Introduction

The agriculture sector (combination of crop, fisheries, forestry and livestock) in Bangladesh has the largest share of land holdings and it is the major contributor to the country’s GDP (16.77%). Individually, crop and fish sectors contribute 9.49% and 3.68%, respectively [1]. The fishery sector has expended more than 5% from 1984/85 to 2011/12, according to the annual reports by Bangladesh’s Department of Fisheries (DOF). During the same period, aquaculture (a sub-sector of the fishery sector) grew more than 9% [2].

Pond culture is becoming the main source of fish production from inland aquaculture in Bangladesh [3]. 'Entrepreneurial pond culture' started in the 1990s and expanded rapidly as a stand-alone enterprise involving significant capital investment. Initially, pond culture/aquaculture was established in the coastal areas where crop fields were transformed into shrimp farms. Later, the practice extended to central and northern parts of Bangladesh as freshwater pond fish farming. The freshwater pond fish area increased from 0.26 million ha in 2001-2002 to 0.37 million ha in 2010-2011 [4]. Entrepreneurially operated ponds were constructed through the conversion of rice fields which were often leased-in for aquaculture to get the appropriate size of pond [2]. The areas of the north-central region of Bangladesh, (i.e. greater Mymensingh, Bogra, Rajshahi, Nogaon, Natore districts, etc.) are flood-free zones and suitable for different types of agricultural farming. Road-side or near to road-side agricultural lands are especially suitable for pond fish farming, which provides more income than crop farming. Therefore, Mymensingh district farmers are choosing pond fish farming instead of rice farming due to the comparative economic profitability of the former [5]. However, the lack of exact information in the current literature on what drives farmers to choose the economic practice for their property has led us to develop this research to try to identify the criteria that influence farmers’ decision to choose between rice and fish farming in the study area.
2 Material and methods

2.1 Area selection

The study focused on rice farming and small-scale freshwater pond fish farming. A multi-stage sampling procedure was followed to select the study area and the sample size. Mymensingh district was chosen as the study district because of the relevant presence of freshwater ponds for aquaculture. Four out of twelve Mymensingh sub-districts were selected based on the concentration of pond fish farming in these areas: Mucktagachha, Trishal, Phulpur, and Bhaluka (Figure 1). These areas are substantial for pond fish farming due to the availability of the hatchery-produced fry and industrially manufactured pelleted feed, favorable resources and climatic conditions, availability of ponds, and cheap and abundant labor [6].

2.2 Commodities selection

A crop calendar year represents two major growing seasons: summer season (or Kharif season, from April to October), and winter season (or Rabi season, from November to March). Rice is the staple food in Bangladesh; therefore, farmers produce rice in both seasons along with other crops and vegetables. The major growing crops in Mymensingh district are rice, jute, and some winter vegetables [8], but farmers who convert their land to fish farming are limited to rice and fish farming activities only. Farmers cultivate different varieties of rice and fish during summer and winter seasons. Although some farmers grow some vegetables, potatoes, sweet potatoes, and mustard, they were excluded from this sample unit because of the negligible amount of land that they use.

2.3 Data collection

A combination of the participatory, qualitative and quantitative methods was used for primary data collection during May-September 2012 in the northern part of Bangladesh. The primary information was obtained by interviewing key informants and doing a questionnaire for farm households. In total, 115 small-scale farmers were purposively selected from four sub-districts. The information was collected from key informants first and then from the household surveys. The participants were briefed about the background of the research, its objectives, and the type of data required for the study. The secondary information was collected from the available literature (publications and research articles) produced by different government and private organizations.

2.4 Analytical framework

The PROMETHEE method is part of the outranking methods proposed by Roy [9]. In 1982, BRANS presented the PROMETHEE I method for partial ranking of the alternatives, and the PROMETHEE II method for complete ranking of the alternatives [10]. PROMETHEE generates local scores as a result of a pair-wise comparison among the criteria that were previously selected by the user. The local scores are then aggregated into a global score, which leads to the PROMETHEE I or PROMETHEE II rankings [11, 12]. In PROMETHEE I, the resulting ranking is a partial pre-order, whereas the resulting ranking is a complete pre-order in PROMETHEE II. Some special types of PROMETHEE models have been developed by different researchers, such as the PROMETHEE GDSS for group decision-making [13], the PROMETHEE GAIA (Geometrical Analysis for Interactive Aid) for graphical representation [14, 15], the PROMETHEE TRI for problem sorting, and the PROMETHEE CLUSTER for nominal classification [16].
PROMETHEE II is the basis for implementing other PROMETHEE methods, referred by the majority of researchers [10]. The PROMETHEE rainbow and GAIA procedure are integrated into the PROMETHEE software package. The PROMETHEE rainbow is a disaggregated view of the PROMETHEE II complete ranking, and each slice of rainbow for each alternative corresponds to the contribution of the criterion [31]. This contribution corresponds to the $\Phi$ net flow score of the alternative taking into account the weight of the criterion. The PROMETHEE GAIA (Geometrical Analysis for Interactive Aid) investigates the strengths or weakness of solutions, incomparability between alternatives, and the quality of the alternatives with respect to the different criteria. In the process of investigation, similar preferences of the criteria vectors point in the same direction, while conflicting criteria are pointing in opposite directions and the power of alternative’s differentiation is defined by the length of each criteria vector [17]. Moreover, the PROMETHEE decision axis, $\Phi$, shows the direction of the compromise result based on the weight, the preference function, and assigned thresholds to the criteria. Therefore, PROMETHEE rainbow and GAIA method were used to identify the best criteria for decision-making regarding farmland in the study areas.

There are some important sequential tasks before proceeding to the use of PROMETHEE method. The first task is to identify the appropriate comparable criteria performance over the different alternatives. All criteria are not equally important to the decision makers. Additionally, PROMETHEE II assumes that the decision makers are able to weigh the criteria appropriately [18]. Then, the next task of this method is for the decision-makers to assign weigh values to the criteria. The final task is to set a particular preference function for each criterion (the difference between the evaluations of two alternatives). The preference function is translated into a preference degree ranging from zero to one [10]. Vincze and Brans [19] proposed six types of function to simplify the selection of the preference function by decision makers: usual criterion, U-shape criterion, V-shape criterion, level criterion, V-shape with indifference criterion, and Gaussian criterion. Gaussian preference is a generalization of the other five forms and it was used in this research. Moreover, Gaussian preference does not have discontinuities, which contributes to the stability and the robustness of the results that it produces [20].

The PROMETHEE II method follows some stepwise procedures (Figure 2). The first step is the determination of deviations based on pair-wise comparisons, which are followed by using a relevant preference function for each criterion [10]. The next step is to calculate the overall or global preference index. The aim is to evaluate the overall preference of alternative ‘a’ over alternative ‘b’. The overall or global preference index $\pi(a,b)$ is calculated by the weighted sum of the preference degrees $P_j(a,b)$. The weight $w_j$ represents the importance of each criterion in the decision making. Each alternative is then compared by $n-1$ other alternative, thus resulting in two outranking flows (a positive and a negative) found in step 4 of PROMETHEE I partial ranking. Some alternatives in the partial ranking are comparable, while others are not. The last step of PROMETHEE II procedure is to calculate the net outranking flow for each alternative, thus completing PROMETHEE II ranking. At this stage, all alternatives become comparable, although a considerable part of the information is lost after taking the difference of the positive and negative outranking flows [21].

Two software packages are available to run the PROMETHEE method: PROMCALC which was developed by Mareschal and Brans [22], and DECISION LAB, developed by Canadian company ‘Visual Decision’ in collaboration with Mareschal and Brans [23]. PROMCALC uses PROMETHEE I, II, V, VI as well as the GAIA visual module for all types of multi-criteria problems [10]. DECISION LAB replaced the PROMCALC because of its computational
help and analytical aids which improved the quality and reliability of this software for decision-making processes [24]. DECISION LAB also includes treatment of missing values, categorization of actions or criteria, and the definition of multiple scenarios [18, 25, 26].

2.5 Model specification

Economic factors are the leading decision making criteria of land use alternatives in the areas selected for the research. Economic factors include: labor requirement, land conversion cost, operating cost production rate, and total revenue. Conversion cost was calculated for the year 2012 by compounding the initial cost of land conversion of the household plus a 10% interest rate [27]. Another important economic performance indicator, growth rate of output market price, was included in the multi-criteria decision making method. Growth rate of market price is a good criterion for choosing any enterprise. Therefore, market price data for crop and fish were collected from the DAM (Department of Agricultural Marketing) database during 1990-2013 to calculate their market price growth rate. The prices of Local Aman (course), Aman (pajam), Local Boro and Boro (pajam) were used to calculate the market crop price growth rate. The fish market price growth rate was calculated based on the prices of Pangus (small: 1.5-2kg), Rohu (small: 1.5-2kg), Catla (small: 1.5-2kg), Mrighel (small: 1.5-2kg), Tilapia, Rui, Koi, Shing and Magur.

Some economic factors were maximized while others were minimized for the PROMETHEE method. The preference functions and weights were also associated with the criteria (Table 2). In the first step, all the weights were set to equal values \( w_i = 1, i = 1, 2, ..., 5 \), without any specific priorities, and the program’s default absolute threshold values were used. Threshold values can be absolute or a percentage. The values fixed for each criterion was based on a selected preference function.

3 Results and discussion

Decision-making is a psychological process. It is influenced by the decision maker’s socio-economic status, and by certain institutional setups. Decision-making factors always depend on a particular time and place. Farm household heads were the decision makers chosen for this research.

3.1 Farmer’s socio-economic characteristics

Socio-economic characteristics of the decision makers are family size, formal schooling level, land holdings, and number of household members that are regularly involved in farming operations. The survey revealed that the average family size per household in aggregate was 6.47; most of the family (79%) was categorized as medium-size, consisting of 4 to 8 members per household. The average family size in the study areas was bigger than the national average of 5.18 [28]. Variation occurred due to the larger number of samples used in the national estimation compared to the sample size of this research.

Education always influences the process of decision making in farming operations. Education is primarily divided in two categories: formal and informal. Since informal education level could not be accurately identified due to its subjective nature, this research only considered the formal schooling level of the decision makers as a sign of literacy. Sixty-nine percent of the decision makers had completed high school. The literacy rate among the decision makers surveyed in this study (90%) was higher than the national average (57.9%, [29]). This higher figure was not surprising because only the decision maker’s or the household head’s literacy level was considered in this study to calculate the literacy level of the sample, whereas in the national survey the education/literacy level of every family member is included.

The number of household members who usually work on the farm (1.50 on average) indicated that the families had the potential to supply labor for the family agricultural activities. Average household size was 6.47 members, but only 1.50 family members regularly worked on the farm, an indication that rural employment forces are becoming less involved in farming activities. This research also showed that 4.94 family members who were part of the active labor force group were between 10 and 60 years of age.

Farm size was categorized according to the amount of land held by the farmers and is as follows: owned, rented/shared/mortgaged-in land, or rented/shared/mortgaged-out land. The average land holding status of small, medium and large-scale farms was 0.53 ha.

3.2 Land use decision making

The values of criteria assessment are summarized in Table 2. Six criteria (three maximized and three minimized) were included in the PROMETHEE analysis of land-use alternatives for decision making. In all situations,
The fish farming alternative dominated over crop farming under the ‘production rate’, ‘total revenue’ and ‘price growth rate’ criteria. Alternatively, crop farming dominated over fish farming under the ‘labor requirement’, ‘conversion cost’ and ‘land conversion cost’ criteria.

The performance of the single alternatives can be seen in Figure 3. Rice and fish farming were in the same rank because of three strong criteria against three weak criteria, but also because of imposing equal weights to all criteria.

Figure 3 shows that both farming activities/practices had equal preference levels for the farmers. Table 2 shows that the favorable criteria for rice farming were labor requirement, conversion cost, and operating cost. It was expected that farmers would minimize these three criteria since small-scale farmers, who were the focus of this research, have fewer resources to provide capital for fish farming; thus, higher total revenue, production rate, and output price growth rate of fish farming would not be decision making factors for this group. However, total

### Table 1: Socio-economic characteristics of the decision maker

| Variables with category                        | Percentage | Mean   | Range |
|-----------------------------------------------|------------|--------|-------|
| Family size                                   |            |        |       |
| Small (less than 4 members)                   | 6.09       |        |       |
| Medium (4-8 members)                          | 78.70      |        | 2 – 16|
| Large (more than 8 members)                   | 15.22      |        |       |
| Average in the study area (no./hh) Bangladesh (2010) | 6.47       |        | 5.18  |
| Formal schooling level of HH’s head           |            |        |       |
| Illiterate (0 level)                          | 10.00      |        |       |
| Primary (1-5 level)                           | 20.43      | 8      | 0 – 18|
| Secondary (6-10 level)                        | 48.26      |        |       |
| Higher secondary (11-12 level)                | 11.74      |        |       |
| More than higher secondary (more than 12 level) | 9.57      |        |       |
| Average literacy rate of the HH’s head        | 90.00      |        |       |
| Literacy rate in Bangladesh (2011)            | 56.70      |        |       |
| HH members regularly work in the farm          |            |        |       |
| Male                                          | 97.98      |        |       |
| Female                                        | 1.45       | 1.50   | 0 – 7 |
| Children                                      | 0.58       |        |       |
| Average land holdings (ha)                    |            | 0.53   |       |

Source: Bangladesh average household size [29]
For literacy rate [30]
Author’s calculation based on field study, 2012

### Table 2: Small farm land-use alternatives in equal weight criteria situation

| Items   | Decision making criteria | Labor requirement man-day/ha Min/Max | Min | Conversion cost (BDT/ha) Min | Min | Operating Cost (BDT/ha) Min | Min | Production rate (Ton/ha) Max | Max | Total Revenue (BDT/ha) Max | Max | Price Growth rate (%) Max |
|---------|--------------------------|--------------------------------------|-----|----------------------------|-----|----------------------------|-----|-----------------------------|-----|-----------------------------|-----|--------------------------|
| S: Gaussian Weight | 16.67       | 16.67 | 16.67 | 16.67 | 16.67 | 16.67 | 16.67 | 16.67 | 16.67 | 16.67 | 16.67 |
| Crop    | 28                | 88,346 | 255,624 | 3.22 | 174,471 | 7.24 |
| Fish    | 265               | 300,860 | 557,673 | 9.41 | 1,041,713 | 11.57 |

Source: Field survey, 2012
revenue, production rate, and output price growth rate for fish farming were, respectively, 6, 2, and 1.6 times higher than those of rice farming. In an economic sense, fish farming was more attractive to farmers than rice farming. However, PROMETHEE results revealed that labor requirement, conversion cost, and operating cost were the major influential criteria for land use decision making. By giving more rather than equal weights to total revenue, production rate, or output price growth rate, the results of the model indicated that fish farming was the preferred activity of the small-scale farmers in the study area.

According to GAIA plane in Figure 4, ‘labor requirement’, ‘conversion cost’ and ‘operating cost’ conflicted with ‘production rate’, ‘total return’ and ‘output price growth rate’. Production rate had a high differentiation power as indicated by the length of its vector. The PROMETHEE decision axis $\Phi_i$ was in the rice and fish farming co-ordinate, with the long decision axis representing the higher reliability of the result. Changes in the weight values will only change the decision axis $\Phi_i$ while the positions of the alternatives and the criteria will remain the same [32].

4 Conclusions

PROMETHEE has strong power for multi-criteria decision analysis. Single criteria decision making is a simple process that can easily provide a final decision when there are conflicting areas. The process becomes difficult when different favorable conflicting criteria need to be considered. In this study, we tried to determine the influential criteria for making land use decisions between rice and fish farming practices in northern Bangladesh. Some assumptions, such as giving equal weight to the criteria and choosing appropriate preference functions, were made in order to run the analysis. Once all criteria were analyzed simultaneously, the model indicated that there was an equal preference between rice and fish farming practices among the small-scale farmers considered in this research. This is an important indicator for policy makers because there has been a debate on whether or not more rice fields should be converted to fish farming in the near future. Noticeably, rice is the staple food to the people of Bangladesh and, currently, we are self-dependent on rice production. Therefore, the conversion of more rice fields into fish farming would be a threat to the overall rice production of the country. However, the findings of this research assured that farmers were more interested in rice farming in the study areas because of three major influential criteria associated with this practice: lower labor requirements, lower operating costs, and zero conversion costs. However, these findings are applicable to small-scale farmers only who, incidentally, correspond to 89% of all farmers in Bangladesh. Otherwise medium or large-scale farmers may prefer the highly profitable fish farming since these producers are likely to have the resources to support the operating costs of such practice.

References

[1] BER, Bangladesh Economic Review, Ministry of Finance, Government of the people's republic of Bangladesh, 2011
[2] Belton, B. et al., Review of Aquaculture and Fish Consumption in Bangladesh. The WorldFish Center, Studies and Reviews 2011-2053, 2011
[3] DOF, Fisheries Statistical Year Book of Bangladesh, Fisheries Resource Survey System, Department of Fisheries, Ministry of Fisheries and Livestock, Government of the People’s Republic of Bangladesh, 2010

[4] DOF, Fisheries Statistical Year Book of Bangladesh, Fisheries Resource Survey System, Department of Fisheries, Ministry of Fisheries and Livestock, Government of the People’s Republic of Bangladesh, 2012

[5] Sarker, R.A., Talukdar, S., and Haque, A.F.M.A., Determination of Optimum Crop Mix for Crop Cultivation in Bangladesh, Applied Mathematical Modeling, 21(10): 621-632, 1997

[6] Costa, T., Naser, M.N., Ahmed, N., Bin Tareque, H., Impact Assessment of Some Selected AFGRP Funded Projects in Bangladesh, Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh, 2006

[7] Bangladesh, Mymensingh Sadar Upazila, National Encyclopedia of Bangladesh, Asiatic Society of Bangladesh, http://www.banglapedia.org/HT/M_0536.htm, Accessed date: February 10, 2014

[8] Bpedia, Mymensingh District, National Encyclopedia of Bangladesh, Asiatic Society of Bangladesh, http://www.bpedia.org/M_0432.php, Accessed date: February 10, 2014

[9] Roy, B., Classement et Choix en Présence de Points de Vue Multiples (la Méthode ELECTRE), Revue Francaises Informatique Recherche Operationnelle, 2(8): 57-75, 1968

[10] Behzadian, M., Kazemzadeh, R.B., Albadvi, A., Aghdasi, M., PROMETHEE: A Comprehensive Literature Review on Methodologies and Applications, European Journal of Operational Research, 200(1): 198-215, 2010

[11] Brans, J.P., Lingenierie de la Decision. Elaboration D'instruments Daide a la Decision Methode PROMETHEE, In: NADEAU, R., and M. LANDRY (Eds.), Laide a la Decision: Nature, Instrument set Perspectives Davenir. Presses de Universite Laval, Quebec, Canada, 1982

[12] Brans, J., Vincke, Ph., A Preference Ranking Organization Method: The PROMETHEE Method, Management Science, 31: 647-656, 1985

[13] Macharis, C., Brans, J.P., Mareschal, B., The GDSS PROMETHEE Procedure – A PROMETHEE – GAIA Based Procedure for Group Decision Support, Journal of Decision Systems, 7: 283-307, 1988

[14] Mareschal, B., Brans J.P., Geometrical Representations for MCDA, European Journal of Operational Research, 34 (1): 69-77, 1988

[15] Brans, J.P., Mareschal, B., The PROMETHEE GAIA Decision Support System for Multicriteria Investigations, Investigation Operative, 4(2): 107-117, 1994(a)

[16] Figueira, J., De Smet, Y., Brans, J.P., MCDA Methods for Sorting and Clustering Problems: PROMETHEE TRI and PROMETHEE CLUSTER, Working Paper 2004/02, Université Libre de Bruxelles, 2004

[17] Dulmin, R., Mininno, V., Supplier Selection Using a Multicriteria Decision aid Method, Journal of Purchasing and Supply Management, 9(4): 177-187, 2003

[18] Macharis, C., Springael, J., De Brucker, K., Verbeke, A., PROMETHEE and AHP: The Design of Operational Synergies in Multicriteria Analysis: Strengthening PROMETHEE with Ideas of AHP, European Journal of Operational Research, 153: 307-317, 2004

[19] Vincke, J.P., Brans, Ph., A Preference Ranking Organization Method The PROMETHEE Method for MCDM Management Science, 31: 641-656, 1985

[20] Brans, J.P., Vincke, Ph., Mareschal, B., How to Select and How to Rank Projects: The PROMETHEE Method, European Journal of Operational Research, 24(2): 228-238, 1986

[21] Gawande, V.V., Bundele, A.T., Girj, P., A Multiple Attribute Decision Making Methodology for Process Optimization in Small Scale Industries, International Journal of Latest Trends in Engineering & Technology, 2(2): 251-259, 2003

[22] Mareschal, B., Brans, J.P., PROMCALC – The PROMETHEE Software User’s Guide, HWPR/034, VUB, Brussels, 1986

[23] Decision Lab, Getting Started Guide. Visual Decision Inc., Montreal, Canada, 2000

[24] Geldermann, J., Zhang, K., Review. “Decision Lab 2000”, Journal of Multi-Criteria Decision Analysis, 10: 317-323, 2001

[25] Climaco, J., Multicriteria Analysis, Springer-Verlag, New York, 1997

[26] De Smet, Y., Mareschal, B., Verly, C., Extending the PROMETHEE II Method to Continuous and Combinatorial Multi-objective Optimization Problems: A First Model, IEEE International Conference on Industrial Engineering and Engineering Management, 1(4): 1608-1611, 2009

[27] Bangladesh Krishi Bank, Crop loan, http://www.krishibank.org.bd/showDocument.php?documentid=1122, [Accessed on July, 2012]

[28] BBS, Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Dhaka, Bangladesh, 2010

[29] HIES, Household Income and Expenditure Survey. Bangladesh Bureau of Statistics, Dhaka, Bangladesh, 2010

[30] BER, Bangladesh Economic Review, Ministry of Finance, Government of the people’s republic of Bangladesh, 2014

[31] Anonymous, Visual PROMETHEE, Visual PROMETHEE 1.1 Manual Version 1.0., www.promethee-gaia.net, 2003

[32] Brans, J.P., Mareschal B., (1994b). The PROMCALC & GAIA Decision Support System for Multicriteria Decision Aid, Decision Support Systems, 12: 297- 310, 1994(b)

[33] DAM, Department of Agricultural Marketing. Ministry of Agriculture, Government of the People’s Republic of Bangladesh, http://www.dam.gov.bd/jsp/index.jsp [Accessed date: September 15, 2013]
## Appendix

### Table 1: Yearly price of crop and fish in Bangladesh

| Year | Crop price (tk/ton) | Fish price (tk/ton) |
|------|---------------------|---------------------|
| 1990 | 6468                | 63010               |
| 1991 | 7619                | 68651               |
| 1992 | 7022                | 75524               |
| 1993 | 5689                | 85172               |
| 1994 | 7455                | 86395               |
| 1995 | 9056                | 115068              |
| 1996 | 6674                | 101362              |
| 1997 | 6529                | 111132              |
| 1998 | 5772                | 118847              |
| 1999 | 9371                | 112903              |
| 2000 | 7869                | 121323              |
| 2001 | 7228                | 128639              |
| 2002 | 7956                | 102001              |
| 2003 | 10054               | 119266              |
| 2004 | 8896                | 109676              |
| 2005 | 12471               | 90055               |
| 2006 | 10798               | 136463              |
| 2007 | 13382               | 165048              |
| 2008 | 19007               | 193926              |
| 2009 | 13380               | 185429              |
| 2010 | 19191               | 175007              |
| 2011 | 19610               | 210730              |
| 2012 | 17166               | 231770              |
| 2013 | 17710               | 237933              |

Source: DAM [33]