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Crop Diversity, Dietary Diversity and Nutritional Outcome in Rural Bangladesh: Evidences from VDSA Panel Household Surveys

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from the British people

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This paper is dedicated to the memory of

Late Dr. Mahabub Hossain

who planned this study

About this paper

Dr. Uttam Deb is currently an Assistant Professor at the University of Arkansas at Pine Bluff. Professor Abdul Bayes is the Director of Research and Evaluation Division, BRAC. The study on "Crop Diversity, Dietary Diversity and Nutritional Outcome in Rural Bangladesh: Evidences from VDSA Panel Household Surveys" was conducted for the LANSA in 2016. Authors acknowledge the suggestions and feedback received from the LANSA secretariat, anonymous referees and participants of the LANSA Knowledge Sharing Workshops entitled "Nexus between Agriculture and Nutrition: Bangladesh Case" held at the BRAC INN Auditorium. The research team also thanks Ms Barnali Chakraborty, Ms. Zeenat Ahmed of BRAC, Ms. Sangeetha Rajeesh, Research Uptake Manager, LANSA and Dr. RV Bhavani, Project Manager, LANSA at MSSRF, for their critical support and feedback. Authors are grateful to Ms. Gita Gopalakrishnan for excellent copyediting.

About LANSA

Leveraging Agriculture for Nutrition in South Asia (LANSA) is an international research partnership. LANSA is finding out how agriculture and agri-food systems can be better designed to advance nutrition. LANSA is focused on policies, interventions and strategies that can improve the nutritional status of women and children in South Asia. LANSA is funded by UKaid from the UK government. The views expressed do not necessarily reflect the UK Government's official policies. For more information see www.lansasouthasia.org

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Acronyms

BMI	Body Mass Index
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GLS	Generalized Least Squares
HDDS	Household Dietary Diversity Score
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IRRI	International Rice Research Institute
SDI	Simpson's Diversity Index
USD	United States Dollar
VDSA	Village Dynamics in South Asia

Abstract

Does crop diversity contribute toward dietary diversity and nutritional status of rural households in Bangladesh? The present study tries to answer this question. It has analysed panel household survey data collected from 500 households by ICRISAT and IRRI (2010/11 to 2014/15) under the Village Dynamics in South Asia (VDSA) project to examine the relationship between crop diversity, dietary diversity and nutritional status. Diversity in crop production has been estimated through the number of crops grown as also using Simpson's Diversity Index. The study has quantified the level of food intake, dietary diversity and nutritional status of each of the members of all the sample households. Fixed effect panel data regression analysis has been carried out to assess the contribution of relevant factors to diversity in crop production and dietary diversity. Nutritional status of the household members has been examined using the Body Mass Index (BMI). Determinants of nutritional status for individual household members have been identified through panel data analysis. Finally, the study has articulated implications of the research findings for public investment, agricultural policies and nutritional programmes in Bangladesh.

Key Words

Agriculture, nutrition, crop diversity, diet diversity, panel data, Bangladesh.

1. Introduction

Bangladesh has made remarkable progress in agricultural development and improvement in nutritional status over time. The agriculture sector has been diversified towards high value crops and non-crop agriculture. Between 1973/74 and 2014/15, agricultural GDP has increased by 5.8 times. The value of agriculture GDP has increased from USD 5.21 billion to USD 28.92 billion. All sub-sectors of agriculture (crop, livestock, fisheries and forestry) have increased substantially. Crop GDP has increased by 4.4 times, livestock GDP by 5.8 times and forestry GDP has increased by eight times. Furthermore, fisheries GDP has increased by more than six times. During this period, total GDP has grown by 20.8 times, increased from USD 8.92 billion to USD 185.43 billion. Per capita income (GNI) has increased by 6.2 times, from USD 211 to USD 1,314 (Deb 2016). The nutritional status of the Bangladesh people has also improved for all (children, youth and adults) over time. Between 2004 and 2014, stunting (height-for-age) level for under-five children has reduced from 51 per cent to 36 per cent. Wasting (weight-for-height) has reduced from 15 per cent to 14 per cent. During the same period, underweight (weight-for-age) has reduced from 43 per cent to 33 per cent (NIPORT et al. 2016).

Policy makers and development investors have been interested in the linkages between agriculture and nutrition. Experts argue that dietary diversity is a strong indicator of the nutritional status of the individuals. It is also believed that diversity in crop production leads to dietary diversity. Several studies have quantified dietary diversity scores (Kant et al. 1993; Drewnowski et al. 1997; Jones et al. 2014, Kavitha et al. 2016). Results from existing studies have shown that an increase in dietary diversity is associated with socioeconomic status and household food security measured in terms of household energy availability (Jones et al. 2014; Lo et al. 2012; Thorne-Lyman et al. 2010; Faber et al.

2009; Migotto et al. 2006; Ohiokpehai 2003; Hoddinot and Yohannes 2002) and monthly per capita caloric availability from non-staples for all households (Hoddinot and Yohannes 2002) and household expenditure (Thorne-Lyman et al. 2010).

In understanding the linkages between diversity in crop production, dietary diversity and nutritional outcomes the important research questions dealt with in this study are: What is the level of diversity in production and consumption of food items among rural households? What is the level of nutritional intake (calorie, fat and protein) and nutritional condition of the sample households? Does crop diversity matter for diet diversity and food consumption?

The broad objective is to analyse the linkages between crop diversity, dietary diversity and nutritional outcomes in rural Bangladesh. The specific objectives are as follows:

- To quantify the diversity in crop production among rural households in Bangladesh
- To calculate the level and determinants of food consumption and dietary diversity among rural households
- To assess the nutritional status of the rural population and analyse the association between crop diversity, dietary diversity and nutritional status.

The paper consists of four major sections. After this introductory section, section 2 discusses the data sources and research methodology. Section 3 describes the results featuring the linkages between crop diversity, dietary diversity and nutritional outcomes. Conclusions and policy implications are put forward in the last section.

2. Data and Research Methodology

2.1 Data

The study is based on household-level panel data collected for the period 2010/11 to 2014/15 from about 500 households located in 12 villages spanning over 11 districts in Bangladesh. The number of households surveyed in 2010/11 was 485. These households, including their split households, were surveyed in the subsequent years. Thus, the total number of households surveyed in 2014/15 increased to 507. Data used in this study have been collected by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and International Rice Research Institute (IRRI) under the Village Dynamics in South Asia (VDSA) project. Data were gathered from the panel households on various aspects of the rural economy (asset ownership, employment, transaction, food and non-food expenditure, prices, cultivation and livestock) through face-to-face interviews carried out on annual, seasonal and monthly basis. Both farm and non-farm households were included in the survey. About 50 per cent of the households had agriculture as major occupation and the other 50 per cent had non-farm as their major occupation. The study villages and sample households are in several agro-ecological zones, with varied infrastructure and socio-economic conditions. Thus, sample households in this study represent the average situation in rural Bangladesh.

The VDSA panel data include detailed information about food and non-food expenditure, quantity, prices and value of purchased items. Data on general endowments of the households, health and

nutritional status (height, weight, arm circumference, waist) of all household members were gathered in July of each year. It was not a food consumption survey. Quantity of different food items consumed on a daily or weekly basis by the households and its members were not collected as such. However, there was enough information about the food items produced, purchased and consumed by the household in a year. Using standard assumptions and prices, the average daily per capita consumption of different food items, as well as the calorie, protein and fat intake of the household members have been calculated.

2.2 Analytical procedures

Both descriptive and econometric analyses have been carried out to examine the research issues. The estimation procedure of key indicators is discussed below.

***Diversity in crop production*:** Diversity in crop production for individual households for each of the crop years has been measured using two indicators: Crop count and Simpson's Diversity Index (SDI) (Simpson 1949). Crop count refers to the number of crops grown by the farm household in a crop year. SDI is widely used to measure the diversity in crop cultivation. It is also known as crop diversity index. Equation (1) measures SDI.

$$\text{Simpson's Diversity Index} = 1 - \sum_{i=1}^{k} P_i^2 \quad \ldots \quad (1)$$

where, P_i is the share of i^{th} crop to the total crop area of farmer.

***Consumption of food items*:** Per capita average daily consumption of food items, calorie intake, protein intake and fat intake were estimated for each household, using information available in expenditure and consumption data collected from the households. Conversion factors available in the *Food Composition Table for Bangladesh* published by the Institute of Nutrition and Food Science of the Dhaka University (Shaheen et al. 2013) were used for calculation of the levels of energy, fat, protein and carbohydrate intake from various food items. Conversion factors used in this study are reported in **Table 1**.

***Determinants of consumption of food items*:** The dietary consumption pattern of rural households in Bangladesh is influenced by region, religion, family and individual food preferences. The fixed effect panel data generalized least squares (GLS) regression model is used to assess the contribution of multiple factors to food intake. Fixed effect models control for all time-invariant differences between the individuals, so the estimated coefficients of such models cannot be biased because of omitted time-invariant characteristics like culture, religion, gender, race, etc. Fixed effect models are designed to study the causes of changes within a person or entity. A time- invariant characteristic cannot cause such a change, because it is constant for each person (Kohler and Kreuter 2009). In separate regressions, the dependent variables were calorie intake, protein intake, fat intake and carbohydrate intake. Explanatory variables were per capita income of the household, diet diversity score, educational level of the household head, engagement of the household in farming, etc.

Equation (2) is used as empirical model in this study.

$$CropDiversity = \alpha_0 + \alpha_1\ operatedarea\ + \alpha_2\ mvadoprate + \alpha_3\ headedu + U_i\ (2)$$

where,
CropDiversity is diversity in crop production, measured through SDI and number of crops grown in alternate specification.
Explanatory variables are:
Operatedarea is total operated area of the household (in acres);
Mvadoprate is adoption rate of modern varieties (%);
Headedu is educational level of the household head (years);
β_i s are the coefficients of associated explanatory variables.

Based on the literature, it was taken that the total cultivated area of the household contributes positively to the diversity in crop production and hence it will have a positive sign; adoption of modern varieties is expected to create opportunities to grow more crops, so it will also have a positive sign. Education helps the household head to take decisions for betterment of its members, so it is expected to have a positive sign too.

***Dietary diversity*:** Dietary diversity is a qualitative measure of food consumption that reflects the household's access to a variety of foods and is also a proxy for the nutritional adequacy of an individual's diet (Ruel 2003; Kennedy et al. 2007). Under the FAO (2013) guidelines for measuring the household dietary diversity score (HDDS) followed in this study, food items consumed by the households can be recorded under 16 food groups (**Table 2**). Data collected through the VDSA household surveys note the foods consumed by the households into 12 food groups:

- Cereals
- White tubers and roots (potato)
- Vegetables
- Fruits
- Meat
- Eggs
- Fish and other seafood
- Legumes, nuts and seeds (pulses)
- Milk and milk products
- Oils and fats
- Sweets
- Spices, condiments and beverages

The dietary diversity score is basically a simple count of food groups that a household or an individual has consumed. Dietary diversity score of an individual indicates the nutrient adequacy, whereas HDDS is a snapshot of the economic ability of a household to access a variety of foods (FAO 2013).

***Determinants of dietary diversity*:** To assess the contribution of multiple factors on HDDS, both bivariate and multivariate analyses were conducted. In the bivariate analysis, the relationship between HDDS, diversity in crop production and number of crops grown were quantified. The impact of income, crop diversity and remittances on dietary diversity were assessed using fixed effect panel data GLS regression, as in Equation (3). Use of the fixed effect model has helped to take care of time-invariant characteristics of individuals such as culture, region and religion, all of which influence diet and consumption of food items in Bangladesh.

$$Consumplevel = \beta_0 + \beta_1\ percapitaincome\ + \beta_2\ dietdiversityscore + \beta_3\ headedu + \beta_4\ Dumyfarm\ + U_i\ (3)$$

where,
Consumplevel is per capita daily consumption level (energy, carbohydrate, protein, fat) of the household members.
Explanatory variables are:
Percapitaincome is per capita annual income of the household (in $);
Dietdiversityscore is diet diversity score of individual household members;
Headedu is educational level of the household head (years);
Dumyfarm is dummy for farm household;
β_i s are the coefficients of associated explanatory variables.

It is hypothesised that per capita income of the household contributes to purchasing power and thereby has an impact on consumption level; hence it will have a positive sign. Dietary diversity helps to enhance consumption level and is expected to have a positive sign. Education helps the household head to take decisions for the betterment of its members, so it is also expected to have positive signs. Farm households are directly engaged in production and therefore, dummy for farm households will have positive signs indicating a higher level of consumption by the members of such households than other households.

***Nutritional status*:** The nutritional status of each individual member of the household was measured through calculation of BMI, defined as a person's weight in kg divided by the square of height in metres. Equation (4) sets out BMI.

Body Mass Index (BMI) = $\frac{W}{h^2}$ ……. (4)

Where, w is weight of individual member in kg, his height of the individual in metres.

Based on the estimated BMI, the members of the household were categorised into four groups: normal weight, underweight, overweight and obese. According to FAO classification, an Asian person whose BMI is less than 18.5 is termed underweight; normal weight ranges between 18.5 and 23, overweight is between 23 and 29.9 and the BMI of an obese person is 30 or more (Nahar et al. 2013).

***Determinants of nutritional status*:** Nutritional status (normal bodyweight, underweight, overweight or obese) may be influenced by income, dietary diversity and other individual and household characteristics. The relative contribution of such variables to the nutritional status of the individual member was estimated using random effect Panel Data Probit Model, as in Equation (5).

$$NS_i = \beta_0 + \beta_1\ initialbodywt\ + \beta_2\ dietdiversityscore + \beta_3\ percapitaincome + \beta_4\ headedu + \beta_5\, Dumyfarm\ + U_i \quad (5)$$

where,
Initialbodywt is initial bodyweight of the individual household member;
Dietdiversityscore is diet diversity score of individual household member;
Percapitaincome is per capita annual income of the household (in $);
Headedu is educational level of the household head (years);
Dumyfarm is dummy for farm household;
β_i s are the coefficients of associated explanatory variables.

It is hypothesised that the initial bodyweight of the household member will have a positive sign. As explained in Equation (3), dietary diversity, per capita income of the households, educational level of the household head and the dummy for farm households will all have positive signs. .
In this analysis, the dependent variable is the nutritional status of the household (normal weight, underweight, overweight or obese) in separate models. It has binary value. For example, if the member is normal weight then the variable takes 1, otherwise it is 0. Explanatory variables are nutritional status in the initial year (2010/11), diet diversity score of the individual member and per capita income of the household. As mentioned earlier, for all household members data were collected for weight, height, circumference of arms and waist in July of each year, and the BMI calculated at the end of each year. In other words, BMI for an individual for the survey year 2010/11 was calculated based on data collected in July 2011. Similarly, for the year 2011/12, BMI refers to the data collected in July 2012, and so on. Thus, consumption by the household members throughout the year (July-June) was reflected in the health and nutritional status of the individual.

3. Results and Discussion

3.1 Basic characteristics of the sample households

Basic characteristics of the sample households are reported in **Table 3.** The average household size was 5.4. About one-fourth of the household members were children, and the average educational level of the household head was 5 years. Dependency ratio was 1.69. Per capita land ownership was only 0.20 acres. An important positive change among the households within a short span of five years was the growth in per capita ownership of non-land assets, which gradually increased from USD 640 in 2010/11 to USD 996 in 2014/15.

Households received incomes from farm and non-farm sources. Farm income sources included crop, livestock, fish and farm labour. Non-farm income sources include service, business, non-farm labour, caste occupation (such as barber, goldsmith, blacksmith, potter), remittances and rental income.

Between FY 2010/11 and FY 2014/15, the average per-capita income of the sample households rose by 32 per cent (from USD 344 to USD 454). Income sources have diversified. Increased dependence on non-farm sector as sources of livelihood among the VDSA panel households was observed. Agriculture played a key role and contributed about 40 per cent of the average income of all rural households and more than 80 per cent for farm households. On the other hand, non-farm households received 80 to 86 per cent of their income from non-farm activities. Among non-farm households, the topmost three income sources were business followed by "foreign service" (migrant work), and salaried jobs (Deb 2016). Increase in income among the VDSA panel households was associated with expansion of irrigation facility, adoption of modern varieties, accumulation of agricultural and non-agricultural capital, access to agricultural credit, market access through better roads and infrastructure, educational attainment, and expansion of rural non-farm economy. Migration within the country and outside the country has also played a key role towards the increase in household income (Deb et al. 2014).

3.2 Cropping patterns

Rice dominated the cropping pattern among the rural households in the rainy season (**Table 4**). More than 99 per cent of the area was under rice, and there was not much change over the five years under study. In the post-rainy season, there was increased production of vegetables, oilseeds, pulses and other high value crops (**Table 5**). Over 45 per cent of the total cropped area was under the cultivation of non-rice crops. In other words, more than half of the total cropped area was still under rice production. About 15 per cent of the cultivated area was under wheat and maize cultivation. Pulses covered about 15 per cent too. The share of jute fluctuated and ranged between 4 to 11 per cent of the total cropped area in the post-rainy season. Allocation for potato and vegetables together was about 4 per cent.

3.3 Diversity in crop production

Estimated value of diversity in crop production (Simpson's Index) is provided in **Table 6**. The value of Simpson's Index may vary from zero to 1. Zero indicates no diversity in production, only one crop is grown. On the other hand, 1 indicates fully diversified crop production, with many crops grown by the farmers. Crop Diversity Score has been measured for each of the sample households. Average value of the crop diversity score for all households has slightly declined during the study period, from 0.21 in 2010/11 to 0.18 in 2014/15. In 2010/11, for 42 per cent of the households the score was zero, indicating two out of five farmers produced only one crop. In 2014/15, the zero-diversity score covered 52 per cent of the farmers, indicating that one out of two farmers had grown only one crop. In the initial year, about 10 per cent farm households showed a high diversity score (more than 0.60), which reduced to 7 per cent in 2014/15. Medium diversity score (>0.20 to 0.60) covered 32 per cent farmers in 2010/11 which reduced to 29 per cent in 2014/15. More than 5 per cent of households had a low diversity score (>0.0 to 0.10) in 2010/11, which reduced to 4.5 per cent in 2014/15. Bangladesh has experienced the adoption of new seed, fertilizer and irrigation technologies. Production risks have reduced significantly over time. With the spread of irrigation and assured production technologies along with expanded road and market facilities in rural areas, many farmers have chosen the path of specialisation in crop production. It was observed that farmers have been cultivating more high value crops in recent years. In other words, there has been diversification

towards high value crops. Several studies (Joshi et al. 2007; Rao et al. 2004) have reported diversification towards high value crops in India also.

During the study period, there has been change in the number of crops grown. Only one crop was grown by 35 per cent of the households in 2010/11, while 32 per cent grew only one crop in 2014/15 (**Table 7**). On the other hand, about 38 per cent households cultivated two to three crops in 2010/11, which increased to 49 per cent of households in 2014/15. About 19 per cent households raised four to five crops in 2010/11 but it had reduced to around 12 per cent in 2014/15. About 8 per cent of the households cultivated six or more crops, which reduced to 7 per cent in 2014/15.

Diversity in crop production has been influenced by several factors. As mentioned earlier, the determinants of crop diversity were identified through fixed effect panel data regression analysis. The estimated model has a good fit which was indicated through probability of F significant at 1 per cent level of significance (**Table 8**). The analysis revealed that total operated area has positively contributed to the Simpson's Index at 1 per cent level of significance. Estimated coefficient indicated that one additional acre of operated land area to the farmer will increase Simpson's Index by 0.03. On the other hand, one additional acre of operated land will increase the number of crops grown by the farmer by 0.4. Similarly, 10 per cent increase in adoption rate of modern varieties will lead to an increase in the number of crops grown by 0.07 per cent. These are quite logical, because more area is needed to grow more crops or there should be high production of the most essential crops from less amount of land. Modern varieties allow farmers to get more output from the same area of land. Educational level of the household head had significant positive contribution to the Simpson's Index at 5 per cent level of significance. Increase in the educational level by one year will increase the Simpson's Index by 0.008.

3.4 Food consumption, dietary diversity and nutritional status

Consumption of food items

Average per capita daily intake of energy increased from 2024 kcal in 2010/11 to 2035 kcal in 2014/15 (**Table 9**). Daily carbohydrate consumption increased from 392 gm in 2010/11 to 396 gm in 2014/15. In all the years, daily protein and fat consumption remained about 55 gm and 19 gm, respectively.

Average daily per capita consumption of the different food items gradually increased over the years, except for milk (**Table 10**). In 2014/15, average daily per capita consumption was 392 gm of cereals (rice and wheat), 68 gm of vegetables, 26 gm of potato, 8.12 gm of fruits, 5.2 gm of spices, 4.5 gm of pulses, 9.3 gm of edible oil and ghee, 45.7 gm of eggs, 12.6 gm of fish, 14.1 gm of milk, 7.2 gm of meat and 5.2 gm of sugar, gur and sweets. Consumption of milk slightly decreased between 2010/11 and 2014/15. Between 2010/11 and 2014/15, daily consumption of cereals (rice and wheat) slightly increased from 392 gm to 396 gm. During the same period, daily vegetable consumption increased by 37 per cent. Potato consumption more than doubled. Consumption of fruits rose by 10 per cent, spices increased by 23 per cent and pulses by 61 per cent. Consumption of edible oil and ghee increased by 19 per cent. Intake of eggs grew by 40 per cent while that of fish increased by 4 per cent. Milk consumption decreased by 22 per cent but meat consumption increased by 20 per cent. Consumption of sugar, gur and sweets increased by 15 per cent. It may be noted here that

Household Income and Expenditure Surveys (HIES) have also reported increased consumption of fruits, vegetables, milk, fish, eggs, and meat over time (HIES 2010).

Average daily consumption of food items by producer households was generally higher than that of non-producer households (**Table 11**). Generally, producer households consumed two per cent more cereals and 15 per cent more vegetables than non-producer households. Potato consumption of producer households was 34 per cent higher while they also consumed 7.5 per cent more of fruits. Spices intake was 14 per cent more and edible oils and fat consumption was 2.3 per cent higher. In case of sweet, sugar and gur, producer households consumed 14 per cent more than others. Only in the case of pulses, non-producer households consumed more than producer households, by 7 per cent.

Table 12 reports the results of the fixed effect panel data regression model. It identifies the critical factors which determine the energy, protein, fat and carbohydrate intake level. The estimated models have good fit, indicated through probability of F significant at one per cent level of significance. Estimated coefficients indicate strong positive association between diet diversity score and energy (kcal) intake level. Similarly, per capita income of the household displays highly significant positive association with energy consumption level. Farm households dummy show significant positive association, indicating that farm households had more energy intake than other households. In case of consumption of carbohydrate, the dietary diversity score displays significant positive association. Farm households have higher level of intake than others. Protein intakes were also influenced by the dietary diversity score and income of the households, with farm households faring better in protein consumption. It is counter-intuitive that households with a higher educational level of the family head had likelihood of consuming less protein. Intake of fat has strong positive association with dietary diversity score as also with dummy for farm households. In brief, intake of energy, carbohydrate, protein and fat of the household members were largely influenced by the dietary diversity score.

Food deprivation: The Food and Agriculture Organization of the United Nations (FAO) defines food deprivation, or undernourishment, as the consumption of fewer than about 1,800 kilocalories a day — the minimum that most people require for living a healthy and productive life. Based on the estimated daily consumption level of energy, households have been grouped into two categories: food deprived and not food deprived. Households whose members consumed less than 1800 kcal a day are defined as food-deprived households. On the other hand, households whose members consumed 1800 kcal or more daily are defined as not food deprived. About one-third of the households were found to be food deprived (**Table 13**). However, year-to-year fluctuations in food deprivation have been observed.

Dietary diversity

In this analysis, rural households have consumed food items from 12 different food groups. Therefore, the maximum possible household dietary diversity score (HDDS) can be 12. Average dietary score increased from 8.2 in 2010/11 to 9.3 in 2014/15 (**Table 14**). Detailed analysis revealed that wide disparity existed among households. In all the study years, less than 8 per cent individuals had a dietary diversity score of 5 or less in 2010/11, which reduced to less than 3 per cent in 2014/15. In 2010/11, 46 per cent showed a medium dietary diversity score (6 to 8), 36 per cent

people had a high diversity score (9 to 10) and 10 per cent people a very high dietary diversity score (11 to 12). The dietary diversity score has gradually increased over the years. In 2014/15, 28 per cent of the respondents had a very high dietary score and 43 per cent had a high dietary score.

The association between dietary diversity, crop diversity, per capita income and other household characteristics was analysed using the fixed effect panel data regression model. Estimated coefficients showed that crop diversity (measured through Simpson's Index as well as number of crops grown) contributed strongly to dietary diversity (**Table 15**). Increase in Simpson's Index by one unit will lead to increase in dietary diversity by 0.39. On the other hand, one additional crop grown by the household will lead to increase in dietary diversity by 0.07. Similarly, per capita income of the household has highly significant positive association with dietary diversity at 1 per cent level of significance. Increase in per capita income by USD 100 will increase dietary diversity by 0.02. Crop diversity has provided more options to choose food items. Further, income level has provided necessary purchasing power to buy a diversified diet. Thus, these two factors (crop diversity and income) have contributed positively towards the dietary score of the same household. Asset ownership of the households has also contributed significantly to the dietary diversity. Additional USD 1000 of asset ownership resulted an increase in dietary diversity by 0.004 unit. Remittances contributed to the dietary diversity of the households at 1 per cent level of significance. The estimated value of the dummy variable for remittances shows that remittances increased dietary diversity by 0.4 unit.

Nutritional status

Based on the estimated Body Mass Index (BMI), individuals were grouped into four categories: underweight (BMI<18.5), normal weight (BMI 18.5 to <23), overweight (BMI 23 to <30) and obese (BMI 30 or more). About 44 percent of the people were in the normal weight category in all the study years (**Table 16**). About 1 per cent was in the category of obese. The percentage of people belonging to the underweight category declined from 48 in 2010/11 to 44 per cent in 2013/14. On the other hand, the percentage of overweight people went up from 6.6 per cent in 2010/11 to 8.5 per cent in 2013/14. Apparently, it looks like that there has been no major change in the nutritional status of the people included in this study.

A detailed nutritional status analysis for both men and women members of the household is provided in **Table 17**. It reveals that the percentage of underweight people decreased for both men and women. The percentage share of normal bodyweight people has increased by two percentage points over the four years. In 2013/14, 46.2 per cent of the male and 46.9 per cent of the female population had normal bodyweight. Overweight and obesity have increased among both men and women. However, the rate of increase was higher for women than their male counterparts. In 2013/14.2 per cent of women were obese against 0.5 per cent of men. During the same year, 11.3 per cent of women were overweight compared to 5.6 per cent of men.

Nutritional status of a person is not static over time. It may improve, deteriorate or even remain same over time for some individuals. So, it is worthwhile to analyse the changes (or mobility) in the nutritional status of the individual household members over time. Existing studies on nutrition have not analysed this important issue of mobility in nutritional status over time. However, mobility analysis is common in sociological investigations and labour studies. According to the Merriam-

Webster dictionary, mobility is the ability to change one's social or socioeconomic position in a community and especially to improve it. To examine the mobility in nutritional status or dynamics of nutritional status over time, we have introduced a new concept, "Nutritional Mobility Matrix". We have defined mobility in nutritional status as the ability of an individual to switch between different nutritional categories (under-weight, normal-weight, over-weight, and obese). Change in nutritional status of each of the household members between 2010/11) and 2013/14 were documented and analysed. **Table 18** reports the calculated nutritional mobility matrix. Rapid and surprising changes were observed. Among all people with normal bodyweight in 2010/11, only two-thirds maintained their status in 2013/14. Twenty per cent of normal bodyweight people became overweight while 12 per cent came down to the underweight category. It would be worth exploring the reasons. During the same period, three-fourths of overweight people retained their status, 4 per cent became obese and another 4 per cent became underweight, while 15 per cent people reduced their weight to the normal bodyweight category. Fifty per cent of the obese people remained obese but 11 per cent fell into the category of underweight. Was it a normal weight reduction exercise or a deliberate shift after obesity-related diseases? Four-fifths of the underweight people were in the same category, 19 per cent improved their health and reached normal bodyweight while 2.6 per cent became overweight. In brief, the double burden of nutrition was observed among the sample households, with the prevalence of both forms of malnutrition (underweight and overweight).

It is interesting to analyse consumption behaviour and identify the agents for such rapid changes in nutritional status. There is a saying: 'You are what you eat'. The food intake behaviour of the members of the sample households with various kinds of nutritional status confirmed this saying. The daily energy, fat, protein and carbohydrate consumption level of underweight individuals was 6 to 7 per cent less than that of individuals having normal bodyweight (**Table 19**). On the other hand, overweight people consumed 2 to 4 per cent higher of these nutrients, compared to the normal bodyweight people. Obese individuals consumed 3 to 5 per cent higher than their normal bodyweight associates. Average daily intake level of normal bodyweight individuals was 2043 kcal energy, 54.8 gm protein, 19.3 gm fat and 398 gm carbohydrate.

Table 20 depicts the results of the Panel Data Probit Model (Random Effect) which identified the determinants of the nutritional status of household members. The estimated regression was significant at 1 per cent level as indicated by the probability of Chi^2 statistics. The signs and magnitude of the estimated coefficients corresponding to the explanatory variables are in line with intuitive expectations. These are described below.

Normal bodyweight: Initial nutrition status (bodyweight) is one of the most important factor to determine whether the person would be enjoying a normal healthy bodyweight indicated through the value of estimated BMI. There was highly significant positive relationship between initial bodyweight in 2010/11 and normal bodyweight of the individual in later years. The dietary diversity score has significant positive association with normal bodyweight. Estimated value of the coefficients shows that the dietary diversity score ensures adequate intake of different nutrients which are needed to attain and maintain normal healthy bodyweight. Moreover, income level supports the individual's aspiration to have adequate diet and good quality food.

Underweight: Initial conditions also matter for people who are underweight. Significant negative relationship exists between an underweight individual's dietary score and weight level in subsequent years. In other words, higher the level of dietary diversity, lower the likelihood of being underweight. Similarly, negative coefficient for per capita income of the individual indicates the reality that a person with a lower level of income has a higher likelihood of being underweight. Money allows people to buy and consume more food and, thereby, reduces the probability of being underweight. The educational level of the household head is negatively associated with bodyweight. In other words, it is less likely that the household members will be underweight if the household head has attained a higher level of education.

Overweight: Initial conditions also matter in determining whether an individual will be overweight or not in subsequent years. Individuals who were overweight in the previous year are most likely to continue as overweight the following year. Significant positive association exists with the dietary diversity score and income level, indicating that increase in income enhances affordability of a diversified diet and, thus, helps to increase dietary diversity.

Obese: The estimated coefficient indicates that if a person was obese in the initial year, then he or she is most likely to be obese in subsequent years.

4. Summary and Conclusions

The relationship between crop diversity, dietary diversity and nutritional status of rural households has been examined in this paper. The analysis revealed that diversity in crop production has increased during the study period. On an average, farmers grew 8.2 crops in 2010/11, which increased to 9.3 in 2014/15. But, the average level of diversity in crop production (measured through Simpson's Index) has slightly decreased from 0.21 in 2010/11 to 0.18 in 2014/15. The daily consumption level of all food items has increased except for slight reduction in that of milk. Average daily consumption of food items by producer household members was higher than that of non-producer household members. Crop diversity, per capita income of the household and educational level of the household head had significant positive contributions to the dietary diversity score of the household. Nutritional status of the household members is measured by BMI. Econometric analysis revealed that crop diversity level has direct influence on dietary diversity and, thereby, on the nutritional status of the individual. Per capita income also plays a vital role in determining the nutritional status of the household member. Thus, this study provides empirical evidence about linkages between crop diversity, dietary diversity and nutritional status in rural Bangladesh. Based on the research findings, it can be concluded that diversification in crop cultivation and related investment have contributed towards nutritional achievement in Bangladesh. Therefore, crop diversification must be promoted for further improvement in the nutritional status of people in Bangladesh.

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Appendix

Table 1: Food items consumed by the sample households

Food Item (100 gm)	Edible Portion Coefficient	Calories	Protein (g)	Fat (g)	Carbs (g)
Leafy vegetables	0.73	21	0.9	0.1	3.7
Other vegetables	0.5	27	2.7	0.3	2.7
Potato	0.84	66	1.2	0.2	14
Fruit	0.74	95	1.3	0.8	19.2
Spices					
Pulses	1	350	23.7	1.2	60.9
Mustard Oil	1	900	0	100	0
Soyabean Oil	1	900	0	100	0
Ghee, vegetable (Dalda, Vanaspati)	1	900	0	100	0
Ghee, cow	1	898	0	99.8	0
Eggs	0.87	139	14.5	9	0
Fish	0.6	130	21.4	4.9	0
Beef	1	126	20.3	5	0
Chicken	0.76	106	22.3	1.8	0
Mutton	0.69	118	21.4	3.6	0
Milk	1	497	26.6	26.7	37.5
Rice	1	344	6.5	0.4	76.8
Wheat	1	344	11.2	2.9	62
Maize	1	344	9.9	3.4	64.7
Sugar	1	385	0.5	0.1	95.4

Source: Food Composition Table for Bangladesh, University of Dhaka

Table 2: Categories of food groups

Sl. No.	Food Group (Total 16)	HDDS Food Groups (Total 12)
1	Cereals	Cereals
2	White roots and tubers	White tubers and roots
3	Vitamin A-rich vegetables and tubers	Vegetables
4	Dark green leafy vegetables	
5	Other vegetables	
6	Vitamin A-rich fruits	
7	Other fruits	Fruits
8	Organ meat	
9	Flesh meats	Meat
10	Eggs	Eggs
11	Fish and seafood	Fish and other seafood
12	Legumes, nuts and seeds	Legumes, nuts and seeds
13	Milk and milk products	Milk and milk products
14	Oils and fats	Oils and fats
15	Sweets	Sweets
16	Spices, condiments, beverages	Spices, condiments and beverages

Source: FAO (2013)

Table 3: Basic characteristics of the sample households: 2010/11 to 2014/15

Indicators	Periods				
	2010/11	2011/12	2012/13	2013/14	2014/15
Number of households	485	490	500	499	507
Household size	5.40	5.35	5.33	5.35	5.28
Children (%)	28.10	27.39	26.55	24.92	24.37
Female-male ratio	0.92	0.90	0.91	0.91	0.91
Reproductive women	48.68	49.44	50.00	50.55	51.43
Child-woman ratio	58.74	57.72	55.67	54.52	55.80
Dependency ratio (%)	1.44	1.45	1.69	1.69	1.69
Own land per capita (decimal)	21	22	21	21	21
Landholding per capita (decimal)	22	21	21	20	20
Age of the household head (years)	50	51	51	52	52
Education of the household head (years)	4.49	4.54	4.62	4.64	5.80
Number of workers per household	1.69	1.72	1.98	1.88	1.88
Per capita non-land assets ownership (current USD)	640	684	809	944	996
Annual income of the household (USD)	1774	2075	1718	2358	2370
Per capita annual income (USD)	344	394	345	454	454
Share of farm income to the total income (%)	49.9	44.7	58.7	42.1	39.3

Source: Authors' calculation, based on VDSA database

Table 4: Cropping pattern (% of area under different crops) in rainy season, 2010/11-2014/15

Crops	2010/11	2011/12	2012/13	2013/14	2014/15
Paddy	99.6	99.8	99.4	99.6	98.9
Pulses	0.3	0.0	0.5	0.2	0.0
Vegetables	0.2	0.2	0.1	0.1	0.7
Others	0.0	0.0	0.1	0.0	0.3

Source: Authors' calculation, based on VDSA panel data

Table 5: Cropping pattern (% of area under different crops) in post-rainy season, 2010/11-2014/15

Crops	2010/11	2011/12	2012/13	2013/14	2014/15
Paddy	54.3	55.1	50.9	54.1	53.6
Wheat	5.6	4.7	5.3	6.2	8.5
Maize	1.1	4.4	5.5	7.4	7.8
Jute	10.7	8.8	7.9	5.3	3.6
Pulses	11.4	12.9	17.0	15.4	15.3
Oilseeds	3.7	2.6	6.8	5.3	4.2
Potato	2.9	2.1	2.1	2.4	2.2
Vegetables	2.8	1.9	2.3	2.2	1.6
Spices	0.9	1.7	1.2	0.7	0.7
Others	6.6	5.8	1.0	0.9	2.3
Total	100.0	100.0	100.0	100.0	100.0

Source: Authors' calculation, based on VDSA panel data

Table 6: Diversity in crop production (Simpson's Index)

Simpson's Index	% of Households in the Year				
	2010/11	2011/12	2012/13	2013/14	2014/15
0	43.78	46.51	42.32	48.86	52.40
>0.0 to 0.10	5.70	6.98	6.20	6.00	4.49
>0.10 to 0.20	8.29	9.30	7.28	9.43	6.89
>0.20 to 0.40	16.84	16.54	21.83	16.57	13.77
>0.40 to 0.60	15.80	12.40	14.56	12.00	15.57
>0.60 to 0.80	9.59	8.27	7.82	7.14	6.89
Total	100.00	100.00	100.00	100.00	100.00
Average crop diversity score	0.21	0.18	0.21	0.17	0.18

Source: Authors' calculation, based on VDSA panel data

Table 7: Number of crops grown by the sample households, 2010/11 to 2014/15

# Crops Grown	% Households in				
	2010/11	2011/12	2012/13	2013/14	2014/15
One crop	34.46	33.59	29.92	32.00	32.04
2 to 3 crops	38.60	40.57	42.59	46.86	49.40
4 to 5 crops	19.17	18.86	18.33	14.86	11.68
6 or more crops	7.77	6.98	9.16	6.29	6.89
All	100.00	100.00	100.00	100.00	100.00
Average number of crops grown by households	2.7	2.6	2.8	2.6	2.5

Source: Authors' calculation, based on VDSA panel data

Table 8: Determinants of crop diversity: Results of the fixed effect panel data regression analysis

Variables	Simpson's Index	Number of Crops Grown
Total operated area (acres)	0.029***	0.409***
	(0.007)	(0.044)
Adoption rate of modern varieties (%)	0.00007	0.007***
	(.0001)	(0.001)
Education level of household head (years)	0.008**	0.006
	(0.004)	(0.028)
Constant	0.079***	1.166***
	(0.022)	(0.149)
Prob > F	0.000	0.000
sigma_u	0.186	1.429
sigma_e	0.132	0.881
Rho	0.666	0.725
Number of observations	2267	2267

Note: *=1%, **=5% and *=10% level of significance. Figures in parentheses are robust standard errors.**
Source: Authors' calculation, based on VDSA panel data.

Table 9: Average per capita daily intake by sample households

Indicator	2010/11	2011/12	2012/13	2013/14	2014/15
Energy (kcal)	2024	2044	1957	2024	2035
Protein (g)	55	54	53	55	55
Fat (g)	20	19	18	19	18
Carbohydrate (g)	392	401	381	392	396

Source: Authors' calculation, based on VDSA panel data.

Table 10: Average daily per capita consumption level (gm) of rural households: 2010/11-2014/15

Food Items	2010/11	2011/12	2012/13	2013/14	2014/15
Cereals (rice and wheat)	392.45	400.61	380.89	391.75	396.16
Vegetables	49.79	56.11	59.44	64.02	68.13
Potato	10.29	19.66	16.08	23.98	26.07
Fruits	7.42	9.52	9.14	9.51	8.17
Spices	4.23	4.43	4.43	5.15	5.20
Pulses	2.78	1.95	3.32	3.35	4.48
Edible oil and ghee	7.81	8.01	8.25	8.67	9.32
Eggs	32.75	34.84	33.25	42.10	45.77
Fish	12.14	12.10	11.95	11.97	12.59
Milk	17.96	15.81	15.60	15.87	14.09
Meat	5.97	5.79	6.00	7.24	7.16
Sugar, gur and sweets	4.51	4.74	5.11	5.37	5.20

Source: Authors' calculation, based on VDSA panel data

Table 11: Average daily per capita consumption level (gm), by producer and non-producer households: 2010/11-2014/15

Food Group	Non-producer Households	Producer Households	All Households
Cereal (rice and wheat)	386.52	394.36	392.37
Vegetables	54.26	62.15	54.96
Potato	16.04	21.52	16.67
Fruits	8.52	9.16	8.54
Spices	4.23	4.82	4.24
Pulses	2.91	2.71	2.87
Edible oil & ghee	7.79	7.97	7.82
Sugar, gur and sweets	4.70	5.36	4.70

Source: Authors' calculation, based on VDSA panel data

Table 12: Determinants of consumption level of individual household members: Results of the fixed effect panel data regression analysis

Variables	Energy (kcal)	Carbohydrate (gm)	Protein	Fat
Per capita income (USD)	0.018**	0.002	0.0007**	0.0004
	(0.008)	(0.0015)	(0.0003)	(0.0003)
Diet diversity score	63.476***	7.29220***	3.059***	2.234***
	(2.720)	(0.492)	(0.099)	(0.084)
Dummy for farm household	31.043***	4.237***	1.233***	0.926***
	(8.494)	(1.537)	(0.312)	(0.263)
Education level of household head (years)	-7.697	-1.116	-0.307***	-0.249
	(7.158)	(1.295)	(0.263)	(0.221)
Constant	1447.295 ***	326.564***	26.872***	-0.450
	(40.413)	(7.314)	(1.483)	(1.249)
Prob > F	0.000	0.000	0.000	0.000
Sigma_u	319.604	58.762	11.191	8.488
Sigma_e	214.181	38.762	7.859	6.622
Rho	0.690	0.697	0.669	0.622
Number of observations	7441	7441	7441	7441

Note: *=1%, **=5% and *=10% level of significance. Figures in parentheses are robust standard errors.**
Source: Authors' calculation, based on VDSA panel data.

Table 13: Percentage of households that experienced food deprivation (<1800 Kcal, 1 = Yes, 0 = No)

Indicators	2010/11	2011/12	2012/13	2013/14	2014/15
Food deprived	30.80	31.21	40.67	33.33	31.57
Not food deprived	69.20	68.79	59.33	66.67	68.43
All	100.00	100.00	100.00	100.00	100.00

Source: Authors' calculation, based on VDSA panel data

Table 14: Dietary diversity scores of sample households (%): 2010/11 to 2014/15

Dietary Diversity Score	2010/11	2011/12	2012/13	2013/14	2014/15
1	0.60	0.20	0.00	0.00	0.20
2	1.00	0.60	0.79	0.20	0.20
3	0.60	0.40	0.00	0.20	0.20
4	1.20	0.20	0.59	0.99	0.39
5	4.00	1.59	3.73	0.99	1.76
6	10.60	4.57	6.88	4.73	4.12
7	15.00	8.95	7.66	8.28	9.61
8	20.20	15.71	16.90	14.00	13.33
9	19.60	22.86	22.20	24.26	20.20
10	16.80	24.45	19.84	24.85	22.55
11	9.40	19.68	18.07	18.34	16.67
12	1.00	0.80	3.34	3.16	10.78
All	100.00	100.00	100.00	100.00	100.00
Average diet diversity score	8.20	9.03	8.90	9.15	9.30

Source: Authors' calculation, based on VDSA panel data

Table 15: Determinants of dietary diversity score (DDS) of household: Results of the fixed effect panel data regression analysis

Variables	Dependent variable = Dietary Diversity Score (DDS)	
	Model 1	Model 2
Per capita income ($)	0.0002*** (0.0001)	0.0002*** (0.0001)
Simpson's Index	0.3903** (0.1873)	
Crops grown		0.0715*** (0.0265)
Asset ownership of the household ('000 USD)	0.0043*** (0.0014)	0.0043*** (0.0014)
Educational level of household head (years)	0.0141 (0.0325)	0.0174 (0.0324)
Dummy for remittance income	0.3533*** (0.0892)	0.3704*** (0.0896)
Constant	8.6273*** (0.1594)	8.5240*** (0.1674)
Prob > F	0.0000	0.0000
Sigma_u	1.4085	1.4069
Sigma_e	1.0746	1.0738
Rho	0.6321	0.6319
Number of observation	2440	2440

Note: *=1%, **=5% and *=10% level of significance. Figures in parentheses are robust standard errors.**
Source: Authors' calculation, based on VDSA panel data

Table 16: Nutrition situation of the members of the sample households

Nutritional Status	Percentage of People			
	2010/11	2011/12	2012/13	2013/14
Normal weight	44.3	43.1	44.6	46.6
Obese	0.9	0.9	1.0	1.2
Overweight	6.6	6.9	7.4	8.5
Underweight	48.2	49.2	47.0	43.7
Total	100.0	100.0	100.0	100.0

Source: Authors' calculation, based on VDSA panel data

Table 17: Nutrition situation of male and female members of the sample households

Indicator	Male				Female			
	2010/11	2011/12	2012/13	2013/14	2010/11	2011/12	2012/13	2013/14
Normal Weight	44.3	43.2	44.5	46.2	44.2	42.9	44.7	46.9
Obese	0.5	0.6	0.6	0.5	1.3	1.2	1.5	2.0
Overweight	3.9	4.2	5.0	5.6	9.3	9.5	9.6	11.3
Underweight	51.3	52.0	49.9	47.7	45.1	46.5	44.2	39.8
All	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Authors' calculation, based on VDSA panel data

Table 18: Change in nutritional status (BMI) of household members from 2010/11 to 2013/14

Nutritional Status	2010/11	2013/14				
		Normal Weight	Obese	Overweight	Under-Weight	Grand Total
Normal Weight	36.88 (621)	68.60	0.00	19.65	11.76	100.00
Obese	1.07 (18)	5.56	50.00	33.33	11.11	100.00
Overweight	15.56 (262)	15.27	4.20	76.72	3.82	100.00
Under-Weight	46.50 (783)	18.90	0.00	2.55	78.54	100.00
All	100.00 (1684)	36.52	1.19	20.72	41.57	100.00

Source: Authors' calculation, based on VDSA panel data

Table 19: Nutritional status and average daily per capita consumption level: 2010-2013

Nutritional Status	Average Daily Per Capita Consumption of			
	Energy (kcal)	Protein (g)	Fat (g)	Carbohydrates (g)
Normal Weight	2043	54.76	19.3	398
Obese	2123	56.32	18.5	417
Overweight	2078	56.43	20.1	403
Underweight	1919	51.10	17.9	375

Source: Authors' calculation, based on VDSA panel data

Table 20: Determinants of nutritional status of household members: Results of the panel data probit random effect model

Variables	Normal Weight	Underweight	Overweight	Obese
Initial bodyweight in 2010/11	3.013*** (0.088)	4.163*** (0.144)	4.308*** (0.185)	6.007*** (0.704)
Diet diversity score	0.049*** (0.017)	-0.101*** (0.021)	0.068*** (0.025)	-0.024 (0.075)
Per capita licome (100$)	0.004 (0.006)	-0.021** (0.008)	0.019** (0.008)	-0.011 (0.018)
Educational level of household head (years)	-0.004 (0.007)	-0.019** (0.009)	0.029*** (0.010)	0.049 (0.030)
Dummy for farm household	0.071 (0.054)	-0.005 (0.068)	-0.131 (0.080)	-0.137 (0.248)
Constant	-2.222*** (0.161)	-1.238*** (0.198)	-3.400*** (0.255)	-5.047*** (0.779)
Log likelihood	-2531.331	-1865.530	-1413.105	-187.692
Prob > chi2	0.000	0.000	0.000	0.000
Sigma_u	0.829	1.073	1.159	1.585
Rho	0.408	0.535	0.573	0.715
Number of observations	7441	7441	7441	7441

Note: *=1%, **=5% and *=10% level of significance. Figures in parentheses are robust standard errors.**
Source: Authors' calculation, based on VDSA panel data