Alleviating climate change impacts in rural Bangladesh through efficient agricultural interventions

Stefanos Xenarios[a], Heracles Polatidis[b], Nagothu Udaya Sekhar[a], Jatish Chandra Biswas[c], Md Maniruzzaman[c], Golam Wahed Sarker[c]

[a]Norwegian Institute for Agricultural and Environmental Research-Bioforsk, Frederik A. Dahls vei 20, N-1432, Ås, Norway
[b] University of the Aegean, Dept. of Environment, University Hill, 81100, Mytilene, Greece
[c] Bangladesh Rice Research Institute, Gazipur-1701, Bangladesh

Abstract
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 paper 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. 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.

Keywords: Climate Change, Rice, Drought, Salinization, Multicriteria, Bangladesh

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). In the north, 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 loses 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, 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 enhanced with weighting factors and a Geometrical Analysis for Interactive Assistance (GAIA) for the assessment of agricultural interventions to tackle climate change effects in Bangladesh. The suggested approach is based on the existent outranking Visual Promethee method (Mareschal, 2013). Visual Promethee has been already implemented in various research fields like energy, manufacturing, building materials and transportation (Macharis et al, 1998; Anagnostopoulos et al, 2003; Dagdeviren, 2008; Prvulovic, 2011; Macedo et al; 2012, Nasiri et al, 2012). Nevertheless, to our knowledge, there are hardly any similar studies in the agricultural sector in Bangladesh and more broadly in South Asia engaging similar methodological approaches.

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.

In Section 2, the interventions, criteria and the outranking methodology to assess the performance of each intervention are presented. Section 3 denotes the results of the assessment process while in Section 4 the discussion and concluding remarks are presented.

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 areas[1]. The interventions investigated 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 attributes of homogenous interventions, which could however suggest different performance when individually applied. All the interventions where equally assessed for both the Rasjahi 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:

[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.

Table 1. Groups and attributes of the Suggested Interventions (about here)

Intervention Groups						
Water Mech.	**Land Mech.**	**Water Stor.Sch.**	**Pest and Dis. Contr. Systems**	**Impr./ hyb.(Barisal)**	**Impr./ hyb (Rahshahi)**	**Training Seminars**
Attributes						
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	BRRI dhan40	BRRI dhan49	Surface and Groundwater management
High lift mechanical pump	Thresher	Shallow Tubewell		BRRI dhan41	BRRI dhan56	
	Weeding Machine		Chemical Pest and Disease Control	BRRI dhan44	BRRI dhan57	Early Forecasting for pest and disease control
Low lift mechanical pump	Seeding Machine	Blocked Canal*		BRRI dhan46	Sawrna	
	Transplanting machine		Integrated Pest and Disease Management	BRRI dhan53	Guti Sawrna	Insurance Schemes
Hand-Pump		Pond		BRRI dhan54		Trading and Selling skills

**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*

For every attribute, the respondent could also select the option "Other" if none of the recommended was deemed to be appropriated for the two study areas. Further, the adopted criteria were respectively 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 (about here)

Criteria	**Explanatory Note**
Marginal Profits per kilo of rice (Tk/kg)	The marginal profit of rice cultivation is the highest amount of net revenues earned by a farmer for an additional kilo of rice production, e.g. 25 Tk / kg
Marginal Water Productivity (kg/m^3)	The marginal water productivity of rice cultivation is the highest amount of rice produced by an additional cubic meter of water e.g. 0.3 kg/m^3
Marginal Land Productivity (kg/ha)	The marginal land productivity of rice cultivation is the highest amount of rice produced by an additional 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 (USD 1.25$/day) from his produce e.g. in a qualitative scaling from 1-5 a respondent could rank with 1 the intervention providing highest security to the farmer

Finally, the respondents were asked to rank the relevant criteria in terms of importance for the assessment of the examined interventions. 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. These features were deemed to help in a better judgment of the proposed measures.

2.2 Visual Promethee structure

The assessment of the suggested interventions was conducted through the Visual Promethee approach, which constitutes a combination of 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 (Vincke, 1994) 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, 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. Further, the introduction of weighting coefficient signifies the importance of each criterion by affecting the pairwise comparison and the final ranking outcome. It is claimed that in case where no preference conditions occur then the outranking methods would be of no difference but like the utility-based functions (DTRL, 2009). In response, a counterargument stands for that even without the preference conditions, the outranking methods are based on comparative pairwise statements rather than single-criterion absolute statements prevailing in utility based methods (Brans and Mareschal, 2005).

The Visual Promethee is initially based on pairwise preference comparison for the evaluation of two alternatives (interventions) over a particular criterion as below:

$$d_j(\alpha,b) = g_j(\alpha) - g_j(b).....(1)$$

Where g_j the criterion for the (α) and (b) interventions. Based on Eq. (1) the indifference and preference thresholds are established. The indifference threshold is the largest deviation, which is considered as negligible by the decision maker, while the preference threshold is the smallest deviation, which is considered as sufficient to generate a full preference. By assuming that the deviation between these preference conditions could vary from 0 (no preference) to 1 (high preference) the following preference setting (Brans and Marerchal, 2005) should appear:

$$d_j(\alpha,b) = \begin{cases} \pi(\alpha,a) = 0 \\ 0 \le \pi(\alpha,b) \le 1 \\ 0 \le \pi(b,a) \le 1 \\ 0 \le \pi(a,b) + \pi(b,a) \le 1 \end{cases} ......(2)$$

Where $\pi(\alpha,b)$ is expressing to which degree (α) intervention is preferred over (b) and $\pi(b,a)$ oppositely how (b) is preferred to (α). Further on, the preference flows between the different interventions over the examined criteria are counted. The preference flows represent the processes of the pairwise calculation for the ranking of each intervention. Initially, the positive preference flow is computed as below:

$$\phi^+(\alpha) = \frac{1}{n-1}\sum_{b\neq a} \pi(\alpha,b).........(3)$$

Where the positive flow $\phi^+(\alpha)$ measures how much an intervention (α) is preferred to the other n-1 ones over the examined criteria. The larger performance of the positive flow implies a better intervention. Respectively, the negative flow:

$$\phi^-(\alpha) = \frac{1}{n-1}\sum_{b\neq a} \pi(b,a).........(4)$$

measures how much the other n-1 actions are preferred to action (α). It is comprehended that the higher the flow implies a lower intervention performance. Finally, the net preference flow $\phi(\alpha)$ is the balance between the positive and negative preference as below:

$$\phi(\alpha) = \phi^+(\alpha) - \phi^-(\alpha)........(5)$$

It is understood that the net preference flow can be positive or negative depending on the relative performance of the intervention over the others in regard to the examined criteria. The larger net preference flow implies a better intervention.

In our study, no preference thresholds were imposed because the survey respondents were requested to either select an intervention group or rank the suggested attributes through a cardinal numeric process. In that sense, each respondent was initially asked to select one out of the six suggested intervention groups for each criterion and study area. Once a group was selected, the set of the attributes were displayed where the respondent should rank at least two of the available options.

The pairwise preference flow process was equally held for all the six groups of interventions for the outranking among each group. For the case of the attributes however, the ranking process has been already conducted by the respondents which made of no avail the scoring outcome of the preference flows.

2.3 Weighting and Geometrical Analysis for Interactive Assistance (GAIA)

The Visual Promethee encourages the introduction of weighting coefficient for a better attribution of the significance of each criterion. Customarily, the indicative weighting values in outranking methods are mostly intrinsic, meaning that they do not depend on the nature of the scale chosen for evaluating performance (Roy 1996) but on personal judgments. The judgments can be given by the analysts, decision makers or some stakeholders. In the current analysis, they 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 alteration of the weighting coefficients could well represent a sensitivity analysis over the final ranking results by indicating the influence of weighting factor in a decision process.

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.

2.4 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 Public Administration	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 Table 4. 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.

Table 4. Suggested weighting coefficients for the four criteria (about here)

Marginal Profits per kilo of rice (Tk/kg)	Marginal Water Productivity of rice (kg/m3)	Marginal Land Productivity of rice (kg/ha)	Sense of food security for rice farmer
31 %	19 %	24 %	26 %

Further on, the scoring of each criterion against the proposed alternatives is identified through the performance matrix. The performance matrix is a consequence table, in which each row describes an option and each column describes the performance of the options against each criterion (DTLR, 2009). The individual performance assessments are often numerical as occurs in Table 5 below:

Table 5. Performance Matrix and Ranking for Barisal division (about here)

Interventions		Criteria				Ranking		
Groups	**Attributes**	**(1)**	**(2)**	**(3)**	**(4)**	$\phi^{+}(\alpha)$	$\phi^{+}(\alpha)$	$\phi(\alpha)$
Improved/ Hybrid varieties	BRRI dhan47	1,00	-0,60	1,00	1,00	0,81	0,11	**0,69**
Seminars	Surface and Groundwater Management	0,60	0,60	-1,00	0,60	0,60	0,39	**0,21**
Water Storage Schemes	Blocked Canal	0,20	1,00	-0,20	-0,20	0,57	0,42	**0,15**
Pest and Disease Control	Integrated Pest and Disease Management	-0,40	-0,60	0,20	0,20	0,36	0,50	**-0,13**
Water Mechanization	Low lift mechanical pump	-0,40	0,20	-0,60	-0,80	0,22	0,66	**-0,43**
Land Mechanization	Transplanting machine	-1,00	-0,60	0,60	-0,80	0,19	0,68	**-0,48**

Note: (1)= Marginal Profits per kilo of rice (Tk/kg), (2)= Marginal Water Productivity of rice (kg/m3), (3)= Marginal Land Productivity of rice (kg/ha), (4)= Sense of food security for rice farmer. Also, the highest scorings against each criterion are shaded with grey color.

As presented in Table 5, an excellent performance of the Improved / Hybrid group is noticed for all the criteria except for the marginal water productivity. In particular, the saline tolerant variety BRRI dhan47 is preferred by experts as the most suitable for Barisal region. An equally high ranking in the positive preference flow $\phi^{+}(\alpha)$ is rendered which cannot be counterbalanced from the negative preference flow $\phi^{-}(\alpha)$. Hence, the group of Improved/Hybrid gains the higher ranking position in a considerable distance from the second ranking group of Seminars.

In the case of Rasjhahi division, the Water Storage Schemes group seems to more clearly surmount the other intervention groups in all criteria but in the sense of food security where an equal ranking with Seminars is given. In particular, the introduction of deep tubewell systems is encouraged by experts as the most prioritized intervention. Since there is no negative preference flow $\phi^{-}(\alpha)$ to consider, the Water Storage Schemes is clearly ranked as the highest ranked group of options.

Table 6. Performance Matrix and Ranking for Rasjhahi division (about here)

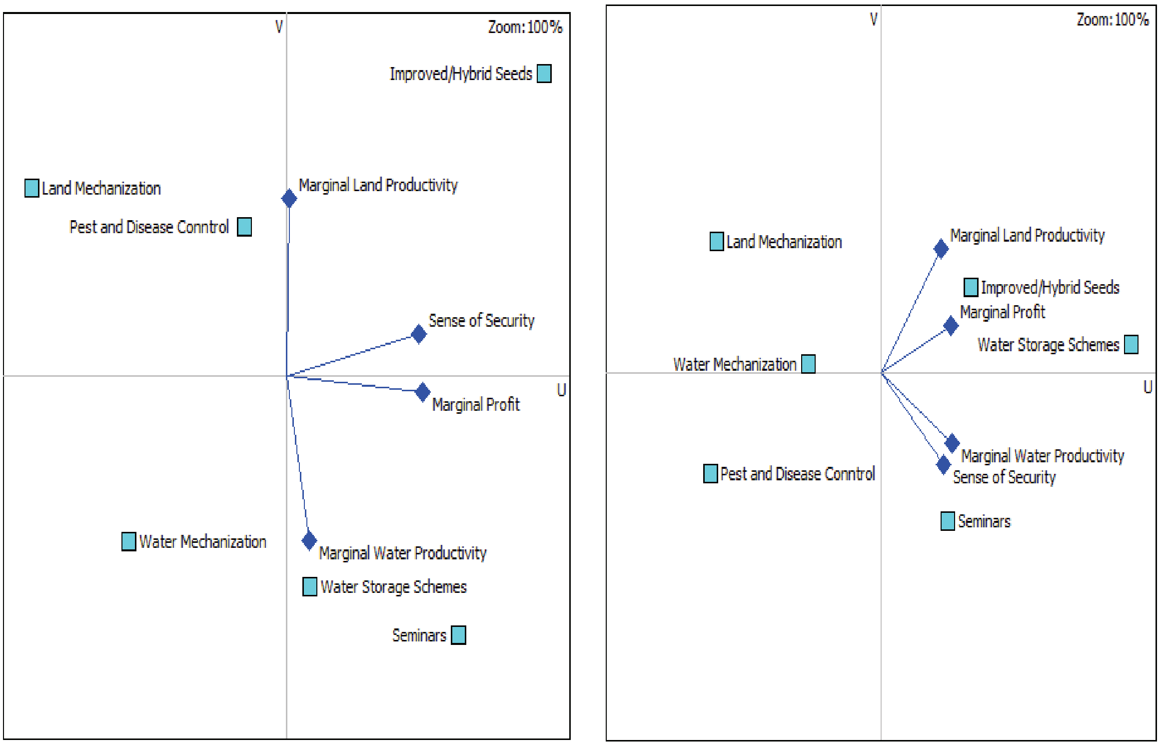
Interventions		Criteria				Ranking		
Groups	**Attributes**	**(1)**	**(2)**	**(3)**	**(4)**	$\phi^{+}(\alpha)$	$\phi^{-}(\alpha)$	$\phi(\alpha)$
Water Storage Schemes	Deep Tubewell	1,00	1,00	1,00	0,80	0,94	0,00	**0,94**
Improved/ Hybrid varieties	BRRI dhan56	0,60	0,00	0,60	0,20	0,67	0,29	**0,38**
Seminars	Surface and Groundwater Management	-0,20	0,60	-0,20	0,80	0,58	0,36	**0,21**
Water Mechanization	High lift mechanical pump	0,20	0,00	-0,60	-0,80	0,31	0,60	**-0,29**
Land Mechanization	Transplanting machine	-0,80	-1,00	0,20	-0,80	0,14	0,74	**-0,59**
Pest and Disease Control	Integrated Pest and Disease Management	-0,80	-0,60	-1,00	-0,20	0,14	0,79	**-0,65**

Note: (1)= Marginal Profits per kilo of rice (Tk/kg), (2)= Marginal Water Productivity of rice (kg/m3), (3)= Marginal Land Productivity of rice (kg/ha), (4)= Sense of food security for rice farmer. Also, the highest scorings against each criterion are shaded with grey color.

3. 3 GAIA Results

The GAIA results indicate a strong opposition between the marginal and water productivity criteria in Barisal as represented for all the examined interventions in Figure 1. 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. These conditions can be also partly conceived when looking through the ranking scores between criteria for the same interventions in Tables 5 and 6. 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.

Figure 1. GAIA Results for Barisal (left Figure) and Rajshahi (right Figure) divisions (about here)



4. Discussion and Concluding Remarks

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.

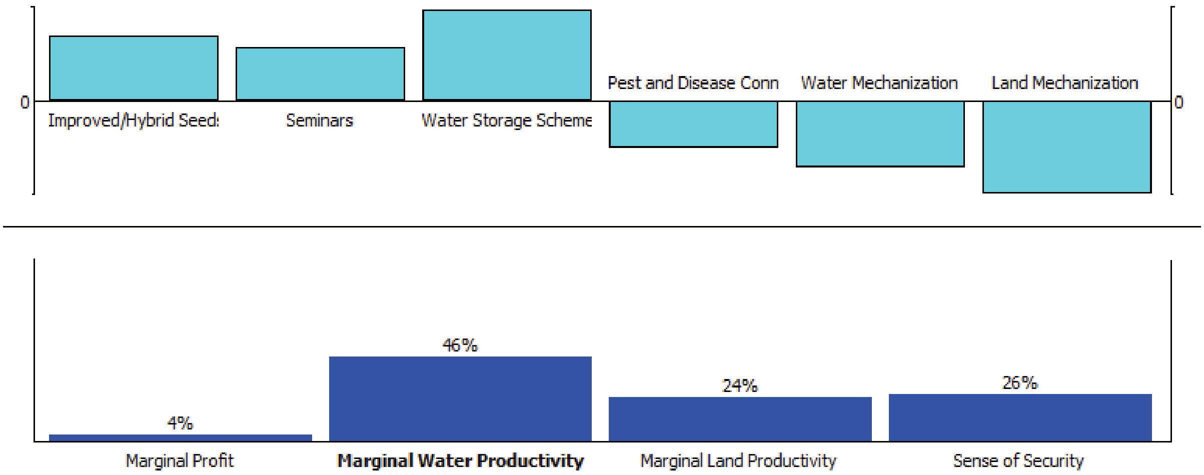
In the case of Rajshahi, the selection of deep tubewell as the most preferred among the Water Storage Schemes group, could be probably related with the discernible improvement of rice production mainly caused by groundwater use in this division. In effect, the extensive groundwater use in Rasjhahi has 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. The farmers purchase electronic cards with irrigation-hour credits and then insert them into electronic terminals next to the submersible BMDA pumps for initiating irrigation. The submersible pumps are installed in a depth of about 70 mt where the groundwater reserves still present relevant abundance. However, the rapid increase of individual tubewells together with the higher groundwater demand from connected farmers has alerted the

BDMA for the establishment of better groundwater conservation practices (BMDA, 2013). To this end, soil conservation measures and farmers' awareness are already initiated from BDMA for the improvement of groundwater resources.

The present findings could undergo some criticism on the outranking analysis approach due to the absence of preference thresholds in any of the criteria. A claim could stand for that the method selected could hardly differ from the results of a single-criterion utility or monetary based approach. It is acknowledged that the absence of threshold values has simplified the ranking process but still the decision analysis was based on a pairwise comparison between different interventions. The users were not to decide on a single-criterion (i.e. monetary value) through complete trade-offs between the interventions but on a set of representative criteria where the trade-offs were mitigated through pairwise comparisons.

Further, the weighting coefficient is a burden issue to be considered against the objectivity of the results (Choo et al, 1999). This could be ratified through an illustrative example for the case of Barisal division. As indicatively presented in Figure 2, the sound weighting increase only of marginal water productivity criterion from 19 to 44 percent with a parallel lowering of marginal profit weight could capsize the ranking outcome. In this case, the Water Storage Schemes are now taking the lead by setting aside the Improved/Hybrid group.

Figure 2. Altering the weighting coefficients in Barisal case (about here)



This example was to underpin the need for cautious use of weighting factors, which appear to be high determinants for the final ranking outcome. Hence, the deliberative or inadvertent misuse of weights could be heavily blamed for the distortion of the selection process and the entailing of falsified results. However, the total weighting absence would potentially reveal the real dynamics among criteria by also concluding to a misleading outcome. In our case, the assignment of weighting values is left to the group of respondents, who deem to reflect a relatively representative opinion.

The experts' selection on weighting process brings forward the wider issue of experts' judgment over users' – farmers in our case, other community groups or random respondents. Pro-expert arguments suggest that experts can better comprehend a situation in regard to an average respondent (Beatty et al, 2011). Also, experts are claimed to be less biased than users or other stakeholder groups who often have particular interests in a subject (Markantonis and Bithas, 2009).

However, counterarguments indicate that the experts' opinion often deviates from reality due to the unawareness of the complications met when the suggested solutions are implemented (Vatn and Bromley, 1995). Also, the experts might be well associated with lobbies' favor of particular interventions by actually manifesting the preferences of specific lobbies instead of personal views. By acknowledging these effects, the current research is already conducting an extensive household questionnaire in selective drought and saline prone areas of Rasjhahi and Barisal divisions. In this questionnaire, the same criteria and interventions are queried by however exploring already applied cases with proven results. The cross-checking between the experts' survey and the household questionnaire is anticipated to offer a more integrated and less subjective overview of the most appropriate interventions.

It is perceived that the absence of cost indicators in each intervention might have set in question the appropriateness of the suggested measures. If these measures are especially to be undertaken by individual farmers then a cost-wise analysis might have discarded many of the indicative options. It is however mentioned that the current results aspire to initially signify the measures to be taken in Bangladeshi rice farming against climate change effects. The consideration of the installation and maintenance costs of each intervention is of particular interest but beyond the scope of this study.

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. In the case of drought areas, the utmost preference of experts to water storage schemes and particularly tubewells accentuated the almost unanimous consent to more groundwater use in rice crop. The sustainable irrigation could be probably ensured through the introduction of better regulatory framework coupled with soil conservation measures and awareness campaigns.

In turn, the firm preference of experts for improved/hybrid varieties and particularly BRRI dhan 47 in saline prone areas, signified the prominent role of seed planting in such saline soils. The almost equally qualitative and quantitative yield of BRRI dhan 47 to traditional varieties and the affordable seed purchasing costs suggest potentially good prospects for saline resistant rice production.

Acknowledgements
The study was carried out through the project "RICE CLIMA" research project (Nr. 2011/000174) funded by the Royal Norwegian Embassy in Dhaka, Bangladesh.

References

Anagnostopoulos, K., Giannopoulou, M., Roukounis, Y. (2003) Multicriteria evaluation of transportation infrastructure projects: An application of PROMETHEE and GAIA methods. *Advances in Transport* 14, 599–608.

Barrind Multipurpose Development Authority (2013), http://www.bmda.gov.bd/ [accessed 06/02/2013]

Basak, (2011) *Climate Change Impacts on Rice Production in Bangladesh: Results from a Model*, Unnayan Onneshan-The Innovators, Bangladesh

BBS, (2011).*Statistical yearbook of Bangladesh*, Bangladesh Bureau of Statistics, Statistics Division, Ministry of planning, Government of Bangladesh (GoB), Dhaka.

Beatty, M., Beutels, P. Meltzer, M., Shepard, D., Hombach, J., Hutubessy, R., Dessis, D., Coudeville, L., Dervaux, B., Wichmann, O., Margolis,H. and Kuritsky J. (2011) Health Economics of Dengue: A Systematic Literature Review and Expert Panel's Assessment, *Am. J. Trop. Med. Hyg.,* 84(3), 2011, pp. 473–488,doi:10.4269/ajtmh.2011.10-0521

Biswas J.K., Ali M.A., Mahbub, A.M., Ansari, T.H., Raghib Hassan A.W. and Islam, M.S. (2009) *Results and Findings from BRRI-FAO Collaboration under Project Improved Adaptive Capacity to Climate Change for Sustainable Livelihoods in the Agricultural Sector (LACC II),* BRRI, Joydebpur, Gazipur-1701 & DAE, Khamarbari, Dhaka-1207

Brans J.P. and Mareschal, B. (2005) PROMETHEE Methods. In J. Figueira, S. Greco, and M. Ehrgott, editors,*Multiple Criteria Decision Analysis: State of the Art Surveys*, pages 163-196. Springer Verlag, Boston, Dordrecht, London

BRRI (2013), *Research Activities,* http://www.brri.gov.bd/research_activities/index.htm [accessed 06/02/2013]

Choo Eng. U. Schoner, B., Wedley, W.C. (1999) Interpretation of criteria weights in multicriteria decision Making, *Computers & Industrial Engineering* 37 (1999) 527±541

Dagdeviren, M. (2008) Decision making in equipment selection: An integrated approach with AHP and PROMETHEE. *Journal of Intelligent Manufacturing* 19, 397–406.

Deb, U. (2008) Boro Procurement and Food Security Strategy *An Actionable Agenda,* Center for Policy Dialogue, Bangladesh.

Debertin, D.L. (2012). Agricultural *Production Economics,* Macmillan Publishing Company, ISBN 0-02-328060-3

Department for Communities and Local Government (2009) *Multi-criteria analysis: a manual,* London, ISBN: 978-1-4098-1023-0

Diakoulaki, D., Karangelis, F. (2007) Multi-criteria decision analysis and cost-benefit analysis of alternative scenarios for the power generation sector in Greece. *Renewable and Sustainable Energy Reviews* 11, 716–727.

Farag, A. and Elhabian, S., (2009*) A Tutorial on Principal Component Analysis,* University of Louisville, CVIP Lab September 2009, http://www.cvip.uofl.edu /wwwcvip/education /ECE523 / PCA%20Tutorial%20-%20Sept%2009.pdf [accessed 01/12/2012]

Food and Agriculture Organization of the United Nations (FAO), Department of Agricultural Extension (2010) *Technical Guideline on Establishment of Adaptation Option Demonstrations for Rabi Season season/October-March in Drought prone and saline areas*, Livelihood Adaptation to Climate Change (LACC-II) Project (BGD/01/004/01/99),FAO, Italy

FAO, (2012) Rice Market Monitor, Trade and Markets Division, Food and Agriculture Organization of the United Nations, http://www.fao.org/economic/est/publications/rice-publications/rice-market-monitor-rmm/en/, [accessed 11/01/2013]

Huq, S. Rahman, A., Konate, M., Sokona, Y. and Reid R. (2003) *Mainstreaming Adaptation to Climate Change in Least Developed Countries,* International Institute for Environment and Development, London, UK

IRIN, A service of the UN Office for the Coordination of Humanitarian Affairs (2013) *Bangladesh :Salt- resistant paddy offers hope to farmers, h*ttp://www.irinnews.org, [accessed 07/02/2013]

Islam KMN, and Mechler R (2007) *ORCHID: Piloting Climate Risk Screening in DFID Bangladesh. An Economic and Cost Benefit Analysis of Adaptation Options*. Institute of Development Studies, University of Sussex, UK

Islam, M.S. (ed.), (2008) Balanced fertilization for increasing and sustaining crop productivity, *Bangladesh J. Agric. and Environ.* 4: 1-8, Special Issue 2008

Islam S.M. Fakhrul , (2011) Decision support system for ex ante cost-benefit assessment of new agro-technology in the context of climate change, *Int. J. of Sustainable Society*, 2011 Vol.3, No.1, pp.82 – 106

Macedo, M.G.C., Gomes, L.F.A.M., Rangel, L.A.D. (2012) Sustainability indicators in the mining industry: an evaluation by PROMETHEE II. *Revista de Administração do Gestor*, 2 (1), 137-166

Macharis, C., Brans, J.P., Mareschal, B., (1998) The GDSS PROMETHEE procedure – a PROMETHEE–GAIA based procedure for group decision support. *Journal of Decision Systems* 7, 283–307.

Mareschal, B. (2013), Promethee-GAIA.Net, http://www.promethee-gaia.net/index.html, [accessed 07/02/2013]

Markantonis, V. and Bithas, K., (2009) The application of the contingent valuation method in estimating the climate change mitigation and adaptation policies in Greece. An expert-based approach, *Environ. Dev. Sustain.* (2010) 12:807–824, DOI 10.1007/s10668-009-9225-0

MoEF, 2009.*Bangladesh Climate Change Strategy and Action Plan 2009.*Ministry of Environment and Forests, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh, xviii+76pp.

Nasiri, H., Darvishi Boloorani, A., Faraji Sabokbar, H.A., Jafari, H.R., Hamzh, M.,Rafii, Y. (2012) Determining the most suitable areas for artificial groundwater recharge via an integrated PROMETHEE II-AHP method in GIS environment (case study: Garabaygan Basin, Iran*). Environmental Monitoring and Assessment*, DOI: 10.1007/s10661-012-2586-0

Nienke, M. Beintema and Wais Kabir (2006) *Bangladesh,* Agricultural Science and Technology Indicators, ASTI Country Brief No. 34, July 2006

Nguyen, N.V. (2006), *Global climate changes and rice food security*, International Rice Commission, FAO, Rome,Italy

Pandey S, Bhandari H, Hardy B, editors. 2007. *Economic costs of drought and rice farmers' coping mechanisms: a cross-country comparative analysis*. Los Baños (Philippines): International Rice Research Institute. 203 p.

Prvulovic, S., Tolmac, D., Radovanovic, L. (2011) Application of Promethee-Gaia Methodology in the Choice of Systems for Drying Paltry- Seeds and Powder Materials. Strojniski vestnik - *Journal of Mechanical Engineering,* 57, 10, 778–784.

Ramamasy, S. and Bass S. (2007) Climate variability and change: adaptation to drought in Bangladesh, A resource book and training guide, Food and Agricultural Organization of the United Nations, Rome, ISBN 978-92-5-105782-7

Ranjan, R. (2010) An assessment of agricultural sustainability indicators in Bangladesh: review and synthesis, *The Environmentalist* , March 2012, Volume 32, Issue 1, pp 99-110

Roy, B., (1991) The outranking approach and the foundation of Electre Methods, *Theory and Decision* 31: 49-73, 1991.

Roy, B. (1996) *Multicriteria Methodology for Decision Aiding.* Kluwer Academic Publisher, Dordrecth.

San Cristobal Mateo, J.R., 2012. Fuzzy PROMETHEE. Multicriteria Analysis in the Renewable Energy Industry, *Green Energy and Technology,* 73–76.

Sidker, T. (2010) *The Impacts of Climate Change on the Coastal Belt of Bangladesh: An Investigation of Risks & Adaptations on Agricultural Sector*, Proc. of International Conference on Environmental Aspects of Bangladesh (ICEAB10), Japan, Sept. 2010

Shlens, J. (2003), A tutorial on Principal Component Analysis: Derivation, Discussion and Singular Value Decomposition, http://www.snl.salk.edu/~shlens/pca.pdf [accessed 20/01/2013]

Vatn, A., & Bromley, D. (1995*). Choices without prices without apologies*. In D. W. Bromley (Ed.), Handbook of environmental economics . Cambridge, Massachusetts: Blackwell Publishers

Vincke, P., 1994. *Multi Criteria Decision Aid Methods.* Kluwer Publ., The Netherlands.

Wassmann., R., Jagadish. S.V.K., Heuer, S., Ismail, A., Redoña, E., Serraj., R., Singh, R.K.,, Howell, G., Pathak, H., and Sumfleth, K. (2009)*. Climate change affecting rice production: the physiological and agronomic basis for possible adaptation strategies*. Advances in Agronomy.Vol 101. Burlington: Academic Press, pp.59-122. ISBN: 978-0-12-374817-1

Winston, Y. , Mozaharul, A., Ahmadul, H., Abu Saleh, K., Ruane, A., Rosenzweig, C., Major, D., Thurlow, J. (2010) *Climate Change Risks and Food Security in Bangladesh*, ISBN 9781849711302, 176pp. EarthScan, London

World Bank (2000) *Bangladesh Climate Change and Sustainable Development*, Rural Development Unit, South Asia Region, Dhaka, Bangladesh

World Bank (2010) *The Economics of Adaptation to Climate Change* : Synthesis Report, World Bank, Washington DC 20433, United States