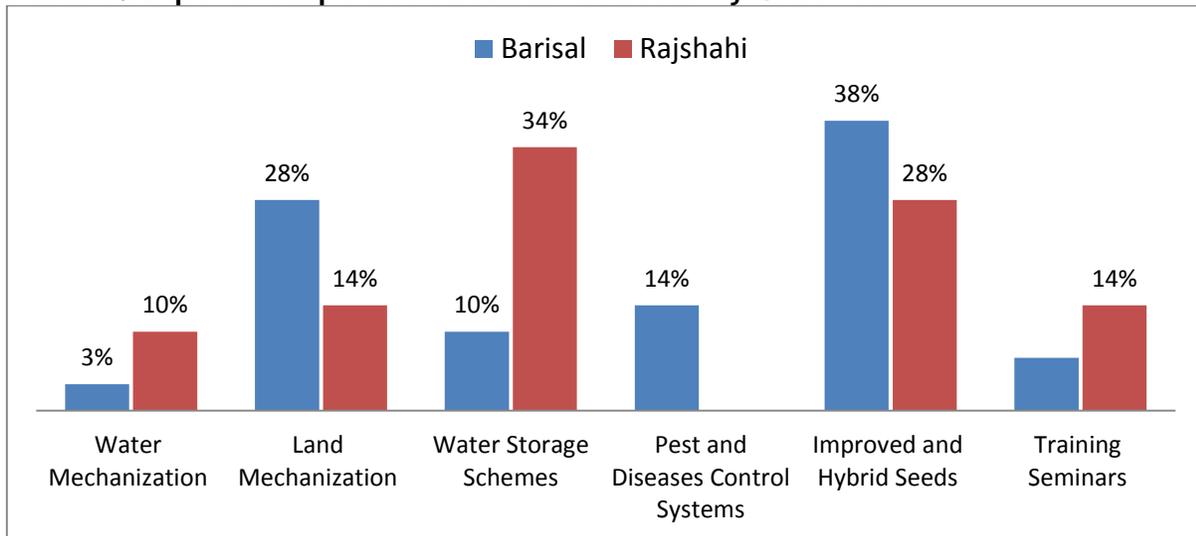
The support on Water Storage interventions is again discerned for Rajshahi region for the water productivity criterion as presented in Table 5. For the case of saline-flood Barisal, the Training Seminars are now emerging as the most prominent solution with slight difference from the water storage group.

Table 5. Experts' responses for Water Productivity Criterion



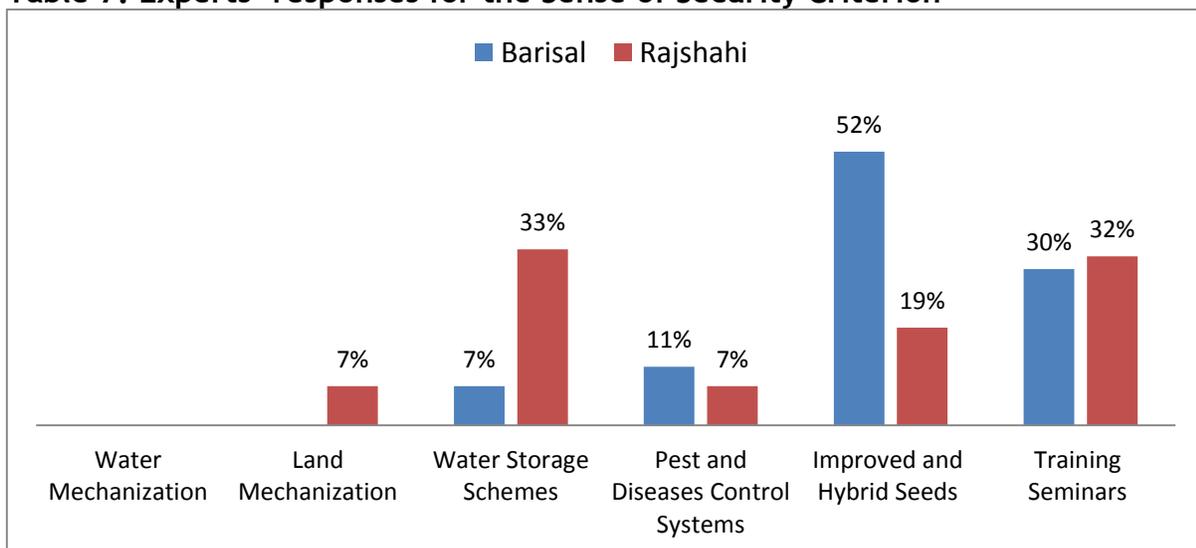
The steady preference of experts on water storage in drought prone Rajshahi is also reflected for the case of land productivity criterion as presented in Table 6. It is noteworthy though that the Improved/Hybrid seeds also take a high share for the Rajshahi region. The Improved/Hybrid seeds also constitute the most favorable intervention group for Barisal region while the land mechanization group is further behind.

Table 6. Experts' responses for Land Productivity Criterion



The leading role of Water Storage group in Rajshahi is also well kept in the case of the Sense of Security Criterion as presented in Table 7. However, an almost equal also voting for the Training Seminar groups is noticed for Rajshahi region. In Barisal region, the adherence to Improved/Hybrid Seeds groups is quite apparent since more than half of the experts are in favor of this option.

Table 7. Experts' responses for the Sense of Security Criterion



3.4 Ranking results of Visual Promethee

The Visual Promethee results for all the four criteria are further presented for Barisal and Rasjhahi regions. Visual Promethee offers a visualization of the ranking assessment conducted through the pairwise comparisons as indicatively shown for Barisal region in Figure 4. The dominance of Improved/Hybrid seeds is rather obvious while the Training Seminars and Water Storage groups are almost sharing the second position. Further behind lays the Pest and Disease Control intervention group while the Water and Land Mechanization are deemed as the least favorable by the sampled experts.

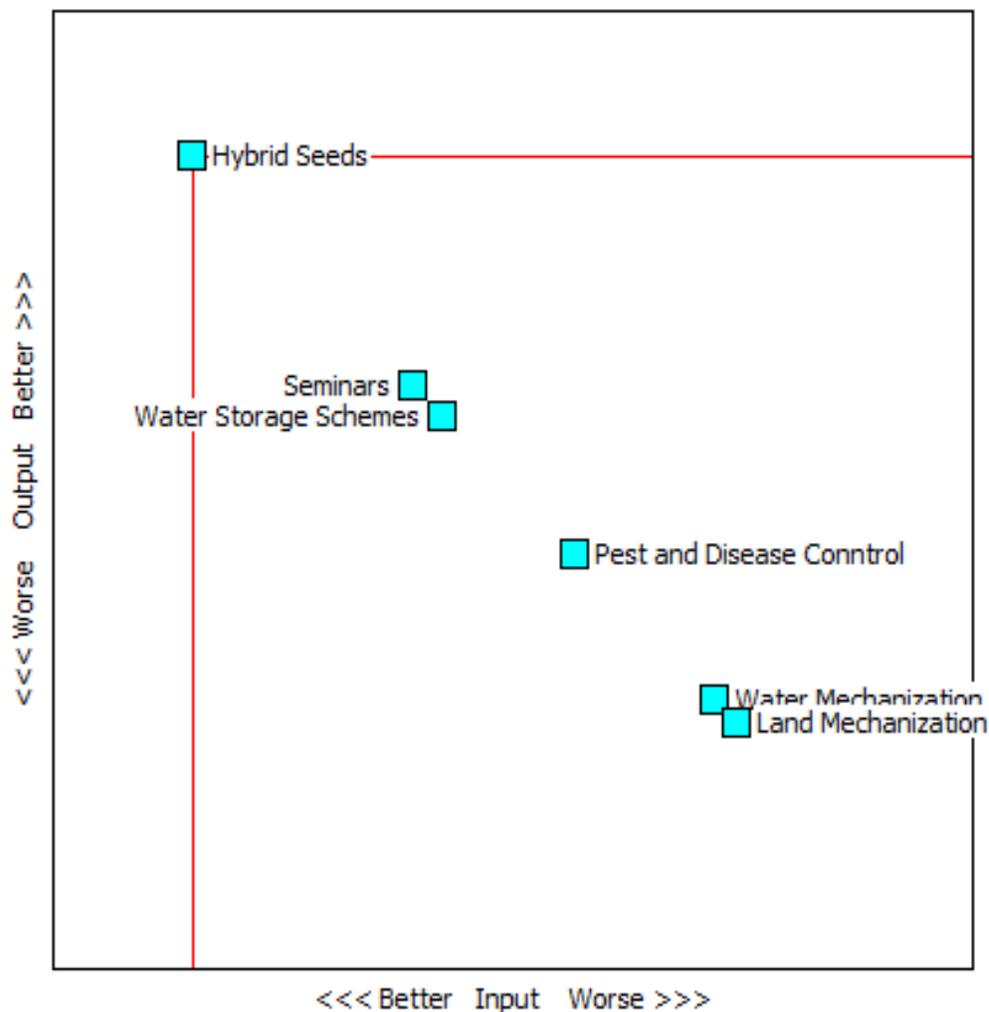


Figure 4. Ranking assessment for Barisal region

In the case of Rajshahi region, the Water Storage group is surpassing all the other intervention groups and is suggested as the most prominent option. Further behind stands the Improved/Hybrid Seeds group while closely in the third position is the Training Seminar option. The Water Mechanization group is better supported in Rajshahi than in the case of Barisal but still without much success. The least preferred options comprise the Land Mechanization, as also occurs in Barisal region, and the Pest and Disease Control Systems which is ranked in a lower position than in the case of Barisal.

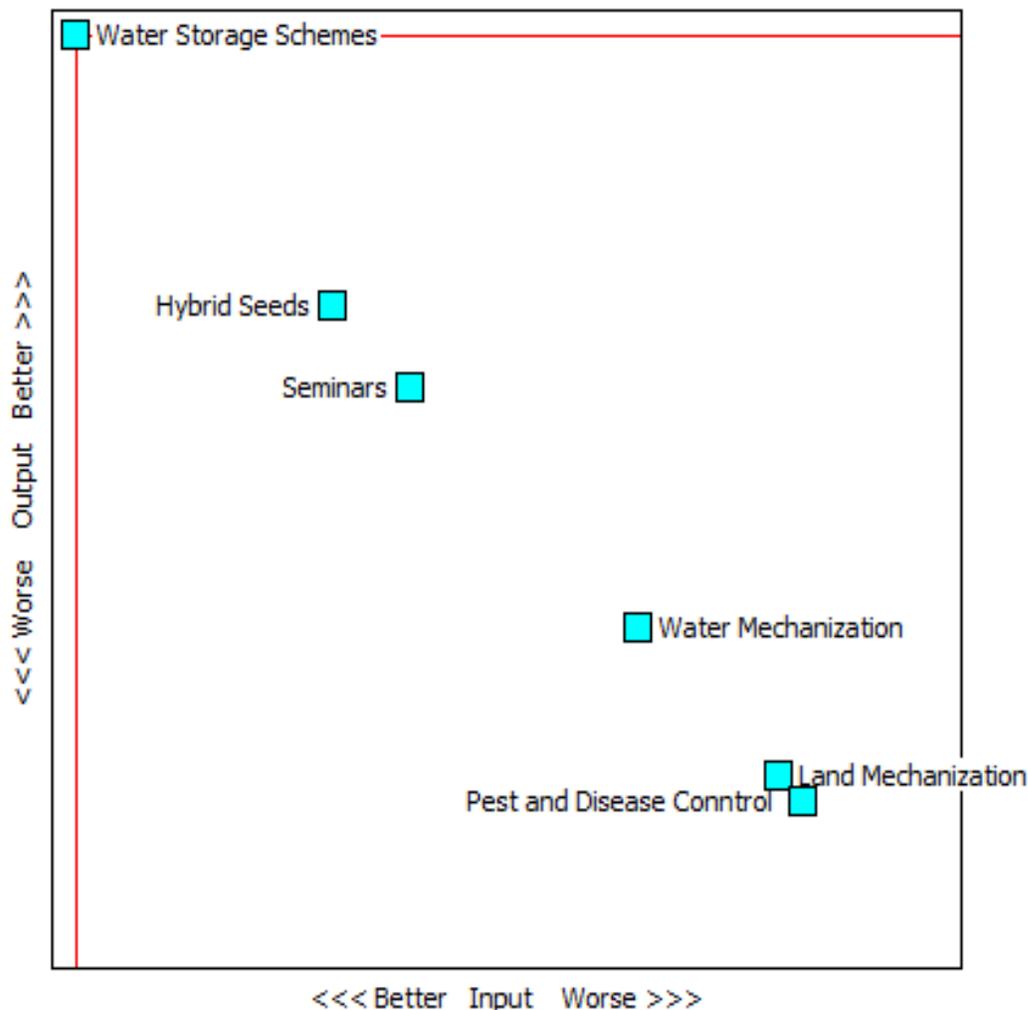


Figure 5. Ranking assessment for Rajshahi region

A numerical representation of the ranking results is shown in Table 8. Also, the individual interventions to be mostly voted in each group are also presented in brackets. For instance, in the case of the flood-saline Barisal region, the Improved/Hybrid Seeds were ranked first and the BRRI dhan 47 was the most favorable

variety suggested by the experts. Likewise, the deep tubewell was voted as the most promising specific intervention within the Water Storage group for Rajshahi region.

The ranking results of both regions signify the overall importance attributed to the Improved/Hybrid Seeds group by experts and the potential to alleviate climate change in rice farming through better rice varieties. It is also worth mentioning that the surface and groundwater management seminar is also perceived as a promising intervention for both regions and indicates the need for further knowledge in the efficient use of water resources.

Table 7. Numerical representation of the ranking assessment

Flood-Saline Barisal Region		Drought Rajshahi region	
Group (Particular intervention)	Scoring	Group (Particular intervention)	Scoring
Improved/Hybrid Seeds (BRRI dhan 47)	0,73	Water Storage Schemes (Deep Tubewell)	0,80
Training Seminars (Surface and Groundwater Management)	0,31	Improved/Hybrid Seeds (BRRI dhan 56)	0,51
Water Storage Schemes (Blocked Canal)	0,15	Training Seminars (Surface and Groundwater Management)	0,31
Pest and Disease Control Systems (Integrated Pest and Disease Management)	-0,21	Water Mechanization (High lift mechanical pump)	-0,41
Water Mechanization (Low lift mechanical pump)	-0,45	Land mechanization (Transplanting machine)	-0,54
Land Mechanization (Transplanting machine)	-0,54	Pest and Disease Control Systems (Integrated Pest and Disease Management)	-0,66

Interesting is the case that the difference between the most and least favored groups in Rajshahi is considerably higher than in Barisal which indicates a stronger preference of the experts for the highly prioritized groups.

3.5 GAIA Results

The GAIA results indicate a strong opposition between the marginal and water productivity criteria in Barisal region as presented in Figure 6. This suggests for instance that a high performance for marginal land productivity criterion in the case of Land Mechanization group would be offset by an almost equally low performance of marginal water productivity criterion in the same group.



Figure 6. GAIA Results for Barisal (left Figure) and Rajshahi (right Figure) divisions

Similarly, the sense of food security appears to have closer bonds with the marginal profit criterion in Barisal division. For Rajshahi division the sense of food security shifts to a much closer bond with marginal water productivity, which is considerably expected in drought prone areas. A loose relation appears between the marginal profit and marginal land productivity criteria.

4. Stakeholders' Input in the Assessment Results

The results of the experts' survey were disseminated together with other research outcomes of the RiceClima project, along a Stakeholders' Workshop conducted in the premises of the Bangladeshi Agricultural Research Council (BARC) at Dhaka in January 2013. Various representatives from international organizations & NGOs, national research institutes & NGOs, national-international universities and Bangladeshi public administration bodies participated in the workshop.

A positive feedback was broadly given on the results of experts' survey regarding the best agricultural intervention to alleviate climate change impacts in Bangladesh. In particular, a representative from the Ministry of Environment welcomed the research outcome and commented on the low ranking that Water Productivity has taken in Barisal in the socio-economic study. He also mentioned that the proposal of blocked canals in Barisal should be cautiously considered because many other side-effects could occur in the ecosystem. He was appreciative of the project since as mentioned it deals with vital issues such as drought and salinity problems.

Then, the representative of Norwegian embassy, Mr. Biswas mentioned that the experts' survey results should be disseminated to extension workers and the users (farmers) in the field and that more broadly RiceClima should have a dissemination strategy to share results with end users. He also asked the team to consider identifying other similar areas in Bangladesh where the RiceClima results could be used.

The Head of the Irrigation Department, BRRI, commented that in Barisal there is surplus surface water and 90% of the rice grown is of local varieties. He expressed the need for deep root water rice varieties for Barisal. For Rajshahi, he noted that groundwater depletion is a serious problem due to increase of Boro season planting. Therefore, measures are needed to address this issue and non-rice crops could be one option. Also, the rainwater conservation should be encouraged and taken up through the constructions of small retaining dams.

A representative from FAO mentioned that the policy makers should be consulted, while extension workers from the Department of Agricultural Extension/officers should be actively involved for the development of an integrated adaptation framework in the project.

5. Policy framework and up-scaling of agricultural investments

5.1 Policy Framework for agricultural investments

The last decades, the national policy of Bangladesh has encouraged research and training in rice farming which in turn has boosted the rice productivity of the country. Indicatively, the rice yield rose to 4.3 tons per hectare in 2012 from 1.7 tons per hectare in 1970 (IRRI, 2014). Still though, Bangladesh faces many challenges in the agricultural sector because of the difficulty to deal with climate change impacts, to confront with scarce and degraded natural resources and to feed a growing population.

The development of an adequate policy framework for agricultural investments is much needed. To this end, representative public bodies like the Ministry of Agriculture and the Bangladesh Agricultural Research Council (BARC) are striving to create favorable conditions for the attractions of new investments mainly from foreign funds for the improvement of farming conditions. Some general policies have been already adopted towards this direction as below:

- Investment promotion and facilitation
- Infrastructure development
- Improvement of financial sector
- More responsible business conduct

These principles are also encompassed in the Policy Framework for Investment in Agriculture (PFIA) designed by the Organization for Economic Co-operation and Development (OECD) (2014). In effect, OECD has developed a policy framework which helps governments to evaluate their investment policies, creating an attractive environment for investors and enhancing the development benefits of agricultural investment. Many developing countries in South and Southeast Asia and Africa have already adopted PFIA principles in their agricultural policy and Bangladesh is moving towards this direction.

The policy framework for agricultural investments in Bangladesh is of high interest also of international organizations. Indicatively, the World Bank has a long-lasting and prosperous cooperation with the national authorities of the country. There is already a common plan of World Bank and the Bangladesh authorities to increase agricultural productivity, and diversification; to improve factor markets and natural resource management and to strengthen rural institutions and livelihoods (World Bank, 2014).

The participation of international organizations, public bodies and research institutes in the development of a policy framework for agricultural investments in Bangladesh has already presented some positive effects in farming sector. Still though, there is

much work to be done for the improvement of rural livelihoods given the anticipated climate change constraints.

5.2 Ongoing initiatives in rice farming

The up-scaling and investment of the suggested interventions was further contemplated for the improvement of rice production and farmers' welfare in the examined regions. To this end, the current initiatives undertaken by other similar projects were reviewed for the identification of the potential synergies and also gaps that our study findings could cover when applied. A lot of similar efforts have been made by public bodies and international organizations for the support of climate change adaptation measures and rice farming in Bangladesh.

Indicatively, a series of projects are currently coordinated by BARC for the enhancement of agriculture and livelihoods in Bangladesh which are highly matched to the objectives of our research. The Bangladesh Agricultural Research Council (BARC) is the representative public body to coordinate and supervise national agricultural projects related to farming, welfare and climate change. A major project currently coordinated by BARC is the National Agricultural Technology Project (NATP). NATP is a comprehensive ongoing project with focus on revitalizing the agricultural technology system and increasing agricultural productivity in Bangladesh (BARC, 2014). Similar interventions to the ones assessed in our survey are also scrutinized in NATP project. The overall objective of NATP is to improve national agricultural productivity and farm income given the climate change constraints, with particular focus on small and marginal farmers.

In another instance, the International Rice Research Institute (IRRI) which is a dominant player in rice farming research and development in the world, has a strong presence in Bangladesh. IRRI has set as a foremost priority to cope with climate change in Bangladesh by building the adaptive capacity of farming households and help policymakers to deliver more effective climate adaptation programs. The improvement of farmers' adaptive capacity is sought by various projects through the development of better rice varieties that can tolerate flooding, drought, and salinity conditions. Also, the development of sustainable rice production systems is another parameter for the empowerment of adaptive capacity through the increase of productivity, profitability, and resilience of rice farming. Further, the knowledge sharing through training and capacity building activities is major aspect supported by IRRI in various projects for the improvement of rice farming conditions against climate change.

The initiative currently implemented by different organizations like BARC and IRRI, should be considered upon the up-scaling of the suggested interventions proposed by our study. Also, additional views expressed by national experts should be taken into account. Indicatively, many rice-farming experts from the Bangladesh Rice Research Institute (BRRI) claim that the water storage is the most prominent solution for

Rajshahi as hinted in the experts' survey but there are strong doubts about the construction of deep tubewells in the region.

The reasoning for the selection of deep tubewell as the most preferred among the Water Storage Schemes group in the experts' survey, could be probably related with the discernible improvement of rice production mainly caused by groundwater use in this division. In effect, the extensive groundwater use in Rajshahi has been strongly supported by the Barrind Multipurpose Development Authority (BMDA, 2013) since the early 1990s. The BMDA acts as an independent organization supervised by the Ministry of Agriculture, which develops and coordinates large scale irrigation projects. The BMDA has established extensive groundwater irrigation systems in Rajshahi where the pumping systems are equipped with sub-surface water pipes for reducing evaporation, friction and leakage losses normally observed in the open canals.

However, the rapid increase of individual tubewells together with the higher demand from connected farmers has provoked many incidents of groundwater depletion. These incidents have discouraged BRRRI scientists to recommend tubewell as an appropriate option. Instead, the rainwater harvesting through the development of small and medium-size ponds is suggested as the most suitable solution in Rajshahi region in regard to water storage options.

5.3 Feasibility study on the implementation of agricultural interventions

A feasibility study has been conducted for the pilot implementation of various agricultural interventions in Rajshahi and Barisal regions in consultation with the results of the experts' survey. The feasibility study suggests the pilot implementation of the three highest-ranked intervention groups of the experts' survey which are the Water Storage, Improved/Hybrid Seeds and Training Sessions. The feasibility study aimed to evaluate interventions that:

- Increase the crop productivity and farm income in the project sites;
- Strengthen the water storage schemes in drought prone Rajshahi,
- Strengthen the high yielding variety (HYV) seed production schemes in saline and flood prone Barisal
- Improve technical knowledge farmers on crop production

The technical, economic and logistic aspects of implementation were considered for different interventions in both regions. A detailed analysis of these parameters is presented in Annex 1. In brief, the following interventions are proposed for the case of Rajshahi:

1. Rainwater harvesting through the construction of small-size reservoirs (ponds) (estimated cost per pond, \$ 1,200 USD)

2. Distribution and cultivation of improved seeds for different rice varieties and other cultivations (estimated cost for a 54ha area, \$ 17,000 USD)
3. Arrangement of seminars on crop production, pest and water management (estimated cost for the training of 540 farmers, \$ 2,300 USD)

Similarly, for the case of Barisal the following interventions have been proposed by the feasibility study as below:

- 1 Distribution and cultivation of improved seeds for different rice varieties and other cultivations (estimated cost for a 54ha area, \$ 17,000 USD)
2. Arrangement of seminars on crop production, pest and water management (estimated cost for the training of 540 farmers, \$ 2,300 USD)
3. Development of Blocked canals (temporary and permanent), sluice gate repairing, re-excavation of irrigation canals (estimated cost, \$ 22,000 USD)

The feasibility study has adopted some representative indicators (World Bank, 2014) for the performance evaluation of the suggested interventions as presented in Table 8. These indicators could roughly estimate the potential improvement of major agricultural production parameters when the suggested intervention would be applied, as below:

Table 8. Evaluation of the potential improvement through performance indicators

Indicators	Performance (in %)	
	Rajshahi Region	Barisal Region
Increase in yield of selected crops	20-25	15-20
Increase in labor productivity	10-12	6-12
Decrease in production costs of selected commodities	6-10	5-8
Increase in volume of processed agricultural products	20-25	15-20
Increase in value of agricultural output	6-12	5-8

The fluctuation of the performance in each indicator is related to the implementation conditions of each intervention.

6. Discussion

This study has revealed a clear tendency of the experts to promote the cultivation of improved/hybrid seeds in the flood-saline prone Barisal region. The favor of the experts for the Improved/Hybrid group in Barisal could be in part justified by the recently encouraging field experiments in south Bangladesh for saline resistance varieties. Currently, the rice growth on soils with high salinity levels in southern Bangladesh can be hardly achieved and if harvested the rice is of poor quality for self-consumption and market exchange use (Deb, 2008). To this end, a series of saline resistant varieties have been lately released from the Bangladesh Rice Research Institute after a long standing cooperation with international organizations (BRRI, 2013). BRRI dhan 47 is a representative improved variety, which can tolerate high salinity levels at seedling stage and during the whole cultivation period. The initial cultivation of BRRI dhan 47 has indicated that a rice yield of almost equal quality and volume with non-saline cases can be produced by providing farmers food security and a sustainable income (IRIN, 2013). This could be useful to farmers located in areas vulnerable to saline intrusion in Bangladesh.

However, there have been many instances where the salinity levels have become so acute along the dry season (October-April) that even the most adaptive seeds can hardly grow. To this end, supplementary mitigation techniques should be also introduced. The canal blocking proposed by the experts' survey and the feasibility study is a supplementary mitigation technique which however may entail undesirable economic and health-related effects if improperly applied. In effect, the blocking of irrigation canal may obstruct the flow to the water-dependent rice crop and result in conflicts among farmers. Also, the stagnant water tables at the soil surface are reported to have increased the incidence of water borne diseases in local communities (BRRI, 2013). To this end, the development of canal blocking practices should be cautiously designed by experienced rice-farming scientists in cooperation with regional agricultural extension officers.

A promising large scale mitigation measure applied until two decades ago was the operation of a polder system for flood protection in the monsoonal (rainy) period and saline water intrusion in the dry season. At present, however, the sluice gates are not properly maintained and many of them are out of order. The polder revitalization could alleviate the current flooding and moreover saline impacts by offering a promising response to climate change as also suggested in the feasibility study. The polder system was not assessed by experts in the current study since it was only existent farm-level practices that were evaluated. By pondering, however, the solutions to be suggested at a regional level, the polder revitalization could be a costly but promising investment for the flood-saline Barisal region.

In the case of Rajshahi, the selection of deep tubewell as the most preferred among the Water Storage Schemes group, could be probably related with the discernible

improvement of rice production mainly caused by groundwater use in this division. Nevertheless, an increasing competition for the same groundwater resources is currently noticed between the BDMA irrigation system and the rapid drillings of individual farmers. This competition has accordingly increased the groundwater abstraction rates by also lowering the water level to an alarming extent. In effect, the in-built BDMA pumps have sometimes failed to deliver groundwater from lower depths than 80m for which they were originally designed. The recent groundwater scarcity incidents have requested BDMA to establish better groundwater conservation practices while other water storage techniques like rainwater harvesting are well encouraged (BMDA, 2013).

The high credit given also to Rajshahi for the introduction of Improved/Hybrid seeds indicates the need for higher focus on the imminent release of more adaptive varieties. Also, the high preference for the groundwater management seminars in both regions is another spotlight to be well considered for rice farming improvement against climate change effects.

The feasibility study attempted to identify in a very initial stage the needs and the anticipated benefits from the implementation of the suggested agricultural interventions in the two regions. It is understood that the absence of detailed analysis might have set in question the appropriateness of the suggested measures. It is however mentioned that the current study aspired to initially signify the interventions to be conducted in Bangladeshi rice farming against climate change. The detailed analysis of the installation, maintenance and cost- effectiveness of each intervention is of particular interest but it requires a more thorough analysis which is beyond the scope of this study. We however provide an overview in Annex 1 of the economic and technical aspects that may be needed for the suggested interventions.

7. Conclusions

The current study has indicated the most prioritized interventions to be taken against climate change in Bangladeshi rice growing areas prone to drought and salinity events. The suggested methodology managed to evaluate a wide range of agricultural interventions through a transparent and user-friendly approach. The introduction of experts from different professional backgrounds and the assessment by various socio-economic and agronomic criteria are expected to have enhanced the reliability of the results.

The input of stakeholders' views through the workshop event in Dhaka have provided valuable feedback for the empowerment of the study findings. The presentation of the current policy framework and the ongoing activities in agriculture may have offered a rough idea on the challenges and constraints to be met upon application of the suggested interventions. It is acknowledged that the feasibility study has not explicitly presented the technical and economic parameters to be met in the implementation phase of each intervention. It is aspired though that an initial overview has been given which could provide the primary source for some detailed implementation studies.

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9. Annex 1. Technical features of the suggested agricultural interventions

Table 1. Interventions suggested for Rajshahi region

Components	Intervention 1: Water Storage Schemes (Rain water harvesting) (Total Est. Cost~ 1,200USD)				
<i>Technical</i>	Farm reservoir (pond) 10m x 10m x3m)				
<i>Economic</i>	Reservoir construction with material and labor expenses		Associated devices (pumps, water pipes, canals etc.)		
<i>Logistics</i>	20 man (labor) for 1 month		1 Low lift pumps	3, Plastic pipe 183 m (61 m/pump)	
Components	Intervention 2: Improved Seeds (Total Est. Cost~ 17,000 USD)				
<i>Technical</i>	Total land 54 ha				
<i>Economic</i>	Purchasing seeds	Storage	Distribution	Land preparation	Awareness and information
<i>Logistics</i>	12 storage facilities	54 ha equally cultivated with boro , aus, aman, wheat, mustard, chickpea		12 group meetings	
Components	Intervention 3: Training Seminars (Total Est. Cost~ 2,300 USD)				
<i>Technical</i>	Training 540 Farmers in Crop production, pest and water management				
<i>Economic</i>	Trainers	Technical support (training materials, banners, decoration etc.)			
<i>Logistics</i>	8-10 Trainers	Note book, pen, file cover, leaflets, booklets etc.			

Table 2. Interventions suggested for Barisal region

Components	Intervention 1: Improved Seeds (Total Est. Cost~ 17,000 USD)				
<i>Technical</i>	Total land 54 ha				
<i>Economic</i>	Purchasing seeds	Storage	Distribution	Land preparation	Awareness and information
<i>Logistics</i>	12 storage facilities	54 ha equally cultivated with boro , aus, aman, wheat, mustard, chickpea		12 group meetings	
Components	Intervention 2: Training Seminars (Total Est. Cost~ 2,300 USD)				
<i>Technical</i>	Training 540 Farmers in Crop production, pest and water management				
<i>Economic</i>	Trainers	Technical support (training materials, banners,			

		decoration etc.)
<i>Logistics</i>	8-10 Trainers	Note book, pen, file cover, leaflets, booklets etc.
Components	Intervention 3: Development of Blocked canals (temporary and permanent) , sluice gate repairing, re-excavation of irrigation canals (estimated cost per pond, \$ 22,000 USD)	
<i>Technical</i>	Repairing, revitalization and adjustment of irrigation canals	
<i>Economic</i>	Blocking canals material and labor cost	Associated devices (pumps, water pipes, canals etc.)
<i>Logistics</i>	100 man (labor) for 1 month	Low lift pumps - 9, Plastic pipe 183 m (61 m/pump)