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Fish Farming Land Allocation in Northern Part of Bangladesh: Exploring Causes across the Farm Sizes

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Abstract The research was conducted to find out the decision-making quantitative and qualitative variables that devise the different types of farmers' involvement in freshwater fish farming in Bangladesh. Combinations of the participatory, qualitative and quantitative methods were used for primary data collection. Researchers considered 29 explanatory variables under the category of economic, socio-economic, institution, ecology, and geography to find out the appropriate causes of increasing or decreasing the fish land ratio. Ten variables were selected for the regression model after applying two multi-collinearity detection methods. Regression model shows that five economic factors (Crop and fish labor requirement, availability of cereal food, least crop area and availability of feed), and one geographical factor (distance of extension office) have a significant effect on making the decision of fish land use. Among the significant factors, fish feed availability plays the vital role to make the decision of freshwater fish farming in Bangladesh.

Keywords: *small farmer, freshwater fish farming, determinants, regression analysis, bangladesh*

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1. Introduction

In Bangladesh, a country of 155.8 million people [6], farmers engage in smallholder subsistence crop (mainly rice) farming. Total cropland area of Bangladesh is 8.44 million ha [1]. Due to rapid population growth (1.37 % per year, [4]), urbanization, industrialization and diversification of agriculture (redistribution of land between agricultural sub-sectors), per capita cropland has been decreasing over time. The cultivated area is at present 0.125 acre per person [27]. As a consequence, efficient use of the small pieces of land is becoming a great challenge for the farm households of Bangladesh.

In some parts of northern Bangladesh, the landscape was once dominated by rice and is now occupied by freshwater ponds for fish as to fulfill the protein requirement domestically and to increase the farm income substantially. Total pond fish production (excluding shrimp) during last decades has increased about two times, from 0.69 million ton in 2001-2002 [11] to 1.22 million ton in 2010-2011 [12]. Expansion of pond aquaculture requires land that normally comes from croplands, wetlands, and seasonal waterbodies.

Crop selection is one of the critical activities of farms, traditionally based on resource fixity, ancestor profession and neighbor land use decision. The areas of the north-central region of Bangladesh, i.e. greater *Mymensingh, Bogra, Rajshahi, Nogaon, Natore* etc. districts, are flood-free zone and suitable for different types of agricultural farming. Especially the road-side or near to road-side agricultural lands are suitable for pond fish farming which provides manifold more income than crop farming. Reference [31] found that the farmers of *Mymensingh* district making decision of pond fish farming bearing in mind the economic profitability of pond fish farming in comparison to cultivating rice or any other crops.

Land is changing all over the world with the passing of time. Obviously there are some causes of changing land use patterns. Land use decisions are influenced by the factors at the local, regional, or global scale. Only some factors have a direct relation to making land use decisions. The other causes are indirect in managing the land, and are thus uncontrollable by these communities [20]. Reference [10] found that households are diverse in terms of resources, and operate within heterogeneous biophysical environments and the land use patterns exhibit spatial dynamics. Farm size, farm household demographic characteristics, off-farm income, farmer group membership (neighborhood context), resource endowments and policy-institutional factors exerted significant effects on land use [9,13,24,26]. So, it is necessary to understand, how various factors interact in particular contexts to identify the causes of land use change [14].

Most of the farmers in Bangladesh are small (about 89 %), who have only less than 2.49 acres or 1 ha land. Landless and the farmers who do not used their land in pond fish farming were excluded from the sample units. Though small but all farmers produce fish for commercial purpose except some small amount kept for home consumption, but crop farming was not commercial farming to the farmers. The primary target of crop farming is to fulfill the family food demand and only sell the surplus amount to the market. Most of the small farmers need to buy a partial amount of rice from the market in the lean season because of forced selling in the harvesting season.

However, after reviewing these factors of land use change and existing literature gaps, the research question is set to estimate the magnitude of different quantitative and qualitative factors that effect on the amount of land to be used for fish farming.

2. Research Methods

2.1. Area Selection

The area was selected on the basis of concentration of freshwater pond fish farming in Bangladesh. The land conversion from crop to fish farming is mostly concentrated in the northern part of Bangladesh. Therefore, the most land-converted area, *Mymensingh* District, from the north part of Bangladesh was considered for this project. Among 64 districts in Bangladesh, *Mymensingh* district is an area of 4363.48 square km and consists of 12 sub-districts. The soil formation of the district is flood plain, gray piedmont, hill brown and terrace [21]. There are small valleys between the high forests; annual average temperature maximum 33.3°C, minimum 12°C; annual rainfall 2174 mm. Agriculture is the main occupation (57.67 %), followed by transport, commerce, service and others. The amount of land used for cultivation is 346117 hectares; single crop 18.58 %, double crop 70.20 % and treble crop land 11.22 % [2]. Four major concentrated sub-districts such as *Mucktagachha*, *Trishal*, *Phulpur*, and *Bhaluka* were considered among 12 sub-districts of *Mymensingh* district. In total 230 samples were collected from four sub-districts following the purposive sampling procedure.

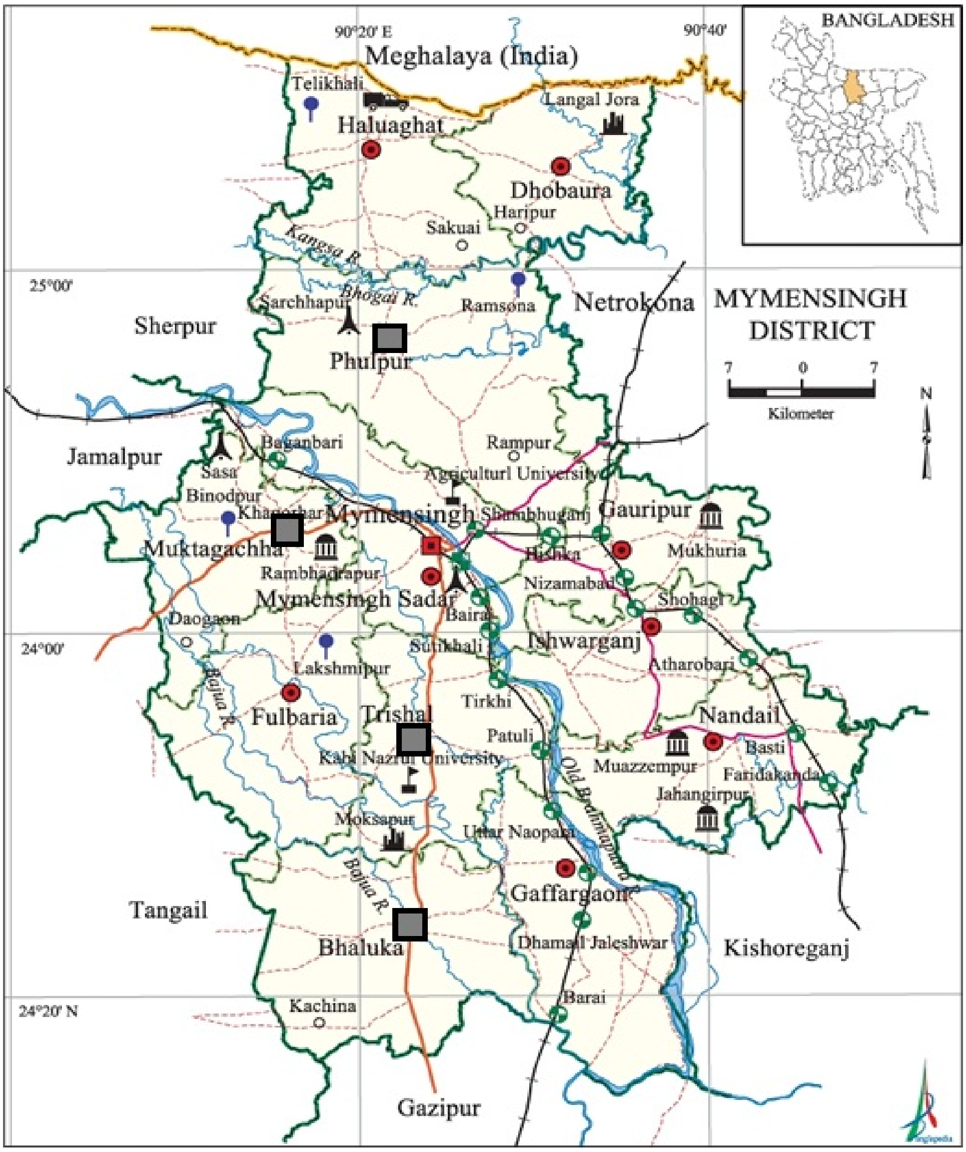

Figure 1. Map of the study areas (rectangle marked area) (Source: *Mymensingh* District, [1])

2.2. Farm Size Selection

The sampling units were classified into different groups based on their land holding status. Most of the farmers in Bangladesh are small and medium-scale farmers (98.45 %) who have only less than 7.5 acres or 3 ha land and some few large-scale farmers (1.55 %). According to agricultural census of Bangladesh, a farm household was classified into three categories such as small (up to 2.4 acres), medium (2.5 to 7.4 acres), and large (7.5 acres or more) [4]. The landless and the farmers not using their land in pond fish farming were excluded from the sample units. All farmers produced fish for commercial purposes except some small amounts kept for home consumption, but crop farming was not commercial farming for the small and medium-scale farmers. The primary target of crop farming is to fulfill the family food demand and only sell the surplus amount to the market.

2.3. Commodities Selection

A crop calendar year represents two major growing seasons namely summer season (locally named *Kharif* season from April to October) and winter season (locally named *Rabi* season from November to March). The summer season is mostly rain-fed and the winter season is mostly irrigated in Bangladesh. The major portion of the cereal food supply comes from winter crops. Rice is the staple food in Bangladesh. Therefore, every farmer produces 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 the farmers who convert their land to fish farming confined themselves only to rice and fish farming activities. Although some farmers produced some vegetables, potatoes, sweet potatoes, and mustards those are excluded in the study because of using a negligible amount of land. Farmers cultivate different varieties of rice and fish during summer and winter seasons. The name of the rice varieties are *Hori dhan*, BR11 (locally called *Mukta*), BR22 (Locally called *Kironmala*), BRRI hybrid3 and BRRI hybrid4, BR28, and BR 29.Most of the farmers practice *Hori dhan* followed by *Mukta* and *Kironmala*. A very few farmers cultivate hybrid rice because of high production costs though its output is highest among all winter rice varieties. Among winter rice varieties, BR28 is the popular rice variety for the farmer though its output is the lowest among all winter crops varieties. The BR29 rice variety is also popular with those farmers who have the ability to apply more fertilizer to the field, which means comparatively large farmers have the capability of cultivating this variety. Like the summer rice, the winter rice hybrid variety is also unpopular to the farmer.

There is a significant difference in fish farming varieties. One variety is significantly different from other varieties in stocking rate, yield and in price also which is not mentioned here. Particularly, in the study areas, farmers are performing polyculture instead of monoculture to avoid the risk. Six polyculture combinations were selected for the research. The name of the fish varieties are Pangus (*Pangasius hypophthalmus*), Koi (*Anabas testudineus*), Shing (*Heteropneustes fossilis*), Magur (*Clarias gariepinus*), Rohu (*Labeo rohita*), Catla (*Catla catla*), Mrigel (*Cirrhinus cirrhosis*), Silver carp (*Hypophthalmicthys molitrix*), Common carp (*Cyprinus carpio*), Tilapia (*Oreochromis mossambicus*), Gulsa (*Mystus cavasius*), Shorpunti (*Barbodes gonionotus*), Bata (*Labeo bata*).

2.4. Data Collection

Combinations of the participatory, qualitative and quantitative methods were used for primary data collection. The primary information was obtained through interview with key informants and questionnaire survey with farm households. At first, the information was collected from the key informants and then followed the household surveys. A short background of the research, study objectives, and data requirements was briefed with the participants.

The secondary information was collected by reviewing the literature (publications and research articles) and obtaining through visiting some organizations such as BBS (Bangladesh Bureau of Statistics), DAM (Department of Agricultural Marketing), DOF (Department of Fisheries), *Upazila* Fisheries Officer (UFO), WorldFish center etc. Some important secondary data obtained from the experts of this field through email communication.

2.5. Model Specification

In the process of land use change, spatial variability creates difficulty in applying statistical models. Reference [20] found that high geographic variability in land cover types, biophysical and socio-economic drivers of land use changes or institutions (including policies) in the most regions. The spatial heterogeneity needs different model parameterization to identify the variability in the causes and consequences of land use changes. Even in the same region, due to different land cover types, socio-economic drivers and ecological factors such as land size, productivity, cropping intensity, etc. also demand separate model parameterization [33].

The model can be designed depending on the objective of the research and the availability of the data; one can use complex or simple analytic models to analyze the factors influencing land use change. Reference [15] used linear regression but designed a model comprising several dependent variables. Alternatively, reference [29] used multivariate analytical methods such as Cluster Analysis and Discriminant Analysis to analyze factors influencing land use and management. In this research, the objective is to understand the way of factors explaining the variation in farmer fish farming land use decisions. For this purpose, multivariate linear regression is a suitable analytical tool. Reference [27] found that regression analyses in this regard could provide a better explanation by identifying the factors that determine the amount of land converted by the households. Reference [34] also stated the analyses of correlation; multiple regression and econometric models have been recognized as useful tools to identify determinants of land use change.

Reference [18,28] mentioned when both independent and dependent variables are numerical then the multiple linear regression models could analyze the influencing factors of land use decisions. The dependent variable, the ratio of fish land, considered in this analysis is numerical and most of the independent variables are numerical (Table 1). Among the independent variables, all economic, socio-economic and geographical factors are numerical but in the case of ecological factors, some variables such as farm size, productivity, overflowed land by water, and depth of the land are numerical. The rest of the ecological factors such as land-type and cropping intensity and all institutional factors are non-numerical, usually a qualitative variable, and turned into a dummy variable to make this variable compatible with the linear regression model.

Table 1. Explanatory variables

Variables	Code	Specification
1. Economic factors		
Farm size	X_{FS}	Actual farm size (decimal/household)
Crop gross margin	X_{CGM}	Gross margin from crop farming (BDT/hectare/year)
Fish gross margin	X_{FGM}	Gross margin from fish farming (BDT/hectare/year)
Other farm income	X_{OFI}	Other farm income (BDT/person/year)
Non-farm income	X_{NFI}	Income from off-farm sources (BDT/person/year, including remittances)
Crop labor	X_{CL}	Labor input in land management and crop production (md/hectare/year)
Fish labor	X_{FL}	Labor input in land management and fish production (md/hectare/year)
Availability of cereal food	X_{HGC}	No. of month home grown cereal feed the household (no.)
Least crop area	X_{LCA}	Least amount of areas want to keep for crop farming (decimal/household)
Amount of credit	X_{Cr}	Amount of credit received in a year (BDT/hectare/year)
Availability of feed	X_{FC}	Money available for feeding the fish (BDT/hectare/year)
2. Socioeconomic factors		
Educational level	X_{EL}	Schooling period of the household head (no. of years studied at a school/college)
Active labor force	X_{ALF}	Active labor force, aged 10–60 years, at home (no./household)
3. Institutional factors		
Crop farming training	X_{CFT}	Crop farming training attended by household head (dummy variable: yes =1 & no = 0)
Fish farming training	X_{FFT}	Fish farming training attended by household head (dummy variable: yes =1 & no = 0)
Crop technology	X_{CT}	Availability of new crop technology (dummy variable: yes =1 & no = 0)
Fish technology	X_{FT}	Availability of new fish technology (dummy variable: yes =1 & no = 0)
4. Ecological factors		
Crop yield rate	X_{CYR}	Crop yield rate (ton/hectare/year) (composite yield of all crops)
Fish yield rate	X_{FYR}	Fish yield rate (ton/hectare/year) (composite yield of all fish)
Highland	X_{HL}	Converted land type (dummy variable: highland = 1& otherwise = 0)
Plain land	X_{PL}	Converted land type (dummy variable: plain land = 1& otherwise = 0)
Lowland	X_{LL}	Converted land type (dummy variable: lowland = 1& otherwise = 0)
Single cropping intensity	X_{SCI}	Converted land cropping intensity (dummy variable: single crop = 1, otherwise = 0)
Double cropping intensity	X_{DCI}	Converted land cropping intensity (dummy variable: double crop = 1, otherwise = 0)
Triple cropping intensity	X_{TCI}	Converted land cropping intensity (dummy variable: triple crop = 1, otherwise = 0)
Overflowed by water	X_{OW}	Converted land overflowed (dummy variable: yes =1 & no = 0)
Depth of land	X_{DL}	Depth of converted land from the paved road (feet)
5. Geographical factors		
Distance of road	X_{DR}	Distance of converted land from the nearest paved road (meter)
Distance of extension office	X_{DEO}	Distance of extension service center from farming household (km)

The dependent variable is hypothesized as being influenced by a set of independent variables: $X_1,...,X_n$ (Table 2) in the multiple regression analysis,. The model has specified as follows:

$$Y = b_0 + b_1 X_1 + b_2 X_2 + ... + b_n X_n + e_i$$

Where,

Y is the dependent variable, b_0 is the intercept, b_1, b_2,...,b_n are the coefficients of explanatory variables.

2.6. Multicollinearity Test

Multicollinearity is a problem that refers to the variables that correlate with other variables in the model. Severe multicollinearity can increase the variance of the estimates, even changing the sign of the coefficients. As a result, it is difficult to specify the correct model and interpret the result of the coefficient of estimates. Reference [5] stated increase variances are problematic in a regression because few variables add very little independent role to the model. In contrast, reference [32] narrated that no statistical test can confirm whether multicollinearity is a problem or not, but there are some mechanisms to identify the presence of multicollinearity [7].

In this research, to obtain the causes of land use change, many explanatory variables were used. So, it should be expected that some variables have a correlation to others. Correlation Matrix Analysis (CMA) and Variance Inflation Factors (VIF) are used to overcome the multicollinearity problem.

Reference [16] described that Correlation Matrix Analysis (CMA) is useful to find out the multicollinearity between two variables, but it does not provide any indication of the collinearity between more than two variables. Therefore, this method cannot provide complete information about the collinearity among all predictors. In this research, firstly CMA was done to identify those variables that have a high degree of correlation between each other and low degree of correlation with the dependent variable. Secondly, the Variance Inflation Factor (VIF) was applied in regression analysis, which explains the degree of multicollinearity amongst the predictors. VIF analysis is probably the most widely used approach, since its measure the effects of estimate precision. However, the shortcoming of this method is unable to determine which variables are mainly responsible for variance inflation [16].

$$VIF\left(\hat{\beta}\right) = \frac{1}{1 - R_i^2}$$

$$Tolerance\left(\hat{\beta}\right) = \frac{1}{VIF} = \frac{1}{1 - R_i^2}.$$

Where, R^2 means the coefficient of determination of the regression equation. This equation gives a VIF value for each explanatory variable after considering other explanatory variables and the dependent variable of the model. There is a significant debate about the acceptance value of VIF. Reference [25] used the acceptance level of VIF is 4, [30] recommended maximum VIF value of 5 and some researchers suggested maximum VIF value can be 10 [17,19,22,23]. So, there is some space for the researcher to set the maximum VIF value considering the characteristics and the necessity of the variables. Tolerance levels (nothing but the inverse of VIF) are also used to determine the collinearity among variables.

2.7. Variables Specification

All selected households, 230 farm households, converted their land from crop to fish farming, but the amount of fish farming land depends on various quantitative and qualitative variables. Surely the amount of fish farming land should be higher for the large farmer than the small farmer. To avoid this trending error, a ratio of fish land was calculated for each farmer. The dependent variable 'ratio of fish land' was set for the three groups such as small, medium and large farm. Farm categories are derived for the seeking of homogeneity on the basis of land size.

Initially, 29 independent variables, including 14 qualitative variables, were selected for regression analysis (Table 1). Some variables were highly correlated with each other and some variables have a low correlation with the dependent variable. Therefore, a multivariate correlation analysis was applied to find out the necessary independent variables for the regression model.

2.7.1. Selection of Independent Variables

CMA revealed 19 independent variables were either highly correlated with each other ($r > 0.5$) or express a low degree of correlation with the dependent variable. Finally, 10 independent variables were included in the model (Table 2) and other variables were dropped from the regression model. Eighteen variables were excluded due to a low degree of correlation with dependent variables that means these variables have less impact on increasing or decreasing the ratio of the fish land area in the study areas. Only one variable (fish yield rate) was excluded because of a high degree of correlation with the variable 'availability of feed'; otherwise it will unnecessarily increase the variance of the estimate, which can lead to the wrong interpretation of the results.

The selected explanatory variables have the assurance that they are not correlated with each other, but it is not sure when they interact simultaneously in a regression model. Variance Inflation Factor (VIF) analysis is the way to find the solution. Table 2 shows the result of VIF of explanatory variables of different farm categories. The values of VIF are not more than 3, for any variable, which explain there is no objectionable degree of multicollinearity amongst the predictors.

Three types of farms were described in the descriptive analysis part of this thesis (small, medium and large). As mention earlier, there are only 25 households in the case of large farms. This does not fulfill the minimum number of samples for testing the t-statistic. Therefore, this group was added to the medium farm size group and a new group name medium-large farm group was made. It will notify whether any differences exist between medium and medium-large group reaction to changing the fish land ratio in the study areas.

Table 2. Variance Influencing Factors (VIF) values of selected explanatory variables

Variables	Code	Farm size		
		Small	Medium	Medium-large
Crop labor	X_{CL}	1.09	1.15	1.17
Fish labor	X_{FL}	1.56	1.46	1.31
Availability of cereal food	X_{ACF}	1.35	1.10	1.10
Least crop area	X_{LCA}	1.50	1.24	1.22
Availability of feed	X_{FC}	1.60	1.41	1.32
Fish farming training	X_{FFT}	1.14	1.04	1.02
Highland	X_{HL}	1.44	1.17	1.13
Single cropping intensity	X_{SCI}	2.72	2.05	1.84
Double cropping intensity	X_{DCI}	2.81	2.03	1.82
Distance of extension office	X_{DEO}	1.14	1.22	1.17

Source: Author's calculation.

Higher values of VIF indicate high chances of multicollinearity of explanatory variables in the model and oppositely, lower values indicate a low chance of collinearity among the predictors.

2.7.2. Measuring the Explanatory Variables

Five variables from the economic category, three variables from the ecological category, and one variable from each of the institutional and geographical categories were selected for the regression analysis. The measurement procedures of these selected variables are discussed below.

In a developed country particularly in Germany, the labor requirement is calculated by hours but in Bangladesh it is calculated in man-days per hectare. Since agriculture is not mechanized, it requires a huge amount of labor for performing all operations manually. Although crop farming is labor intensive but fish farming is more labor intensive than crop farming. The average labor requirement for crop farming is 197, 198 and 182 man-day per hectare, and for fish farming is 257, 274, and 265 man-day per hectare for small, medium and medium-large farm respectively.

How many months can the homegrown cereal feed the family? That was the question in the interview schedule to see whether the farmers have cereal food sufficiency or not. Particularly the medium and medium-large farmers have cereal food sufficiency but the small farmers do not. The average results show that small farmers can provide 10.45 months and medium and medium-large farms can provide an entire year of their cereal food requirement from their own fields respectively. This is an important variable in the context of Bangladesh because farm households hesitate buying cereal food from the market. Although this behavior is disappearing with the passing of time it still exists in the study areas.

This is also an important decision making variable involved in increasing or decreasing the fish to land ratio. Although, other agricultural farming (except crops) is more profitable farmers allocate a certain percentage of land for crop farming in both cropping seasons. Many reasons are behind this, a) farmers want to secure their whole years cereal food requirement from their own field, b) some lands are only suitable for crop farming, and c) other farming is expensive. The average minimum cropland area desired by small, medium and medium-large farmers are 67.87, 192 and 376.94 decimal per household respectively.

Availability of feed is an important factor in transforming cropland into fish farming. If the farmers have no assurance of getting sufficient feed (whether in cash or credit from the dealer), they will not increase the fish farming area. Farmers repay the feed loan within a year after selling the fish in the market. Availability of feed is calculated in monetary terms because it is difficult to calculate all feed in their weight and aggregate in a single unit. However, the average feed cost requirement per household per year is BDT 378,237, BDT 517,960, and BDT 560,810 respectively.

Fish farming is a new venture in the study areas, so farmers require training facilities to run the farm properly. Information access is not so easy in the least developed countries. Although household heads in this research have at least the basic education level, due to the lack of adequate information technology, farmers are not informed about the new innovations or information in crop and fish farming. As a consequence, fish-farming training is necessary and it is a qualitative variable.

The overall cropping intensity of agricultural land is 191 % in Bangladesh, which implies that the most of cultivable lands have the capability of growing two crops in a crop calendar year. In the beginning, farmers try to transfer single cropped land to fish farming but later they transferred all types of land to fish farming. Most of the converted land came from the double-cropped area (60.20 %) followed by a single cropped area (37.03 %). Therefore, the variable ‘single and double cropped area’ was included as a qualitative explanatory variable to see the effect on the fish land ratio decision.

The northern part of Bangladesh especially *Mymensingh* District is a flood free zone. A flood free zone means it is comparatively higher than other parts of Bangladesh. The average height of Bangladesh from sea level is only 10 meters therefore, flooding is the major problem of fish farming in the coastal areas as well as other flood-prone areas of Bangladesh. There are three types of lands available for farming in Bangladesh namely high, medium and lowland. It also has the hilly areas on the northern border side but those areas are under different types of agricultural farming. Therefore, the variable ‘high land’ was included as a qualitative explanatory variable to see the effect on the fish land ratio decision.

The extension is a substantial part of agricultural farming. The distance is a factor for the extension worker where communication systems are not well developed. It is also well known that extension workers are not interested in visiting areas distant to their stations. The distance is measured in kilometers. This could also have an effect on decision-making.

2.8. Finalizing the Model

Different types of farm households have different capabilities of using their natural and acquired resources. Correlation Matrix Analysis and Variance Influence Factor (VIF) were used to finalize the variables that had a high degree of correlation with the dependent variable and low degree of correlation between each other’s. Therefore, out of 29 variables, only 10 variables were selected to explain the dependent variable (fish land ratio of the farmer).

Regression model

$$Y = b_0 + b_1 X_{CL} + b_2 X_{FL} + b_3 X_{ACF} + b_4 X_{LCA} + b_5 X_{FC} + b_6 X_{FFT} + b_7 X_{SCI} + b_8 X_{DCI} + b_9 X_{HL} + b_{10} X_{DEO} + e_i$$

Where,

Y = Fish land ratio of the farmer

X_{CL} = Crop labor

X_{FL} = Fish labor

X_{ACF} = Availability of cereal food

X_{LCA} = Least crop area

X_{FC} = Availability of feed

X_{FFT} = Fish farming training

X_{SCI} = Single cropping intensity

X_{DCI} = Double cropping intensity

X_{HL} = Highland

X_{DEO} = Distance of extension office

e_i = Error term.

3. Results and Interpretation

3.1. Factors Influencing Small Scale Farmers’ Fish Farming Land Use Decision

All variables are not statistically significant in the case of small-scale farming. Table 3 shows that the variable ‘fish labor’, ‘availability of cereal food’, ‘least crop area’ and ‘availability of feed’ have a significant influence on the amount of land allocated to fish farming. The sample size of the small-scale farmers group is 115. The following section interprets the significant variables effect on the land use decision.

Table 3. Factors affecting the small famers’ decision on fish land ratio

Variables	Coefficients	Standard error	Significance
(Constants)	94.5436	18.13394	**0.000**
Crop labor	0.00583	0.04474	0.897
Fish labor	-0.09494	0.03178	**0.004**
Availability of cereal food	-3.35530	0.87511	**0.000**
Least crop area	-0.09977	0.04876	**0.044**
Availability of feed	0.00002	0.00001	**0.060**
Fish farming training	5.66891	7.19141	0.433
Highland	2.11374	7.08736	0.766
Single cropping intensity	12.23459	8.81027	0.169
Double cropping intensity	4.45398	8.59417	0.606
Distance of extension office	-0.21571	0.25369	0.398
R-square	0.38		
Adjusted R-square	0.30		
F	4.86		**0.000**

Source: Author’s calculation.

3.1.1. Fish Labor Requirement

Day by day agriculture labor is becoming short in supply. Often farmers have to pay higher wages to acquire labor in the peak season. The result of the regression also shows that if fish farming labor requirement is increased 100 md per hectare, the fish land ratio decreases by about 9 %.

3.1.2. Availability of Cereal Food

Small farmers cannot provide their entire year cereal food requirement from their own farmland. On average they can provide about 10 months cereal food from their own production. If they want to increase 1 month more cereal food supply from their cropland, they have to decrease 3.4 % fish farming land area.

3.1.3. Least Amount of Land Desired for Crop Farming

Resource fixity and secureness of home consumption cereal food, limits the fish land area extension of small-scale farmers. All croplands are not suitable for fish farming and most of the farmers are not interested in converting their entire land. Only seven percent of farmers showed interest in converting the whole land to fish farming if possible. If the small farmer wants to increase the availability of cropland by one decimal then they have to sacrifice 0.09 % of fish land from the farming.

3.1.4. Availability of Feed for Fish Farming

Feed availability has a positive significant impact on fish land area. It makes economic sense and was expected by the researchers. Regression results show that if fish feed availability is increased by BDT 100000 per hectare then the fish land area is also increased by about 2 % and vice versa. Small farmers always face the problem of getting the quality feed in sufficient amounts because of having little operating capital.

3.2. Factors Influencing Medium Scale Farmers' Fish Land Use Decision

Ninety medium farms were selected from the medium scale farmer group. Results of the regression analysis show that the allocation of fish land is significantly influenced by five independent variables. Included explanatory variables have the adequate level of explanatory power since the adjusted R-square is 33 %. However, it can partly explain the causes of converting cropland to fish farming in the northern part of Bangladesh. The explanation of significant independent variables is discussed below.

Table 4. Factors affecting the medium famers' decision of fish land ratio

Variables	Coefficients	Standard error	Significance
(Constants)	210.30200	37.34230	**0.000**
Crop labor	-0.18722	0.06472	**0.005**
Fish labor	-0.10396	0.03865	**0.009**
Availability of cereal food	-9.36254	2.70294	**0.001**
Least crop area	-0.00499	0.01127	0.659
Availability of feed	0.00003	0.00001	**0.005**
Fish farming training	5.05953	4.49698	0.264
Highland	7.12468	6.66821	0.289
Single cropping intensity	1.63618	6.40129	0.799
Double cropping intensity	1.11941	7.50949	0.882
Distance of extension office	-1.02634	0.36205	**0.006**
R-square	0.41		
Adjusted R-square	0.33		
F	5.15		**0.000**

Source: Author's calculation.

3.2.1. Labor Requirement for Farming

Medium scale farmers are also faced with the problem of labor availability for farming. Regression results show almost the same reaction by this group of farmers as small-scale farmers showed. Medium scale farmers will increase or decrease the fish farming area with the decrease and increase of per hectare labor requirements for crop and fish farming. The response rate is different for each type of farming for example, if the crop farming labor requirement is increased by 100 md per hectare then the fish land ratio is decreased by about 19 % and in the case of fish farming, the fish land ratio is decreased by about 10 %. This implies medium farmers are more responsive to the crop farming labor requirement changes.

It is a debatable issue why the fish land ratio is decreasing with the increase of the crop farming labor requirements. The fish land ratio has to be raised in this situation. Due to a lack of sufficient operating capital and fish feed availability, farmers use their farmland for crop farming. Moreover, fish farming requires more labor, which comes from hired labor sources. Therefore, if the crop farming labor requirement is increased then obviously farmers will reduce the fish farming land area to fulfill the labor requirements of crop farming.

3.2.2. Availability of Cereal Food

Medium scale farmers have the capability of providing the entire year cereal food requirement from their own fields, but some farmers sell their produce to the market for fulfilling some undesirable monetary requirements and purchase again later time from the market. However, regression results show if they want to increase their cereal food supply by 1 month from their cropland, they have to decrease 9.4 % of fish farming land area. This figure is little bit higher than for small group farmers. Particularly, medium scale farmers have more solvency than small-scale farmers, so they can purchase required food from the market at a later time. As a result, this group of farmers has no intention of decreasing the fish farming land unless they want to store more cereal food to avoid a risk situation.

3.2.3. Fish Feed Availability

This group farmer shows more positive/negative response if the availability of fish feed is increased or decreased. Regression results show that if fish feed availability is increased by BDT 100,000 per hectare then the fish land area is also increased by about 3 % and vice versa. The response rate is a little bit higher than for small-scale group because of the higher land availability of this group.

3.2.4. Distance of the Extension Office

Small farmers always follow their neighboring medium or large farmer in implementing any new technology or to get information if they encounter trouble in any unwanted farming situation. Therefore, this variable is not significant for the small-scale group but it has a significant effect on the land use decision of the medium scale group. Table 4 shows that if the distance to the extension office is increased by 1 kilometer then the fish land area is decreased by about 1 % and vice versa.

3.3. Factors Influencing Medium-Large Scale Farmers' Fish Land Use Decision

The farmers who have more than 3 hectares of land are treated as large farmer. It was difficult to find such type of farmers in the study areas. Twenty-five large farmers were interviewed during the data collection period having a land size of 3 hectare to 5.66 hectare per household. Though 25 large farmers could be enough for mathematical programming but it is not enough for econometric analysis. So, the last category was created adding the large farmer group to the medium farmer group because these two groups have some similarities. Otherwise, the regression results of the large farmer group give spurious results. Therefore, the newly created medium-large farmer group consists of 115 sample households and R-square value is the same as the value of the medium scale farmer group. Table 5 shows six variables are statistically significant in this group.

Table 5. Factors affecting the medium-large famers' decision of fish land ratio

Variables	Coefficients	Standard error	Significance
(Constants)	205.62200	36.20842	**0.000**
Crop labor	-0.16667	0.05313	**0.002**
Fish labor	-0.07115	0.03397	**0.039**
Availability of cereal food	-9.32000	2.69460	**0.001**
Least crop area	-0.01528	0.00821	**0.066**
Availability of feed	0.00002	0.00001	**0.012**
Fish farming training	6.21098	3.99367	0.123
Highland	6.63489	6.51507	0.311
Single cropping intensity	6.01465	4.92252	0.225
Double cropping intensity	-4.89480	5.87307	0.407
Distance of extension office	-0.87398	0.30803	**0.006**
R-square	0.41		
Adjusted R-square	0.35		
F	6.89		**0.000**

Source: Author's calculation.

3.3.1. Labor Requirement for Farming

All groups are sensitive to the labor requirement for farming and responded almost in the same way. Medium-large scale farmers will also increase or decrease the fish farming area with the decrease and increase of per hectare labor requirements for crop and fish farming. This indicates fish farming is labor intensive farming and at the same time if crop farming requires more labor then they will also reduce the fish farming land area to fulfill the labor requirement for crop farming.

3.3.2. Availability of Cereal Food

This group farmer is also in the position of cereal food self-sufficiency. Regression results show if they want to increase 1 month more cereal food supply from their cropland for their security, they have to decrease 7.9 % fish farming land area. Particularly, this group of farmer has no intention of decreasing the fish farming land unless they receive more profit from crop farming.

3.3.3. Amount of Land Desired for Crop Farming

Medium-large scale farmers have a sufficient amount of land for crop farming which can provide the home cereal food requirement, as well as sales in the market for commercial purposes. However, if the medium-large farmer group wants to increase the availability of cropland by one decimal then they have to sacrifice 0.02 % fish land from fish farming. The figure is quite a bit lower as compared to the small farmer group because this group has more available farming land area.

3.3.4. Distance of the Extension Office

This group is also affected by this variable. Table 5 shows that if the distance to the extension office is increased by 1 kilometer then the ratio of fish land to cropland area is decreased by about 0.87 % and vice versa. Numerically the figure is less than the medium scale farmers group but in volume (area of land) it will be more because the medium-large scale group has more available farming land.

3.4. Overall Categorical Discussion of Influencing Factors

Results of the regression analysis indicate that the percentage of the fish land ratio is influenced by only economic and geographical factors. The following section explains how these factors influence the fish land area of different types of farm household in the study areas.

3.4.1. Economic Factors

Mostly economic factors cause the land use change in the study areas. Farmers are moving out from subsistence farming with the help of modern information technology and accessibility to the local market. They are trying to optimize their man-made and natural resources. Therefore, they are always thinking of how to get more benefit from farming. In this research, ten economic factors were considered in the beginning, but all of these were not important to explain the land use change for different types of farm sizes. Small, medium and medium-large farm models considered five out of eleven economic factors because of collinearity. After testing collinearity among independent variables, and between independent and dependent variables, 'crop labor', 'fish labor', 'availability of cereal food', 'least crop area' and 'availability of feed' were selected for the regression analysis.

Regression results show (Table 3, Table 4, Table 5) all economic factors have a significant effect on the fish land area using decisions in the study areas. Among these three factors that are important for each type of farming are: 'Least crop area' factor is important for small and medium-large type of farming, and 'Crop labor' factor is important for medium and medium-large type of farming.

'Fish labor requirement ', 'availability of cereal food and 'availability of feed' are factors important for each type of farming. All types of farmers are aware of the labor requirement since it is getting scarce day by day in the rural areas and they are also aware of the availability of cereal food supply from their own farming. Fish feed availability is the major concern in the land use change decision. Therefore, each farm type responds significantly with the changes of the availability of fish feed in the study areas.

'Least crop area' should have a significant effect on fish farming land allocation decision for each type of farming. Regression result show that it is significant for small and medium-large farmers group but not for the medium scale farmer groups. Quite possibly, collected data on this issue from the medium group of farmers were not accurate otherwise this factor would be significant for this group also to make the decision of fish land use.

The last significant economic factor is 'crop labor requirement', which has a significant effect on determining the fish land ratio in case of medium and medium-large group of farmers. Small farmers have less capability of increasing fish farming area because of less operating capital and fish feed availability. Therefore, crop labor requirement is not significant to the small farm group. However, it has a negative significant effect on the land use decision of medium and medium-large farmers group.

3.4.2. Geographical Factors

Only two variables included in this category such as 'distance of road' and 'distance of extension office', and the latter is statistically significant to explain the amount of fish land ratio. In every *Upazila*, there is one branch of agricultural extension office and *Upazila* fisheries office in Bangladesh. Besides, selected research areas are near to a big technology innovation center such as Fisheries Research Institute (FRI) in *Mymensingh*. Certainly, this institution has a significant effect on improving the agricultural systems in the nearby areas of those regions. Therefore, the factor 'distance of extension office' is negatively related to the dependent variable. This implies with the increase of the distance to the extension office, the land conversion amount will decrease significantly. There is a strong reason for small farmers not to respond with the distance of extension office. On the one hand, most of them are operating the small size of pond fish farming and on the other hand, they get required information from the neighbor medium and large farmers.

4. Conclusion

Fish farming is labor and capital intensive, therefore, should be influenced by farming labor requirement and major capital items. Feed is the major and important capital item in fish farming. Farmers need a huge amount of money for purchasing the feed from the market. As mentioned earlier, there is a feed credit system developed in the study area to flourish the fish farming sector. However, along with other significant variables, the involvement in fish farming also depends on the availability of feed from the market by cash or credit. The findings of the study have the important policy implications for accelerating or hindering the process of fish land allocation for the purpose of economic development of the country.

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