# The impact of crop diversification on food security of farmers in Northern Bangladesh

Nazmun Nahar[1], M. Wakilur Rahman[1], M. A. Monayem Miah[2] and Md Mahfuzul Hasan[3*]

## Abstract

**Background**  Crop diversification is the potential for greater dietary diversity, and reduced micronutrient deficiencies and malnutrition. Despite the increasing global concern of improving food security, the nature and extent of food security at the household level in rural areas are not well-documented. This paper determines the factors that influence crop diversification and its association with food security which helps policy maker to take proper steps in norther part of Bangladesh.

**Methods**  The effect of crop diversification on household food security in northern Bangladesh was measured by adopting the Herfindahl index (HI). Food Consumption Score (FCS) and Household Food Insecurity Access Score (HFIAS) were used to determine the food security status. The binary logistic regression model and multinominal logit model were performed to identify the factors influencing crop diversification and food security, respectively. All these analyses were performed based on 609 household samples collected from six northern districts of Bangladesh.

**Results**  Descriptive statistics show that the majority of farmers in the study districts reported 12–13 different crops, while only farmers in Bogura mentioned 19 different crops grown in their field. After calculating crop diversification using HI index, it is apparent that about 64% respondents irrespective of region produced different types of crops and around one third of them possessed in the middle categories neither they were fully crop diversified nor non crop-diversified. About 40% households had better Food Consumption Score lead to only 3.28% belonged to below poverty line and rest of the household fall in borderline. The analysis confirm that the crop diversified households were found to be more food secured or marginal food secured then that of less crop diversified households.

**Conclusion and policy recommendation**  We may infer from the factor analysis that, in line with the government policy to raise significantly the standard of living of the farmers, government should facilitate and encourage farmers to grow several crops rather than just one and provide training opportunities. In addition, food insecure people as well as the low food secure group might overcome their circumstances if the government places greater emphasis on education, training, and off-farm activities by providing financial support.

**Keywords**  Crop diversification, Food consumption score, Herfindahl index, Household food security, Household Food Insecurity Access Score (HFIAS)

*Correspondence:
Md Mahfuzul Hasan
Mahfuzul44998@bau.edu.bd
[1] Department of Rural Sociology, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh
[2] Agricultural Statistics and ICT Division, BARI, Gazipur 1701, Bangladesh
[3] Department of Agribusiness and Marketing, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

## Background

A developing nation with a large agricultural sector, Bangladesh dedicates about 70% of its territory to growing crops, with agriculture accounting for the principal occupation of approximately to 50% of the population. Aside from that, agriculture accounts for 12.68% of GDP [1]. In 2022, Bangladesh Population growth rate was 1.22% and 68.49% people lived in rural areas with a

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population density of about 1265 per Km$^2$ [2]. In rural areas, agriculture is the primary source of employment. Small-scale farmers are the ones who produce for consumption, nutrition and additional earning for the households. Bangladesh is working to achieve sustainable development goals 1 and 2, which call for the eradication of hunger and poverty, respectively. Goal 2 clearly indicates that promoting sustainable agriculture can ensure food and nutritional security. "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" [3]. Bangladesh faces a significant chronic food insecurity issue, with 21% of the population suffering from IPC Levels 3 and 4. Rangpur division (northern Bangladesh) has the highest proportion of people in moderate or several chronic food insecurities, followed by Mymensingh and Barishal divisions [4]. Factors contributing to this issue include geographic location, economic conditions, and climate change. Crop diversification can increase farm revenue, create jobs, reduce poverty, and preserve soil and water resources, which are essential for resolving these crises in developing nations [5].

Crop diversification is the shift of crop or cropping system to another more sustainable, local specific, need based one to use the available resources in a best possible way. Crop diversity includes a range of aspects, including crop species diversity, crop variety diversity within crop species, and crop species genetic variation [6]. Crop diversification is an important component of agricultural policies in Bangladesh and is recognized as a mechanism for improving food and nutrition security, relieving pressure on the environment, and promoting economic growth and rural development [12]. To improve the production of minor crops, the government started the crop diversification programme (CDP) in 1989 [40] and follow-up specific program under Northwest Crop Diversification Program. However, there were clear regional trends, with higher rates of crop diversification in Nepal and more limited crop diversification in Rangpur. In 2023, Brown and a few other researchers show in their research paper that the average non-cereal diversification across the region was only 1.5 crops per household, highlighting limited cropping diversification [41].

Diversification of agricultural production systems may improve dietary quality as well as have environmental benefits [8, 9]. Crop diversification is the potential for greater dietary diversity [10] and reduced micronutrient deficiencies and malnutrition [11, 12]. It has significant implications on household food security and dietary diversity. In recent years, diversification has been highlighted as one of the salient tools for safeguarding the production from climate change, improved household

income, risk management tool, and ensuring food security. Rural households (HHs) diversify their income sources to smooth consumption and mitigate risk [13] and farmers from drought and risk-prone areas, cultivate more crops to maintain food supply, and reduce staple crop failure risk [14]. Adjimoti and Kwadzo asserted that crop diversification has a positive relationship with food security, and it makes households more resilient to food insecurity [15]. According to additional research, diversity improves food and livelihoods. [16]. Furthermore, Lovo and Veronesi found that crop diversification has a positive effect on a child's long-term nutritional status [17]. While evidence of a similar positive relationship between crop diversification and improved household diet, has also been found in several studies in various developing countries, such as Bangladesh [18]. Such as, In Bangladesh, women's empowerment, market accessibility, farm commercialization, and income diversification from non-farm sources all significantly and favourably effect on household dietary diversity [12]. Additional research yields the same conclusion: in Bangladesh, diversification is positively correlated with the diversity of household meals [7]. Furthermore, some found that, homestead vegetable farming can be helpful for generating income and provide food security to the vulnerable communities in the basin regions [19]. In the coastal area of Bangladesh, researchers analyse which factors contribute more on dietary diversity and they found crop diversification systems combining agriculture with aquaculture, and agroforestry seem to improve diverse diets among households [38]. According to Herforth the relationship between crop diversity was associated with the diversity of food groups in households and individual child diets and positively associated with the diversity of home-produced fruits and vegetables consumed [20]. In the rural highlands of Ecuador, on-farm species diversity and family-level dietary diversity were also positively correlated [21]. In western Mali, the number of crops cultivated by a household was positively associated with adult nutrient adequacy [22].

One study found that crop diversification contributes significantly to improving household food security in Northern Ghana, with occupation, technology adoption, labour, extension contact and farm size being the most important determinants [34]. In addition, some think agricultural diversification is an important mechanism for managing household food security and poverty in developing economies. They indicate that access to tillage equipment, fertilizers, credit and market information is key to encouraging farmers to diversify [33]. Another paper recommends that improved access to credit for rural households and diversification of household economic activities to include off-farm income generating

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businesses to improve food security at the household level [35]. The Karnataka state has seen a vast increase in crop diversification after the introduction of world trade organization in their area, influenced by infrastructural and technological factors. To foster agricultural development and crop diversification, basic infrastructural facilities such as irrigation water, markets, fertilizer availability, roads and transportation are essential [7].

## A conceptual framework of crop diversification and food security

To balance out unequal regional and national food distribution, food availability is referred to as "food security". Though accessibility is an important factor, it was immediately understood that it is insufficient to guarantee food security, because food may exist physically but be inaccessible to those who need it the most. Four dimensions make up the idea of food security: a categorical dimension, a socio-organizational dimension, a managerial dimension, and a situation-related component. Categorical factors include "availability," "accessibility," "utilization," and "stability." The framework is influenced by two factors—a physical and temporal determinant. Stability is the temporal determinant of food and nutrition security and influences all three of the first three physical elements. The first three elements are presented as physical determinant [32].

Food security is a complex and multidimensional concept that refers to the ability of individuals, households, and communities to access sufficient, safe, and nutritious food that meets their dietary needs and preferences for an active and healthy life [23]. A conceptual framework for food security can aid in identifying the critical elements that have an impact on it at various levels and serve as a guideline for the creation of programs and policies aimed at enhancing it.

A conceptual framework for food security that takes into account the numerous aspects and factors of crop diversification which effects on food security is as follows:

Figure 1 shows that there are several factors such as age, education, farm income, farming training, off farm income, farm experience, farm size, family working members as well as gander which was mainly used in different research work for estimating significance factor on crop diversification. In addition, more sustainable agricultural system, increased revenue, and food security can all be achieved by farmers by taking all of these factors into account and put crop diversification ideas into in practice.

## Methods

### Sampling and data collection

This study was conducted in the six northern districts including Nilphamari, Dinajpur, Natore, Kurigram, Bogura and Chapainababganj. Using multistage sampling method, about 100 samples were collected from each selected district. A total of 609 sample households were interviewed from 5 villages of each district which is presented in Table 1. A semi-structured interview scheduled was used to collect relevant data.

### Analytical techniques

This study employs a range of tools and techniques for analysis of the data. A descriptive statistic of some
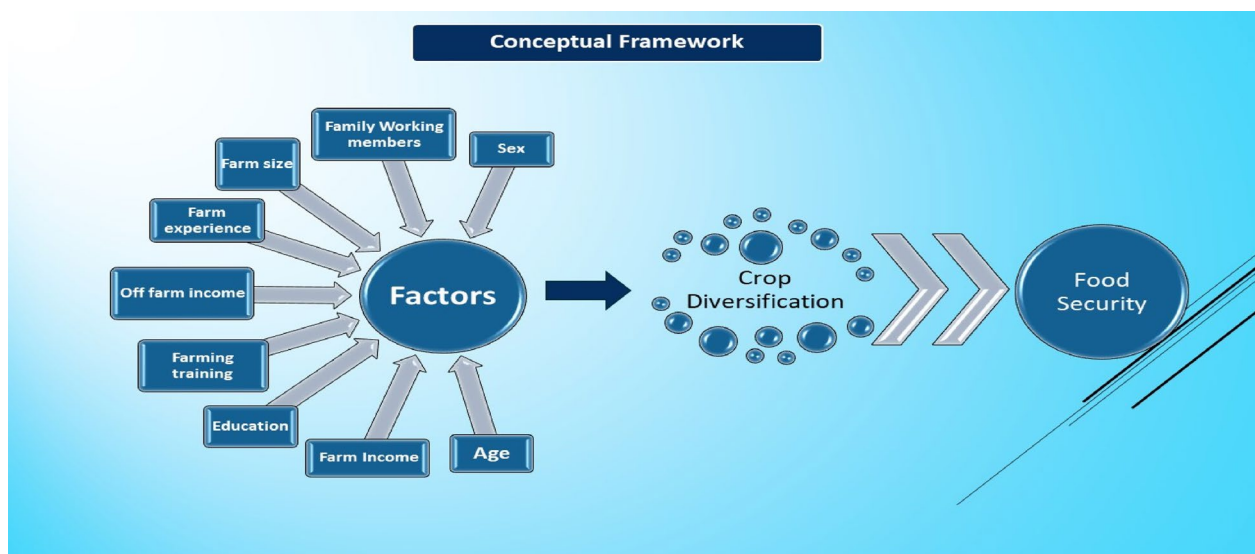


**Fig. 1** Conceptual framework of crop diversification and food security

**Table 1** Sample distribution of across study sites

| District | No. of Village | Sample |
|---|---|---|
| Nilphamari | 5 Village | 102 |
| Dinajpur | 5 Village | 102 |
| Natore | 5 Village | 102 |
| Kurigram | 5 Village | 102 |
| Bogura | 5 Village | 99 |
| Chapai-Nawabganj | 5 Village | 102 |
| Total | | 609 |

selected variables of the sample households was estimated. For measuring the crop diversification, this research used Herfindahl index (HI). while for food security estimation we used Food Consumption Score (FCS) and Household Food Insecurity Access Score (HFIAS). These indexes have been utilized in different research also [24–28]. All of them were adopted in this analysis and briefly presented the analytical methods.

**Measuring crop diversification**
*Herfindahl index (HI)*
Herfindahl index is used to study the extent of crops diversification. This is computed by taking sum of squares of acreage proportion of each crop in the total cropped area.

HI=$\sum_i^n p_i^2$ where, $P_i$ represents area proportion of the ith crop in total cropped area.

HHI index takes the value 1 when there is total concentration and tends to zero as the level of diversification increased [29].

*Measuring food security*
For evaluating the impact of adopting crop diversification on farmers' food security status, Food Consumption Score (FCS) and Household Food Insecurity Access Score (HFIAS) were used, respectively.

*Food consumption score (FCS)*
The FCS is frequently used in surveys and evaluations to track the results of nutrition and food security at the family or neighbourhood level. To estimate food security, this study used FCS approach and computed in accordance with guidelines provide by EFSA [30]. FCS was measure based on dietary diversity, food frequency, and the relative nutritional importance of nine different food groups. The FCS is designed to reflect the quantity and quality of people's diet at household level. A composite score is derived from a weighted sum based on the food type and frequency of consumption during a 7-day period. Precisely, dietary recalls questions were used to collect information on the consumption of selected food groups common in Bangladesh.

The formula can be expressed as:

FCS=a×f (cereal and or tubers)+a×f (pulse)+a×f (milk)+a×f (fruit)+a×f (meat and or fish)+a×f _ sugar_+a×f _vegetables_+a×f (oil)+a×f (condiments).

where FCS=Food Consumption Score, f=frequency of food consumption (number of days for which each food group was consumed during the past 7 days), a=weighted value representing nutritional value of selected food groups [30].

Food poverty and nutritional condition are measured using the Food Consumption Score (FCS). It is determined using information about dietary variety, meal frequency, and the proportional nutritional worth of the items eaten. Scores between 21 and 35 suggest moderate food insecurity, while those below 21 imply serious food insecurity. A number of 35 or higher signifies little to no food instability.

*Household food insecurity access score (HFIAS)*
A method was used for determining a level of food poverty in households is the Household Food Insecurity Access Score (HFIAS). It is a survey-based method that measures the regularity and significance of food access issues that families have encountered over the last four weeks.

The HFIAS consists of nine items that address three areas of food insecurity: worry and apprehension about family food supplies, insufficient quality and amount of food eaten, and coping mechanisms like reducing meal size or skipping meals [31].

The occurrence questions were summarized as follows: (Q1a) reduction in the number of meals per-day; (Q2a) reduction in size of meals; (Q3a) skip food consumption for an entire day; (Q4a) restrict consumption of female to allow more for male; (Q5a) borrow food from a friend or relative; (Q6a Purchase food on credit; there are five response options representing a range of frequencies (0=never, 1=hardly, 2=sometimes, 3=often and 4=regular).

Each subject was evaluated on a scale of 0–4, with higher scores indicating increased food insecurity. The outcomes of each question were added to yield the final number, which ranges from 0 to 24. A high HFIAS number indicates a household is very food insecure, whereas a low score indicates a household is food secured.

*Factors affecting on crop diversification*
To determine the effect of different factors on diversification a Binary logistic regression model was used. The values of Herfindahl index (HI) computed for measuring crop diversification was taken as dependent variable,

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where HI value converted to 1 (0–0.5) for crop diversification and 0 (0.51–1) for crop non-diversification and different factors affecting diversification was taken as independent variables [39]:

$$Z = (p/1\text{-}p) = e^{\alpha+\beta 1X1+\beta 2X2+\beta 3X3+\beta 4X4+\beta 5X5+\beta 6X6+\beta 7X7+\beta 8X8+\beta 9X9}$$

where:

Z = Herfindahl index (crop diversification index).

X1 = Age; X2 = Sex; X3 = Education; X4 = Farm experience; X5 = Family working members; X6 = Farm size; X7 = Farming training; X8 = Farm income; X9 = Off farm income; α = Intercept.

### Effect of crop diversification on household food security

Multinomial logit model was used because of HFIAS score was divided into four different categories based on their score such as high food secure, marginal food secure, low food secure, food insecure. The marginal food secure was taken as a base outcome and estimated the results.

The model is defined by the following equation:

$$P(Y = k|X) = \frac{e^{\beta 0k+\beta 1kX1+\beta 2kX2+\cdots+\beta pkXp}}{\sum_{j=1}^{K} e^{\beta 0j+\beta 1jX1+\beta 2jX2+\cdots+\beta pjXp}}$$

where $p=1$ food secure households; $p=2$ Marginal Food Secure households; $p=3$ Low Food Secure households and $p=4$ food insecure households; βj is a vector of coefficients on each of the independent variable's X [37].

## Results

### Descriptive statistics

The socioeconomic characteristics of the respondents are summarized in Table 2. Most of the sampled population (95.24%) were male household heads, and a nearly equal proportion were married. The average age ranged from 31 to 60 years old indicates the middle-aged farmer as was an economically active person. More than one quarter of individuals completed primary education, and nearly one third completed secondary education. In contrast, 24.3% people among respondent have no education and rest amount of respondent claimed higher education and honours & master's degree about 7.22% and 7.72% respectively. One notable point is nearly 50% respondents have more than 20 years of farming experience and one fifth of the respondents have 16–20 years (Fig. 2).

Figure 3 shows about what proportion of various crops grown by the household. All Farmers Produced Aman in about 39% of the total, with Boro coming in second with 19%. The majority of farmers produced slightly more than 10% of their crops as vegetables and lentils, and the remaining crops made up less than 10% of their total land, respectively.

According to Fig. 4, farmers in the Natore district only grow tobacco and sugarcane, whereas farmers in the Nilphamari district only grow sugarcane. With the

**Table 2** Some selected socio-economic characteristic of the study households

| Household characteristics | Frequency | Percentage |
|---|---|---|
| Sex | | |
| Male | 580 | 95.24 |
| Female | 29 | 4.76 |
| Age group | | |
| Under 20 | 9 | 1.48 |
| 21 to 30 | 94 | 15.44 |
| 31 to 40 | 148 | 24.3 |
| 41 to 50 | 148 | 24.3 |
| 51 to 60 | 128 | 21.02 |
| Above 60 | 82 | 13.46 |
| Education group | | |
| No formal education | 148 | 24.3 |
| Primary education | 172 | 28.24 |
| Secondary education | 198 | 32.51 |
| Higher Education | 44 | 7.22 |
| Honours/Masters | 47 | 7.72 |
| Farming experience | | |
| Less than 5 | 40 | 6.57 |
| 6 to 10 | 67 | 11 |
| 11 to 15 | 77 | 12.64 |
| 16 to 20 | 122 | 20.03 |
| Above 20 | 303 | 49.75 |

exception of Kurigram, every district handles the same number of onions, roughly 20%. Bogura and Natore farmers responded more than 85% separately in terms of banana and Khesari (field pea) production. Overall, it is clear that the majority of district farmers' answers refer to 12–13 different crops, while only farmers in Bogura district produced maximum number (19) of crops.

## Crop diversification

### Measuring Herfindahl index

The distribution of HI index values of six distinct districts is shown in Figs. 5, and 6 The illustration shows that the majority of farmers' Herfindahl index values fall between 0.2 and 0.6. Only 0.5% found in the 0–0.2 range, and all of them are in Natore, while nearly 64% were found in the 0.2–0.4 range. In addition, 33% fall into the range of 0.4–0.6, and the remaining growers fall into another two groups. Therefore, it can be concluded that crop diversification is relatively high for 64%, because they are in the range of 0.2–0.4. In addition, more or less 84% respondents from Natore and Bogura farmers fall into that category, respectively. In comparison, Dinajpur, Nilphamari, and Chapai-Nawabganj farmers also make up more than 50% of that group.
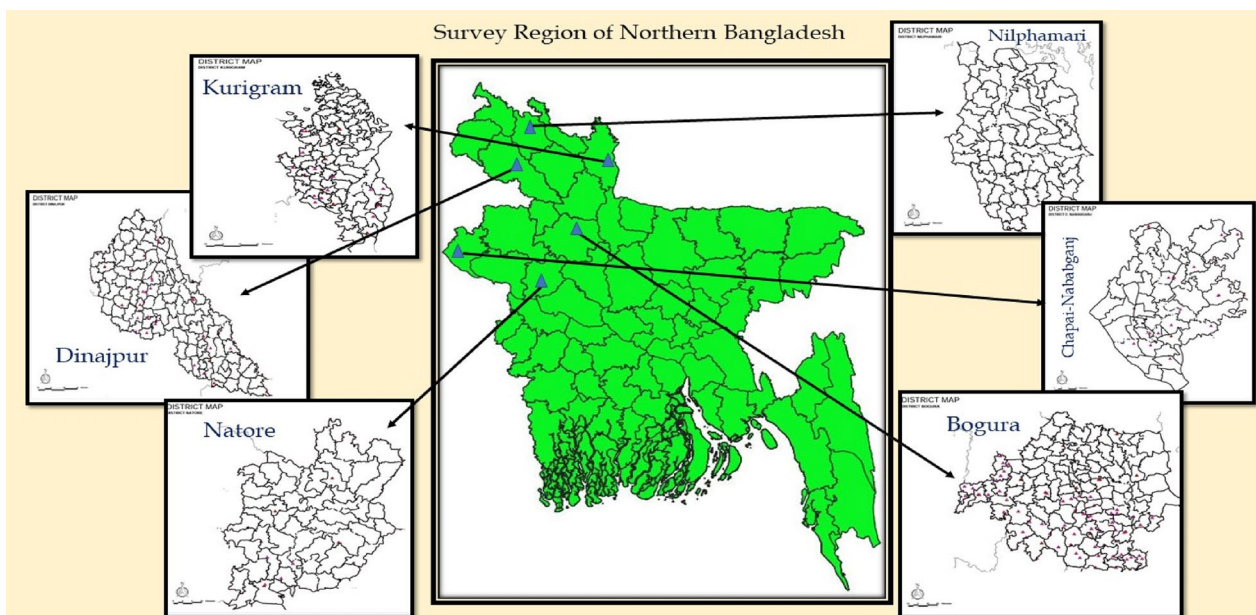
**Fig. 2** Survey districts of Bangladesh

## Measuring food consumption score (FCS) and household food insecurity access score (HFIAS)

The categories of food items and their weights used to calculate the Food Consumption Score are given in Table 3. We can divide the roughly 48 dietary items into 9 groups including main staples, pulses, vegetables, fruits, meat and fish, milk, sugar, oil, and condiment based on the guidelines on Food Consumption Score calculation for Bangladesh mainly food types and weight value based on nutritional value of items [36].

Based on FCS, the distribution shows that more than one third of the household (244 out of 609) are food secure, 56.6% (345 out of 609) have borderline food consumption, and only 3.28% (20 out of 609) have poor food consumption.

In terms of HFIAS, results show that about 0.5% of the households are highly food secure, 52% are marginal food secure 43.8% are in low food secure, and to be exact 3.6% are severely food insecure. In overall, 3.62% (22 number) and 3.28% (20) people are food insecure and poor according to HFAIS and FCS, respectively. They are showing almost equal result. We used both model for getting more accurate results.

Table 4 provides information on the FCS and HFAIS for different ranges of HI index values and specific districts separately. The HI is used in this study to measure the extent of crop diversification. HI is divided into ranges (0–1), and for each range, the table provides percentages of households in different FCS and HFAIS categories.

In comparison with FCS and HI range, for the HI range 0–0.2, 33.3% of households fall into the borderline category and a significant 66.7% of households are in the acceptable category means that higher crop diversification (indicated by lower HI) is associated with a predominantly acceptable food consumption status. For the 0.2–0.4 HI range the majority (54.2%) fall into the borderline category, with a substantial proportion also in the acceptable category (42.4%) indicating the increase in the HI is associated with a slight increase in the percentage of households classified as poor. For both HI range 0.6–0.8 and 0.8–1, The majority (66.7%) are in the borderline category. In contrast, at the lowest HI value possesses higher percentage of household in the marginal food secure group which was about two thirds of the respondents and when farmers belong to 0.8–1 range in that case, we can see the opposite trends (one thirds for marginal food secure and nearly two thirds for low food secure).

The variation between Food Consumption Score in the district level shows that, the Bogura district has the lowest percentage of respondents in the acceptable (8.1%) group and the highest in Dinajpur district. For borderline group indicate both Chapai Nawabganj and Kurigram districts have the same proportion which is around 74%. Furthermore, the highest ratio belongs to the Bogura district and the lowest percentage belongs to the Dinajpur district. The poor was observed in the Bogura district whereas in Nilphamari district there was no poor. Besides that, from HFAIS shows nearly 60% of the respondents in
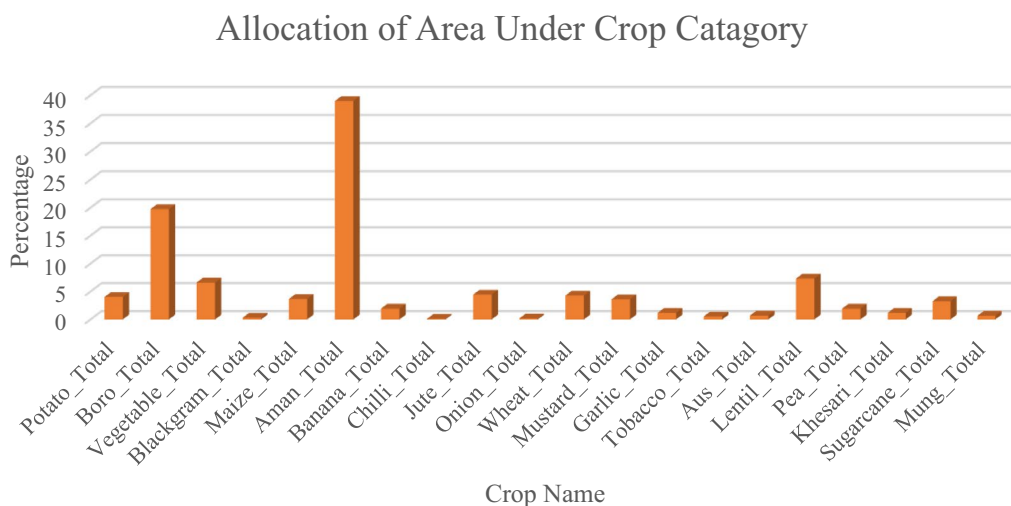
## Allocation of Area Under Crop Catagory



**Fig. 3** Allocation of area under crop category
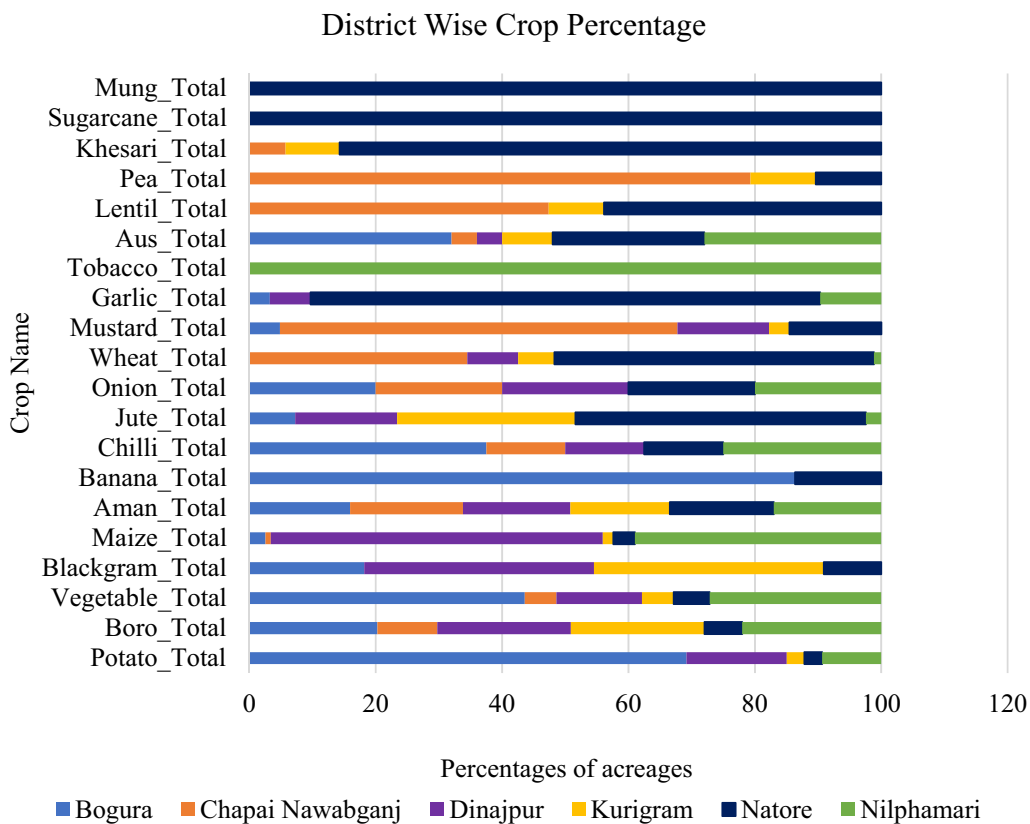
## District Wise Crop Percentage



**Fig. 4** Districtwise crop percentage

Kurigram districts fall in low food secure groups whereas FCS shows above 70% in borderline. Therefore, there is an inverse relationship between the higher the HI value lower the food secure status.

Overall, as the Herfindahl Index increases (indicating lower crop diversification), there is a trend towards a higher proportion of households falling into the borderline FCS category. The HI may be a factor influencing food consumption status, with a higher index
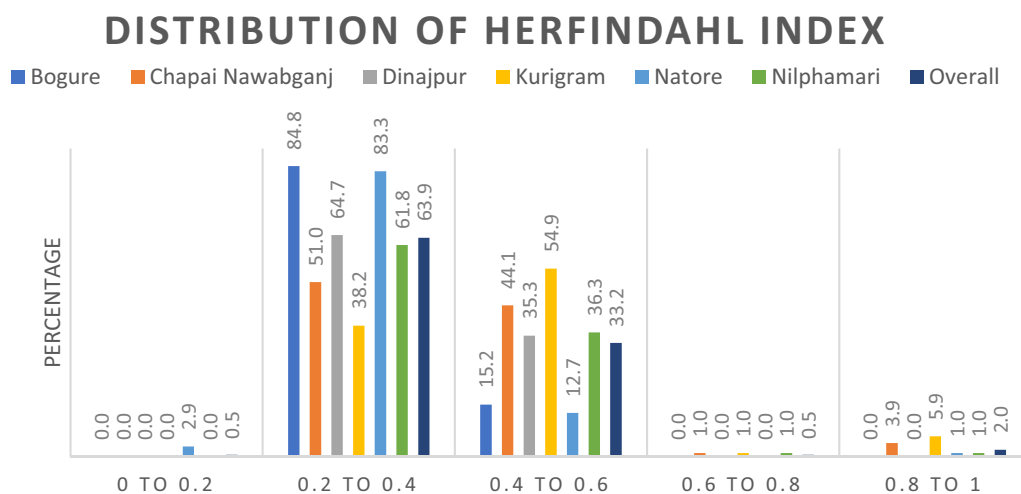
## DISTRIBUTION OF HERFINDAHL INDEX



Fig. 5 Distribution of Herfindahl index

potentially indicating challenges in food security. This interpretation suggests a potential relationship between crop diversification (as measured by the Herfindahl index) and the food consumption status of households, as reflected in the FCS. The specific proportions in each category provide insights into the dynamics of this relationship.

### Descriptive analysis of explanatory variable

For the purpose of determining which component has the greatest impact on crop diversification and food security, we present the mean, standard deviation, minimum, and maximum values of our chosen independent variable in Table 5.

### Identifying influencing factor on crop diversification and food security

Binary logistic regression was utilized to determine the factors that impact crop diversity. The independent variables were examined for multicollinearity prior to the econometric model being run, and the VIF shows that there was not any significant multicollinearity between the independent variables (Table 6).

The estimated parameter coefficients in the binary logistic model are summarized in Table 7. The $\chi 2$ test statistic of the model was significant at 1% level.

Age and crop diversification involvement had a favourable and significant relationship ($p < 0.05$). As a farmer becomes older, there is a greater likelihood
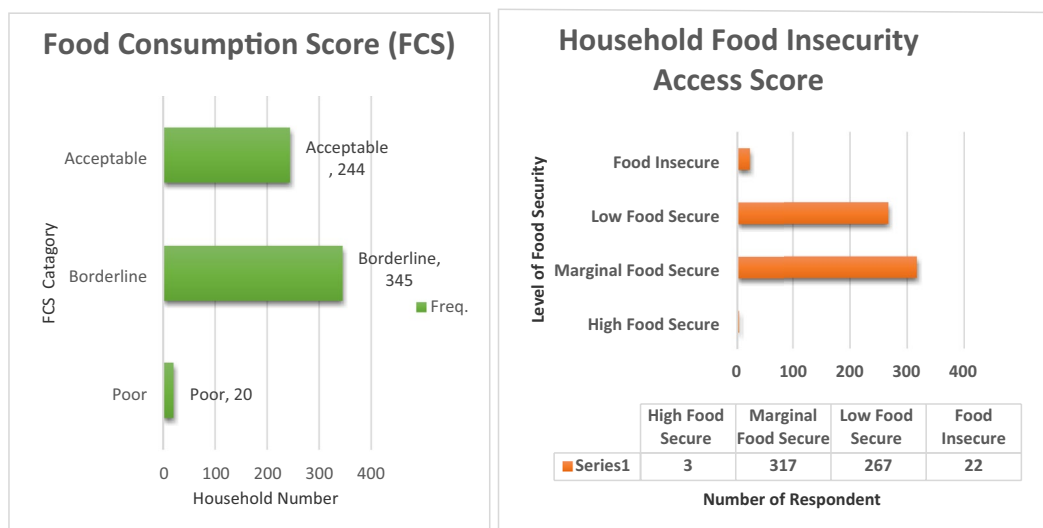


Fig. 6 Food Consumption Score (FCS) and Household Food Insecurity Access Score

**Table 3** Calculation of the Food Consumption Score (FCS)

| Food Items | Food groups (definitive) | Weight (definitive) |
|---|---|---|
| Rice, Wheat, Bread, Potatoes, Bottle gourd, sweet potato/otrs root | Main staples | 2 |
| Liver, kidney, heart, Beans/long bean, Peas, Lentils/pulses, Nuts | Pulses/Beans | 3 |
| Pumpkin, Carrot, Squash/cucumber, Green/leafy, vegetables, Amaranth, Cabbage, Kale/coriander, Spinach, Tomato, Eggplant, Green Papaya | Vegetables | 1 |
| Orange + lemon, Mangoes/apple, Vitamin-A rich fruits, other fruits/papaya | Fruit | 1 |
| Beef, Lamb/goat, Chicken or duck, Fish, Egg | Meat and fish | 4 |
| Milk | Milk | 4 |
| Sugar, Chocolate, Cakes/biscuits, Honey | Sugar | 0.5 |
| Mustard oil, Palm oil/Soyabean | Oil | 0.5 |
| Onion, Green paper, Garlic, Ginger, Yogurt/Curd, Spices mixed, mixed powder, chilli turmeric), Tea, Coffee, Others | Condiments | 0 |

**Table 4** Percentage of food security status of households and intensity of crop diversification

| HI | FCS | | | HFAIS | | | |
|---|---|---|---|---|---|---|---|
| | Poor | Borderline | Acceptable | High food secure | Marginal food secure | Low food secure | Food insecure |
| 0 to 0.2 | 0.0 | 33.3 | 66.7 | 0.0 | 66.7 | 33.3 | 0.0 |
| 0.2 to 0.4 | 3.3 | 54.2 | 42.4 | 0.5 | 56.6 | 40.4 | 2.6 |
| 0.4 to 0.6 | 3.0 | 60.9 | 36.1 | 0.5 | 45.0 | 49.0 | 5.4 |
| 0.6 to 0.8 | 0.0 | 66.7 | 33.3 | 0.0 | 0.0 | 100.0 | 0.0 |
| 0.8 to 1 | 8.3 | 66.7 | 25.0 | 0.0 | 33.3 | 58.3 | 8.3 |
| District | | | | | | | |
| Bogura | 10.1 | 81.8 | 8.1 | 3.0 | 72.7 | 23.2 | 1.0 |
| Chapai Nawabg | 2.0 | 73.5 | 24.5 | 0.0 | 45.1 | 44.1 | 10.8 |
| Dinajpur | 2.0 | 31.4 | 66.7 | 0.0 | 45.1 | 52.0 | 2.9 |
| Kurigram | 3.9 | 73.5 | 22.5 | 0.0 | 36.3 | 59.8 | 3.9 |
| Natore | 2.0 | 46.1 | 52.0 | 0.0 | 60.8 | 39.2 | 0.0 |
| Nilphamari | 0.0 | 34.3 | 65.7 | 0.0 | 52.9 | 44.1 | 2.9 |

**Table 5** Explanatory variable description

| Variable | Obs | Mean | Std. dev | Percent | Min | Max |
|---|---|---|---|---|---|---|
| Sex (Male) | 580 | | | 95.24 | | |
| Age | 609 | 45.66 | 13.49 | | 18 | 75 |
| Education (Years of schooling) | 609 | 5.89 | 4.94 | | 0 | 18 |
| Marital Status (Married) | 579 | | | 95.07 | | |
| Main occupation (Agriculture) | 525 | | | 86.21 | | |
| Farm experience (Years) | 609 | 24.94 | 13.67 | | 1 | 60 |
| Working member (Number) | 609 | 2.96 | 1.31 | | 1 | 9 |
| Farm size (decimal) | 609 | 219.23 | 186.73 | | 30 | 1396 |
| Farming training (Yes) | 126 | | | 20.69 | | |
| Afford fertilizer (Yes) | 181 | | | 29.72 | | |
| Farm income (Tk) | 609 | 133,096.1 | 105,125.7 | | 12,800 | 672,500 |
| Off farm income (Tk) | 609 | 149,461.4 | 130,736.2 | | 0 | 1000,000 |
| Electricity (Yes) | 554 | | | 90.97 | | |
| Water (Yes) | 601 | | | 98.69 | | |
| Borrowed money (Yes) | 350 | | | 57.47 | | |

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**Table 6** The presence of multicollinearity

| Variable | VIF | 1/VIF |
|---|---|---|
| Farm experience | 3.68 | 0.271951 |
| Age | 3.63 | 0.275543 |
| Farm income | 2.08 | 0.481924 |
| Farm size | 2.06 | 0.485849 |
| Education | 1.26 | 0.793818 |
| Family working members | 1.18 | 0.85076 |
| Off farm income | 1.14 | 0.876767 |
| Farming training | 1.05 | 0.950383 |
| Sex | 1.05 | 0.956609 |
| Mean VIF | 1.9 | |

**Table 7** Factors affecting the choice of crop diversification

| HI | Odds ratio | Std. err | z | P > z |
|---|---|---|---|---|
| Age | 0.969496** | 0.013387 | -2.24 | 0.025 |
| Sex | 0.66932 | 0.331254 | -0.81 | 0.417 |
| Education | 1.013798 | 0.022819 | 0.61 | 0.543 |
| Farm experience | 1.024894*** | 0.013635 | 1.85 | 0.065 |
| Family Working members | 1.260665** | 0.117656 | 2.48 | 0.013 |
| Farm size | 1.002016** | 0.001063 | 1.9 | 0.058 |
| Farming training | 0.354975* | 0.108702 | -3.38 | 0.001 |
| Farm income | 1.000005* | 0.0000018 | 3.02 | 0.003 |
| Off farm income | 0.999999 | 0.00000089 | -0.82 | 0.414 |
| _cons | 12.78203 | 12.60416 | 2.58 | 0.01 |
| Number of obs | 609 | | | |
| LR chi2(15) | 78.36 | | | |
| Prob > chi2 | 0 | | | |
| Pseudo R2 | 0.1120 | | | |

*1% level of significance ** 5% level of significance *** 10% level of significance

that they will "participate in crop diversification." It is quite probable that farmers gain knowledge, expertise, and the crucial advantages of crop diversification as they mature. In addition, farmers tend to produce more crops as their experience grows, since crop diversity and experience are positively correlated. This association holds true for farm size, family worker engagement, farming revenue, and farming training. Every aspect shown has a favourable impact on farmers' decision-making.

Table 8 shows about the which factor influence on Household Food Insecurity Access Score, which is described below.

### Herfindahl index

If HI score increase by one unit, the multinomial log-odds for HFIAS score of marginal low food secure household would be expected to increase by 1.34 units while holding all other variables in the model constant as well as 2.4 unit increase for marginal low food secure household status to food insecure status. That means if farmers are tend to shift in one crop instead of producing more crops their farm income will be decreased and their food insecurity status also increased. Age: if age increases by one unit, the multinomial log-odds for HFIAS score of marginal low food secure household would be expected to decrease by 0.02 units while holding all other variables in the model constant. Because of age increases household may work in different sector as well as their food choice will be changed that's why their food security status also changed. Education: if education level increase by one unit, the multinomial log-odds for HFIAS score of marginal food secure household status to low food secure would be expected to decrease by 0.06 units while holding all other variables in the model constant as well as 0.2 unit decrease for marginal food secure household status to food insecure status. Education is a great source of knowledge.

By taking more knowledge farmers will be more conscious about their health as well as they can utilize their resources efficiency. Farm experience: if farm experience increases by one unit, the multinomial log-odds for HFIAS score of marginal food secure household status to low food secure would be expected to increase by 0.03 units while holding all other variables in the model constant. Farm and off farm Income: if farm and off farm income increase then we can see that people status will increase from food insecure and low food secure position. Because with the increase of income their HFIAS score may decrease. On the other hand, who are in high food secure group they have no change if their income will increase.

### Discussion

The level of education of a farmer has a beneficial impact on their devotion to crop diversification. Higher educated people those with primary, secondary, and advanced secondary education know more about the advantages of modern technology and high-tech equipment, which encourages them to grow more crops on a given plot of land. Aside from that, farmers learn the fundamentals of farming as they get older and become more knowledgeable about how to use their resources effectively. Furthermore, this expertise enables them to recognize various methods for cultivating several plant species in a single growing season. They clearly become a diversified farmer if training opportunities are also provided. On the other hand, it is evident that those who work in both the agricultural and non-agricultural sectors see a rise in income, because they might consume more than others. A multinominal logistic regression model reveals a negative correlation between

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**Table 8** Factor effecting on food security

| Household food insecurity access score | High food secure | | | Low food secure | | | Food insecure | | |
|---|---|---|---|---|---|---|---|---|---|
| | Coefficient | z | P > z | Coefficient | z | P > z | Coefficient | Z | P > z |
| HI | −2.4121 | −0.29 | 0.77 | 1.340978*** | 1.66 | 0.10 | 2.4*** | 1.72 | 0.086 |
| Age | 0.0693 | 0.96 | 0.34 | −0.029428** | −2.3 | 0.02 | 0.0 | − 0.06 | 0.949 |
| Education | 0.0409 | 0.45 | 0.65 | −0.068023* | −3.29 | 0.00 | -0.2* | − 2.6 | 0.009 |
| Farm experience | −0.0075 | −0.09 | 0.93 | 0.03222* | 2.59 | 0.01 | 0.0 | 1.01 | 0.311 |
| Farm size | 0.0042** | 2.03 | 0.04 | −0.00027 | −0.38 | 0.71 | 0.0*** | 1.81 | 0.071 |
| Farm income | 0.0000** | 2.19 | 0.03 | -0.000002*** | −1.82 | 0.07 | 0.0* | − 2.99 | 0.003 |
| Off farm income | 0.0000* | −2.63 | 0.01 | −0.000002* | −2.77 | 0.01 | 0.0*** | −1.64 | 0.101 |
| Total Expenses | 0.0000** | −0.67 | 0.50 | 0.000001 | 1.11 | 0.27 | 0.0 | − 0.07 | 0.943 |
| _cons | 12.0111 | 2.11 | 0.04 | 0.36013700 | 0.49 | 0.63 | 11.7 | 5.43 | 0 |
| Log pseudolikelihood | −464.02899 | | | Number of obs = | 609 | | | | |
| | | | | Wald chi2(30) = | 1674.42 | | | | |
| | | | | Prob > chi2 = | 0 | | | | |
| | | | | Pseudo R2 = | 0.1009 | | | | |

Base value: marginal food secure household.

*1% level of significance **5% level of significance.

moving from one category to another, with farm and off-farm income having a greater influence on the food insecure and low food secure groups compared on the marginally food secure group. For example, if household income from farming or other sources increases by one unit, the household's shifting attitude from marginal to low decreases. Numerous studies produced similar findings [42, 43]. Furthermore, educated individuals are conscious of how much food they consume and result shows the same things more educate people are more food secure than less educate people, this point agreeing with view of other researcher also [41, 44]. In households with higher crop diversification intensities, there is a greater chance of eating a variety of foods and a greater use of impoverished coping strategies for food insecurity. The same finding is shown by a study conducted in Malawi: more varied home meals may be influenced by more diversified agricultural systems [45]. Generally speaking, households that produce multiple crops have greater food security and revenue, making them better able to meet their household's food needs.

## Conclusions and policy recommendations

The impact of crop diversification on household food security in northern Bangladesh has been explored in this study. The study reveals that the majority of the household belongs in the borderline and acceptable area engaged in different crop cultivation. The binary logistic regression model implies that there are several factor effects on crop diversification such as age, farm experience, training, farm income, farm size and working family member. Moreover, multinominal logistic model shows that (HFIAS) highly impacted by HI along with age, education, farm experience, farm size, farm income and non-farm income. The Herfindahl index has a positive relationship with the Household Food Insecurity Access Score (HFIAS) and however, education level and farm revenue have a negative correlation with the HFIAS. Therefore, crop diversification enhances food security by enhancing food stock vs in terms of quantity and variation as well as by enhancing revenue through the sale of crops made from a variety of grown crop species, which is then used to further enhance consumption patterns. Though crop diversification program was commenced in Bangladesh 34 years ago but crop diversity rose by 4.5% [40]. Therefore, it is suggested that the government should facilitate and motivate farmers in producing a diversity or a variety of crops rather than one or a few crops to ensure food and nutritional security of the masses. Accordingly, government should give more focus on education and off farm activity through financial support which might improve the condition of food insecure and low food secure household in Bangladesh and northern region in particular.

Despite the fact that 609 sample respondents from the northern parts of Bangladesh were included in our research, it does not necessarily represent the state of affairs in Bangladesh as a whole. In addition, we had to collect food intake data during the previous four weeks in order to measure HFIAS, but depend on qualitative data considering time, resource and complexity of getting precise and quality data. Therefore, future research should

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consider combining both quantitative and qualitative data to measure food security.

## Availability of data and materials
The raw data of this study are stored securely in the computer of the principal investigator of the article. However, the raw data can be shared on reasonable request to M. Wakilur Rahman (wakilur.rahman@bau.edu.bd). where the data provision is highly secured in strict confidence.

## Declarations

### Ethics approval and consent to participate
Not applicable.

### Consent for publication
Not applicable.

### Competing interests
The authors declare no competing interests.

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