Review Article

Status of agricultural diversification and its influencing factors in Bangladesh: Qualitative review

ABSTRACT

Agricultural diversification has been recognized as one of the important adaptation strategies for sustaining rural livelihoods which enhances farm income, generates employment opportunities and manages risk in agriculture. Despite a wealth of data supporting the advantages of agricultural diversity, farmers' decisions and determinant factors regarding diversification in agriculture have not been well defined. This review was made to measure the status and influencing factors of agricultural diversification in Bangladesh. Different published and unpublished research articles, papers, books, government reports etc., on agricultural diversification were collected through different search engines from different databases, Google scholar and Google.

This paper revealed that Bangladesh has made remarkable progress in cereals & non- cereals food production during the last 25 years. This progress in cereals food (rice, wheat and maize) production during the period of 2000-2022 increased by 1.75 times and non-cereals food (potato, vegetables, fruits, pulse, oilseeds, spices, milk, meat) production increased by 4.75 times. As a result, the percentage of non-cereals food consumption increased from 46.74% in 2000 to 65.92% in 2022. Diversity in agriculture was measured using different methods such as Simpson Diversity Index (SDI), Herfindahl Index (HI), Entropy Index (EI), Herfindahl–Hirschman Index (HHI), Counting the number of activities etc. The crop diversification has shown an upward trend over the time period while overall diversification in agriculture and on-farm was an increasing trend with fluctuating nature.

There are numbers of factors influencing crop and non-crop diversification which was identified by using different technique like Probit model, Tobit mode, correlation co-efficient (r), multiple regression etc. Among these, age, education, farm size with number of plots, farming experience, family working members, availability of irrigated land, availability of hired labour, family income, farm asset & infrastructure, share of non-agricultural income, access to markets, credit facility, training received, extension linkage, membership in social organization, participation of women in farming are key factors that had significant positive influence on agricultural diversification in Bangladesh. The major limitations of this study were to summarize the status of agricultural diversification in Bangladesh from the different measurement methods of diversification and also prepare the list of influencing factors of agricultural diversification from insufficient research studies and empirical evidences regarding diversification. Therefore, further investigations could be conducted to identify the extent and nature of agricultural diversification and its association with livelihood security in different geographical locations for better implementation of diversification program in Bangladesh.

Keywords: Agricultural diversification, sustaining rural livelihoods, trend of food production, diversification index

1. INTRODUCTION

Agriculture plays a crucial role in the economy of developing countries, and provides the main source of food, income and employment to their rural populations. The share of agriculture in global gross domestic product (GDP) has been stable at around 4% since 2000, while agriculture employed 873 million people in 2021, or 27% of the global workforce, compared with 1027 million (40%) in 2000 [1]. In Bangladesh, agriculture is one of the most important sectors of the economy which contributes 11.61% to the GDP. This sector comprises crop, livestock, fisheries and forestry sub-sectors accounting for 47.00%, 16.45%, 21.75% and 14.80% of

agricultural GDP respectively[2]. Although the overall share of agriculture to GDP has declined through the years, a remarkable change has occurred with respect to the relative shares of agricultural sub-sectors to GDP. The annual growth rate of the crop sub-sector decreased and its growth potential has become limited. On the other hand, the growth rates for livestock, fisheries and forestry sub-sectors increased over the period. Thus, the non-crop agriculture exhibited a relatively higher rate of growth than crop agriculture during the recent years[3].

The economy of the rural sector of Bangladesh is mostly driven by agricultural activities where about 50 percent of the population are employed in this sector and about 70 percent people overall depend on agriculture for their livelihood[4].Rural households depend on the production of food and different crops such as rice, maize, wheat, potato, vegetables and fruits to earn their livelihood. Besides crops, other agricultural subsectors such as fisheries, livestock and poultry provide additional sources of income for the rural households in Bangladesh[5]. But agriculture of Bangladesh is constrained due to climate change induced hazards e.g. drought, flood, salinity, riverbank erosion and by a number of challenges such as in adequate management practice, population growth, unfair crop prices, insufficient credit facilities, loss of arable land, and lack of investment in agricultural research [6, 7]. In addition,[8] indicated that availability of quality seed, market access facility, lack of storage facility and slow technology transfer also slow down the agricultural development process.

Agricultural diversification is considered as an important strategy to overcome these challenges faced by many developing countries due to the opportunities it offers for risk management, tackling heterogeneous production conditions, and increased income generation through entry into new markets [9]. It implies a shift of resources from primary staple crops, namely rice, to other cereal crops, from cereals to non-cereal crops, and from crops to non-crop (livestock, fisheries and forestry) agriculture[3]. Agricultural diversification towards products with higher value addition contributed to more rapid agricultural income growth and might contribute to local employment creation by stimulating small farmers' participation in the market. Diversification in production is also likely to lead to diversification in consumption, which is required for healthier and more balanced diets. Therefore, the government is giving emphasis on promoting agricultural diversification involving high-value crops, fruits, vegetables, livestock and fisheries through appropriate packages of seed-fertilizer-irrigation along with other improved technologies[3]. Different studies confirm that agricultural diversification has positive impacts on employment, rural income, promoting exports and improved nutritional standards [10,11,12,13,14,15].Despite ample evidence of the benefits of agricultural diversification (including genetic resources and management practices) to agricultural production, natural resources and rural livelihoods, farmers' decisions regarding agricultural diversification have not been well understood [16,17,18]. Adequate understanding of the social, economic and ecological drivers of smallholders' diversification strategies are the key for rural policy makers and developers to improve agricultural and livelihood resilience in rural areas[18].

The majority literature that has been written about this topic in Bangladesh has concentrated on crop diversification, paying little attention to Bangladesh's overall agricultural diversification. Hence, reviews made on the status of agricultural diversification and its influencing factors of agricultural diversification in the context of the country level are few. The studies conducted in relation to the topic lack consistency in term of measurement technique and findings. So, the aims of this review are to: (1) Summarize the status of agricultural diversification and (2) Review the influencing factors of agricultural diversification in Bangladesh.

2. METHODOLOGY

This paper is based on secondary information. To fulfill the objective of this paper different published and unpublished research articles, papers, books, government reports etc., on agricultural diversification were collected through different search engines from different databases, Google scholar and Google. Through all the search, 194 published and unpublished papers were collected. Only 74 published and unpublished papers were considered to review the paper. Decision to include or exclude particular studies was made based on recent, relevance for the review topic and data type. At last, all collected data were analyzed through narration and interpretation qualitatively.

3. REVIEW OF FINDINGS, AND DISCUSSION

3.1 Concept of Agricultural Diversification: The concept of diversification has varying interpretations and connotes different meanings to different peoples. The term “diversification” has been derived from the word ‘diverge’ which means to move or extend in the direction different from a common point[19]. In a popular notion, diversification means a shift of resources from farm to non-farm activities, use of resources in a larger mix of diverse and complementary activities within agriculture, and a movement of resources from low-value crops to high-value crops. Vyas [20] defined agricultural diversification as a shift from one crop to another crop, or from one enterprise to another enterprise. Besides, Singh [21] defined agricultural diversification as the process where producers allocate their productive resources to a wider range of economic activities which enables farmers to be viewed as businessmen. In other words, diversification involves the changes in the production portfolio from the low-value to high value commodities like vegetables, milk, meat, eggs and fish based on the market demand that creates a new horizon for the rural income source [22].

From a narrow point of view, agricultural diversification implies increasing the variety of agricultural commodities produced at the farm level [23]. But a broader view suggests that agricultural diversification is a process of a gradual movement out of subsistence food crops (particularly staple foods) toward diversified market-oriented cash crops that have a larger potential for returns to land[24]. At the conceptual plane diversification of agriculture could be classified into the following three categories[20,25]:

1. Shift of resources from farm to non-farm activities;
2. Shift of resources within agriculture from less profitable crop or enterprise to more profitable crop or enterprise;
3. Use of resources in diverse but complimentary activities.

Agricultural diversification in favor of horticulture and livestock products is desirable to increase farm employment and income; reduce disparities across space and time; check degradation of natural resources; and enhance exports[12]. Horticulture and livestock products utilize more workforce than the traditional crops. Apart from effect on direct employment, diversification also provides scope for indirect generation of employment through boosting agro-processing industries[26]. The process of diversification can be classified into horizontal and vertical diversification. Horizontal diversification is one of the most common phenomena. Through this approach the diversification takes place by adding more crops in the existing cropping system as a way to improve the overall productivity of a farm or region’s farming economy, or a shift from subsistence farming to high value crops, whereas vertical diversification stands for the addition of value in the existing cropping system through processing, packaging and branding or other efforts to enhance the product value[27].

3.2 Status of Agricultural Diversification in Bangladesh: Agricultural diversification is appallingly low in Bangladesh, where the majority of farm households largely maintain a mono-cropping system[28,29,30]. This is because the Green Revolution program and the Grow More Food program that were launched in the 1970s heavily prioritized mass production of rice throughout the year, spearheaded by the introduction of complementary inputs[31,32,33,28,3,29,34]. The aim of these initiatives was to make Bangladesh self-sufficient in food grains. The agricultural growth has accelerated from an average annual rate of less than 2% during the 1970s-1990s to around 3% in the 2000s and to 3.5% in the next decade [35]. But the steady growth of agriculture is dominated by staple crop production, which is reflected in Bangladesh’s primary dependence on rice cultivation and consumption (Tisdell et al., 2019)[36]. However, the sustained growth in income per capita in Bangladesh is shifting the consumption pattern toward non-rice crops such as fish, meats, milk, fruits and vegetables.

These non-rice foods and crops are highly valued and more profitable [37,38,39,40]. Therefore, it is anticipated that farmers will have sufficient incentives to diversify their agricultural output portfolios at the farm level due to the increasing demand and greater profitability of non-rice products. Moreover, The Government of Bangladesh (GoB) has also set several policy agendas to promote greater agricultural diversification [30]. Thus, in the context of Bangladeshi agriculture, shifting away from rice production and engaging in unconventional non-rice crop

cultivation and/or non-crop agriculture such as livestock, poultry, and fisheries is referred to as agricultural diversification[41].

3.2.1 Trend of Agricultural Production: Bangladesh has made remarkable progress in domestic food production (cereals and non-cereals) during last 25 years due to adoption of new technologies and good practices. The trend of food production (Table. 1) during the period of 2000-2022 indicates that the progress in cereals food (rice, wheat and maize) production increased by 1.75 times and average annual growth of 3.25% while progress in non-cereals food (potato, vegetables, fruits, pulse, oilseeds, spices, milk, meat) production increased by 4.75 times and average annual growth of 16.28%. Due to this continued progress, Bangladesh has moved up to 3rd position in terms of global rice production; after China and India in 2020.

Additional milestones achieved in the frontiers of diverse crops in global rankings are 2nd in jute, 6th in potato, 8th in mango and guava. Bangladesh also ranks 4th in the world in number of goats and meat production, 12th in cattle production, 1st in hilsa fish catching, 3rd in inland open water fish catching and 5th in closed water fish catching[42]. A healthy and normal person needs to eat at least 496 g rice, 250 g vegetables, 63 g fish, 120 g meat per day and 104 eggs a year [43], and 130 ml milk and 57 gm fruits per day [44]. Considering a population of 166 million in 2021, the per capita availability of rice, vegetable, fruits, fish, milk, meat, and egg has been increased to 620 g/day, 239 g/day, 84 g/day, 74 g/day, 196 ml/day, 138 g/day and 123 number/year, respectively[45].

Table 1. Agricultural production of Bangladesh from 2000-2022

Commodity	**Production(MMT)/Number (million)**		
	2000	**2022**	**Increment (times)**
Rice	23.06	38.14	1.65
Wheat & Maize	1.81	5.34	2.95
Potato	2.90	10.14	3.50
Vegetable	1.60	6.00	3.75
Fruits	1.43	5.33	3.72
Pulses	0.38	0.43	1.13
Oilseeds	0.41	1.03	2.51
Condiments and spices	0.41	4.02	9.80
Livestock*	215.2	432.37	2.00
Milk	2.10	13.7	6.52
Meat	0.50	9.27	18.54
Egg*	3600	23350	6.48
Fish	1.66	4.75	2.86

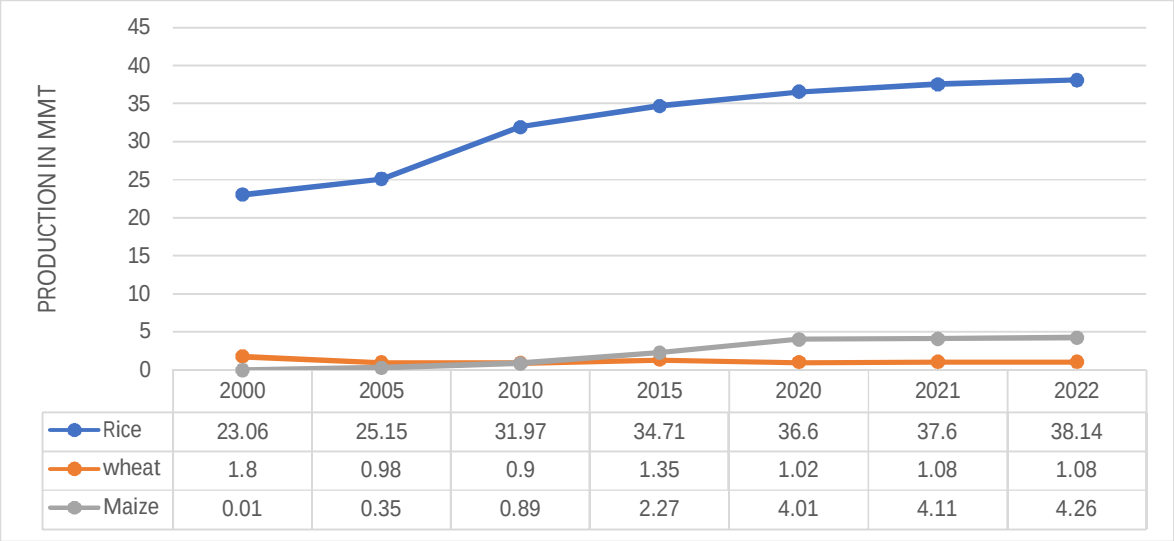
Source: BARC, 2023; BBS, 2023; BBS 2012

**Number(million)*

3.2.1.1 Crop sub-sector: Food crops alone account about 75% of the total agricultural output. Major crops in Bangladesh are cereals, jute, potato, fruits, vegetables, oilseeds, pulses etc. Major industrial crops are jute, tea, tobacco, sugarcane etc. Rice is the major crop that covered around 75% of the total cropped area, and accounted for about 70% of the value of total crop

output [46], while wheat, potato, pulses and oilseeds are the other principal food crops of Bangladesh.

Rice, wheat and Maize: The dominance of rice in the crop sub-sector almost assures stability in the structure of production. The rice growing area reported an increase from 10.7million hectares to 11.69 million hectares during the period of 2000-2022 [45,2]. In relation to rice area coverage, the volume of rice production has increased by 1.65 times from 23.06 MMT in 2000 to 38.14 MMT in 2022 indicating an annual growth rate of 2.84%. Despite a slow growth rate of rice area increase being attributed mainly to the transfer of agriculture land to infrastructure, a massive growth of rice production was possible due to introduction of high yielding varieties integrated with improved management practices and inputs like irrigation, seeds, fertilizers, pesticides, credit assistance etc. [45].



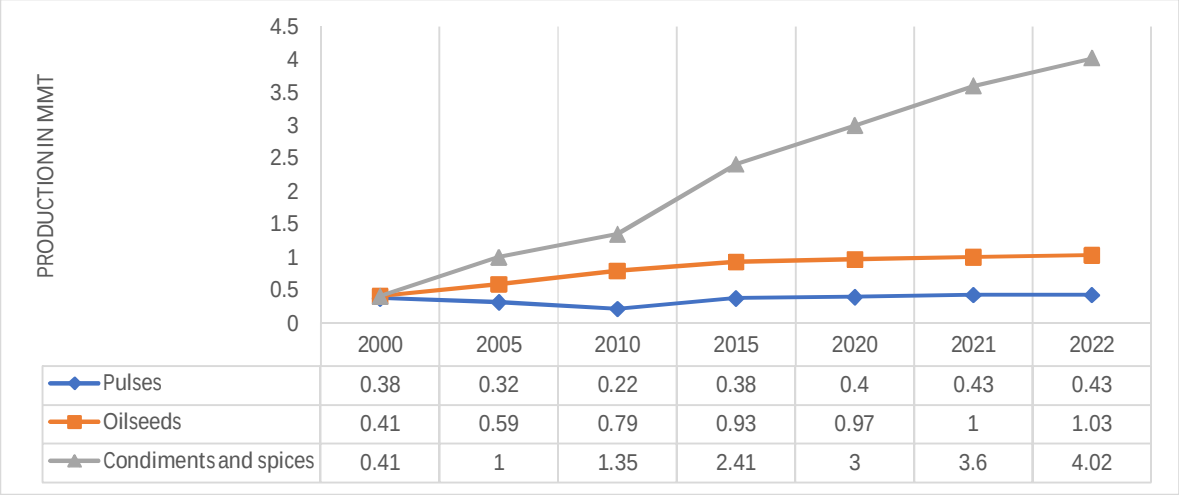
	2000	2005	2010	2015	2020	2021	2022
Rice	23.06	25.15	31.97	34.71	36.6	37.6	38.14
wheat	1.8	0.98	0.9	1.35	1.02	1.08	1.08
Maize	0.01	0.35	0.89	2.27	4.01	4.11	4.26

Source: BARC, 2023; BBS, 2023; BBS 2012

Figure1.Trendof Rice, Wheat and Maize Production inBangladesh

The wheat area has decreased from 832,000 hac in 2000 to 315,000 hac in 2022 while maize area increased by 160 times from 3,200 hac in 2000 to 513,270 hac in 2022[45,2]. As a result, the production of wheat has reduced from 1.80 MMT to 1.08 MMT and maize production has increased significantly from 0.01 MMT to 4.26 MMT during this period (Figure1). This decrease in wheat area might have been the result of an aggressive boro and maize expansion on wheat lands and also gained better outputs from these crops.

Potato, Vegetable and Fruits: The area under potato increased by 1.91 times from 243,000 ha in 2000 to 464,327 ha in 2022 while production of potato increased by 3.5 times from 2.90 MMT in 2000 to 10.14 MMT in 2022 during this period[45,2]. This is a combined effect of both area expansion and high yield potato. The vegetable production depicts a similar trend to potato showing an increase from 1.6 MMT in 2000 to 6.0 MMT in 2022 (Figure2). The total vegetable production (potato and different vegetables) increased gradually from 4.5 MMT in 2000 to 16.14 MMT in 2022 which is close to the per capita requirement of 250 gm as per FAO and WHO [43]. Fruit production also fluctuated and became almost static around 1.5 MMT during 1972 to 2000[45]. After there a significant increase occurred from 1.43 MMT in 2000 to 5.33 MMT in 2022 over the last 23 years the country's fruit production increased by 3.72 times. The remarkable improvement in vegetable and fruits production could be attributed to technological advancement through development of HYV, hybrids and improved management technologies.

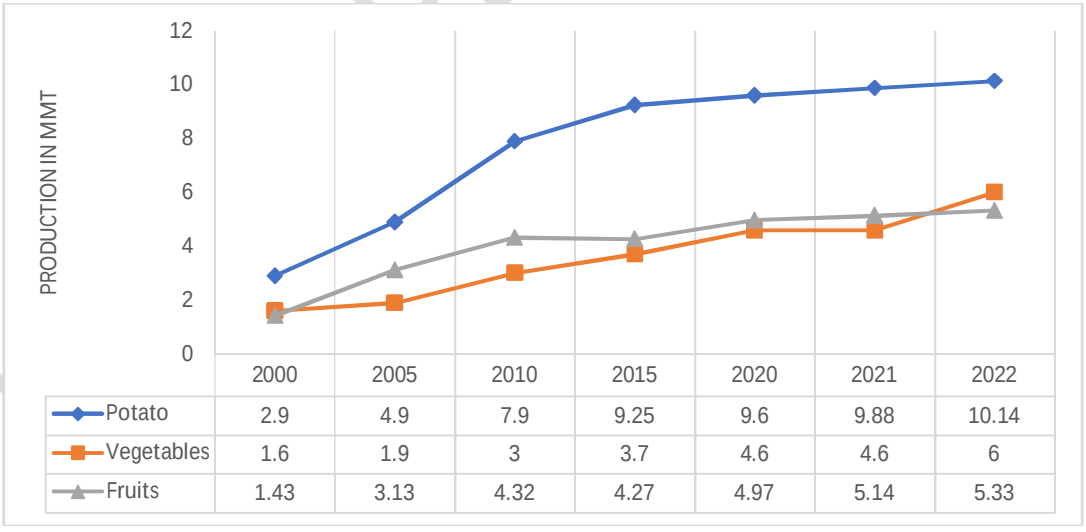


	2000	2005	2010	2015	2020	2021	2022
Pulses	0.38	0.32	0.22	0.38	0.4	0.43	0.43
Oilseeds	0.41	0.59	0.79	0.93	0.97	1	1.03
Condiments and spices	0.41	1	1.35	2.41	3	3.6	4.02

Source: BARC, 2023; BBS, 2023; BBS 2012

Figure2.Trendof Potato, Vegetables and Fruits Production inBangladesh

Pulse, Oilseed and Spices Crops: The production of pulse crops revealed a fluctuating trend of increase and decrease during 2000-2022, but there was an overall increase from 0.38 MMT to 0.43 MMT (31.5%). Pulse production increased at a slower pace (0.22 to 0.43 MMT) than the pulse requirement (1.22 to 3.03 MMT) during 1972-2021[45]. Production of oilseed crops increased by many folds from 0.41 MMT in 2000 to 1.03 MMT in 2022 due to combined effect of area expansion and yield increase implying a significant adoption of high yielding varieties and improved management practices. However, the trend of oilseed production increased at a lower level (0.20 to 0.99 MMT) than that of the requirement (2.19 to 5.45 MMT) during 1972-2021[45]. The production of spices increased from 0.41 MMT in 2000 to 4.02 MMT in 2022. The trend of spice production increased at a higher level from 2005 (1.0 MMT) to 2021 (3.60 MMT) than that of the requirement (1.0 to 1.21 MMT) during the same period although their trend was reversed during 1972-2000 resulting in spices surplus after 2005 [45]. Expansion of cultivated area coupled with HYVs and other technological interventions helped increase spices production.



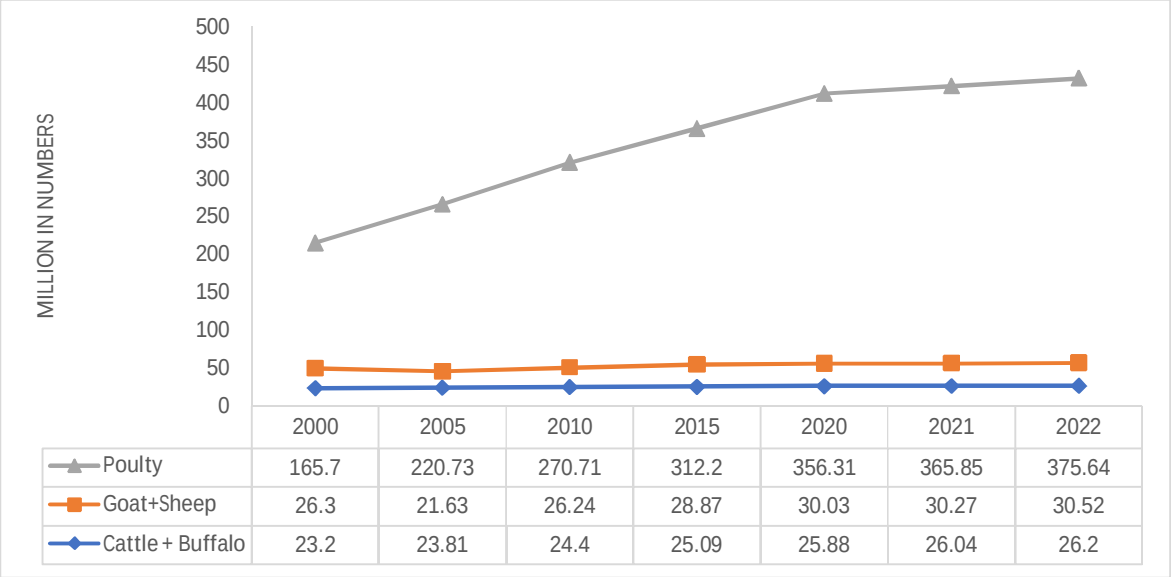
	2000	2005	2010	2015	2020	2021	2022
Potato	2.9	4.9	7.9	9.25	9.6	9.88	10.14
Vegetables	1.6	1.9	3	3.7	4.6	4.6	6
Fruits	1.43	3.13	4.32	4.27	4.97	5.14	5.33

Source: BARC, 2023; BBS, 2023; BBS 2012

Figure3.Trendof Pulses, Oilseeds and Condiments & spices Crops Production inBangladesh

3.2.1.2 Livestock sub-sector: Livestock viz., cattle, buffalo, goat and sheep, and poultry viz., chicken and duck are the important domestic animals in Bangladesh, which provide milk, meat and egg as food for human consumption. The actual head counts and growth of livestock resources covering the period 2000-2022 are presented in Figure 4. It is revealed that the progress of the cattle and buffalo remained static from 23.2 million in 2000 to 26.2 million in

2022 while the increase of goat and sheep were slightly upward during this period. This trend in livestock population growth is not encouraging; however, meat and milk production got a boost from technological advancement comprising cross breeding and improved management practices in respect of feeds and fodders, disease control etc. The growth in livestock sector mainly occurred in the poultry sector as expected as its overall increase was 2.26 times for 23 years counting from 165.7 million in 2000 to 375.64 million in 2022.

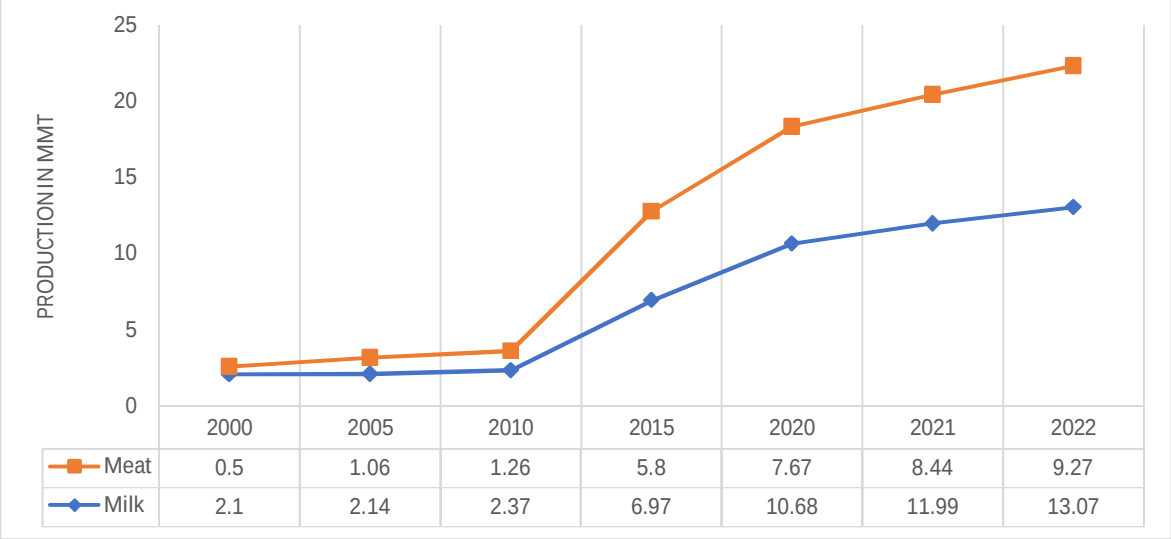


	2000	2005	2010	2015	2020	2021	2022
Poulty	165.7	220.73	270.71	312.2	356.31	365.85	375.64
Goat+Sheep	26.3	21.63	26.24	28.87	30.03	30.27	30.52
Cattle + Buffalo	23.2	23.81	24.4	25.09	25.88	26.04	26.2

Source: BARC, 2023; BBS, 2023; BBS 2012

Figure4.Trendof Livestock production inBangladesh

Milk, meat, and eggs are three important products of livestock which production are showed an increasing trend[45]. During the last 23 years, meat production increased from 0.50 MMT in 2000 to 9.27 MMT in 2022 with an overall increase by 18.5 times and an average annual growth of 76.26%. Similarly, milk production increased from 2.1 MMT in 2000 to 13.07 MMT in 2022 with an overall increase of 6.22 times indicating a much lower growth of milk production compared to meat production during the same period. Egg production also increased from 3.6 billion in 2000 to 23.35 billion in 2022 with the overall increase of 6.48 times and an average annual growth of 23.85 % over 23 years[45,2].

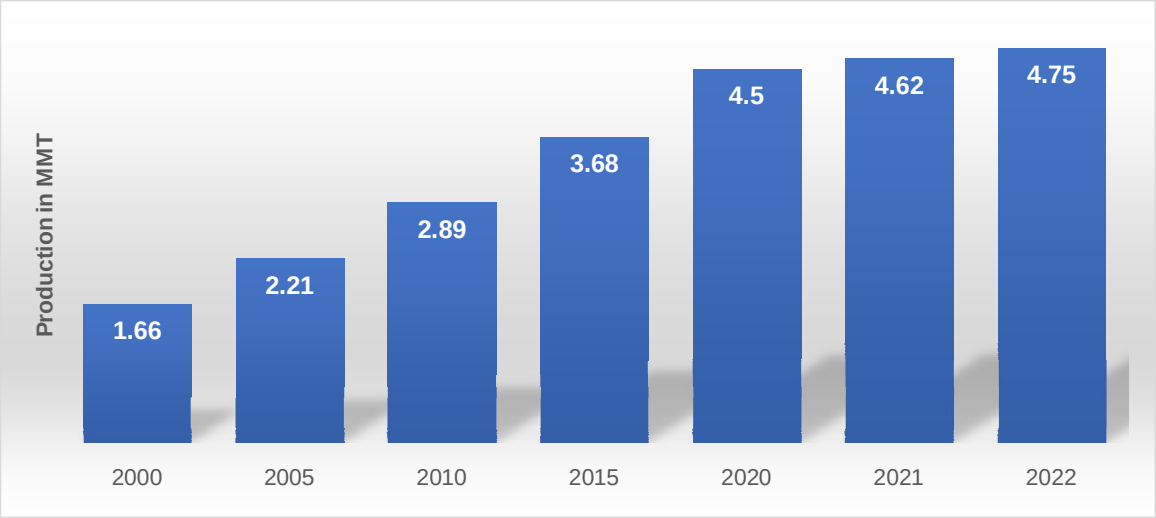


	2000	2005	2010	2015	2020	2021	2022
Meat	0.5	1.06	1.26	5.8	7.67	8.44	9.27
Milk	2.1	2.14	2.37	6.97	10.68	11.99	13.07

Source: BARC, 2023; BBS, 2023; BBS 2012

Figure5.TrendofMilkandMeatProduction

3.2.1.3 Fisheries sub-sector: Total fish production increased dramatically over the last 2 decades from 1.66 MMT in 2000 to 4.74 MMT in 2022 (Figure6). Bangladesh has achieved self-sufficiency in fish; whereas the per capita consumption of fish was 7 kg/year in 1990, now it is about 30 kg/year [47].



Source: BBS, 2023

Figure6. Trend of fish production in Bangladesh

3.2.2. Trend of food consumption: The household consumption patterns in Bangladesh, as well as in other South and Southeast Asian countries, are heavily dependent on cereals, as food consumption diversity in these regions is not yet widespread. When households engage in more diverse agricultural activities, such as cultivating different crops, raising various livestock, and participating in fisheries, it contributes to a greater variety of food consumed within the household [48,49]. So, we summarized the average daily per capita intake of major food items from last five surveys (2000, 2005, 2010, 2016 & 2022) to understand the food consumption pattern and its diversity that presented inTable2.

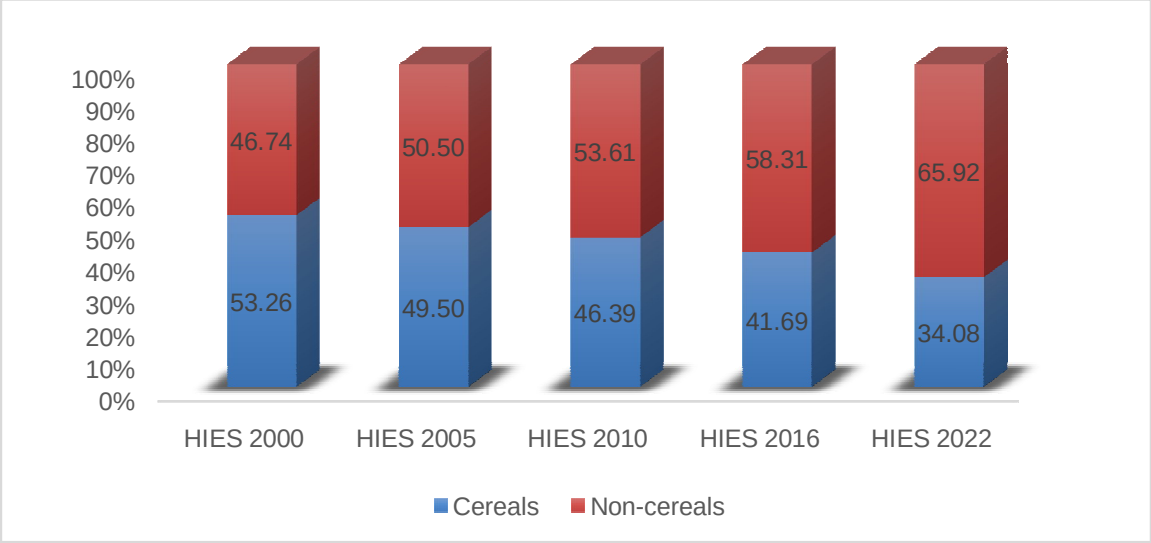
Table 2. Average per capita daily food intake (grams) by food items

Food Items	HIES 2000	HIES 2005	HIES 2010	HIES 2016	HIES 2022
Total	**893.1**	**947.8**	**1000**	**975.1**	**1129.8**
Cereals	475.7	469.2	463.9	406.5	385
Potato	55.5	63.3	70.3	64.8	69.7
Vegetables	140.5	157	166.1	167.3	201.92
Pulses	15.6	14.2	14.3	15.7	17.15
Milk/Milk Products	29.7	32.4	33.7	27.3	34.1
Edible Oils	12.8	16.5	20.5	26.8	30.85
Meat, Poultry, Eggs	18.5	20.8	26.2	39	52.78
Fish	38.5	42.2	49.5	62.6	67.83
Condiments & Spices	24.5	53.4	66	74.1	63.97
Fruits	28.4	32.5	44.7	35.8	95.4
Sugar/Gur	6.9	8.1	8.4	6.9	16.37
Miscellaneous Items	46.5	38.2	36.5	48.29	94.7

Source: BBS, 2023; BBS 2012 & HIES, 2022 & 2010

The Table indicates that the per capita daily intake of cereals group at the national level was recorded at 385.0 grams in 2022. It was observed that the consumption of cereals declined by 23.55 % in 2022 compared to 2000. Besides, the Figure 8 shows that the consumption level of non- cereals food items like vegetables, pulses, potatoes, milk & milk products, fruits, edible

oils, meat, poultry and fish, sugar and gur increased gradually which values of 46.74% in 2000, 50.50% in 2005, 53.61% in 2010, 58.31% in 2016 and 65.92% in 2022. As a result, the percentage of Per Capita Daily Calorie Intake from non-cereals food has been increased from 35.68 % in 2016 to 42.34 % in 2022[50]. These findings indicate that food consumption pattern has been changed over the time period as households engage in more diverse agricultural activities, change in consumption behaviour, and increased purchased power.



Source: BBS, 2023; BBS 2012 & HIES, 2022 & 2010

Figure 7. Percentage of cereals and non-cereals items in average per capita daily food intake

3.2.3. Measurement of diversification: Very little research on the measurement of agricultural diversification (crop and non-crop diversification) in Bangladesh has been conducted. Most of the research in relation to diversity in agriculture is focused to crop diversification. So, crop diversification and agricultural diversification with its measurement methods are discussed here separately based on available documents to understand the status of diversification in agriculture of Bangladesh.

Crop diversification: Metzel &Ateng[51]used Simpson Index of Diversity (SID) as well as Rice-sharing index for measurement of crop diversity by the data from 10 thanas representative of major geographical and agro-ecological zones in Bangladesh and found the average value of the SID is 0.596. Similarly, Alam [52] assessed crop sector diversity in Bangladesh by Simpson Diversity Index (SDI) and found value 0.37 in 1972-73, 0.42 in 1989-90, and 0.43 in 2001-02 which showed an upward trend over time. Later on, Islam & Hossain [53] used Simpson index and Rice Share index of crop diversification to calculate the nature and extent of crop diversity in Bangladesh from 40 years- time series data on crop acreage, yield and production data and found values of crop diversification of 0.35 in 1971-72 and 0.42 in 2011-12. These index values of three studies indicate that magnitude of crop diversification has been increasing gradually.

Rahman [54] measured overall crop diversification from farm-level cross-section data for crop year 1996 collected from three agroecological regions of Bangladesh by using Herfindahl index which value 0.60 which indicates that the cropping system is relatively diverse. Tisdell et al. [36] assessed diversity of crop production by the adaptation of the Herfindahl–Hirschman index which value 0.4479 that implies low diversity of the type of crops grown in Bangladesh. Azad [55] used Herfindahl index to measure crop diversification using Mahabub Hossain Panel Data (MHPD) and found index value 0.47 that indicates farms are perhaps moderately diversified. Similarly, Nahar et al. [56] measured crop diversification of 609 farmers of five northern districts in Bangladesh and found that the majority of farmers' Herfndahl index values fall between 0.2 and 0.6 indicating about 64% respondents irrespective of region produced different types of crops.

Zaman et al. [57] calculated crop diversity using the equation described by Kshirsagar et al. [58] and found the overall CDI of Rangpur region 0.871. In a simultaneous study, Nasim et al. [59]

found the CDI value is 0.952 at national level that indicates Rangpur region is relatively less diversified. Recently, Brown et al. [60] also found lowest crop diversification in Rangpur (average of 2.9 crops), with a regional average of 3.8 crops where cropping diversity was measured by the average number of crops ever grown by each respondent of various locations.

Rahman& Kazal [61] used the Shannon index to measures the level of crop diversity using thepanel data of 17 regions of Bangladesh covering the 19-year period (1990–2008). Result reveals that the level of crop diversity is significantly different across the regions and saw a decline in 2008 compared to 1990 levels in most regions except Faridpur, Khulna and Sylhet. Islam & Hossain [62] used the Entropy index (EI) to measure the crop diversification which value 0.56 indicates that cropping system in the study area is relatively diverse. Uddin [63] measured crop diversification in relation to dietary diversity using Simpson Index (SI) & Entropy Index (EI) and found that crop diversification has increased nationally in rural Bangladesh over the period of four years (2011/12-2015), but this positive change is not significant. In terms of the divisional estimates of SI and EI, crop diversification has not changed significantly across seven administrative divisions of Bangladesh, except for Sylhet division. In Sylhet division, EI or crop diversification has decreased significantly from 0.11 to 0.07.

Table3.List of studies related to crop diversification/diversity measurements in Bangladesh

Authors	**Focus**	**Method used**	**Diversification/diversity index**	**Data Design**
Metzel &Ateng [51]	Diversification in Bangladesh	Simpson Index	0.596	Primary data from 200 farm households
Alam [52]	Status of CGPRT crops and magnitude of agricultural diversification	Simpson Index	0.37 in 1972-73, 0.42 in 1989-90, and 0.43 in 2001-02	32-year database, starting from the early 1970s
Islam & Hossain[53]	Present situation of Crop Diversification in Bangladesh	Simpson Index	0.35 in 1971-72 and 0.42 in 2011-12	40 years-time series crops acreage, yield and production data
Rahman[54]	Determinants of crop choices in Bangladesh	Herfindahl index of crop diversification	0.60	Farm-level cross-section data from crop year 1996 with a total sample size of 406 households.
Tisdell et al. [36]	Agricultural Diversity and Sustainability	Herfindahl–Hirschman index	0.4479	Secondary data from BSS
Azad [55]	Determinants of Crop Diversification	Herfindahl index	0.47	Mahabub Hossain Panel Data (MHPD)
Nahar et al. [56]	Impact of crop diversification on food security of farmers	Herfindahl index (HI)	0.2-0.6	609 HHs of five northern districts
Zaman et al. [57]	Crop Diversification in Rangpur region	Kshirsagar et al. (1997)	0.871	Secondary data from DAE in 2014-15
Nasim et al. [59]	Crops and Cropping Patterns in Bangladesh	Kshirsagar et al. (1997)	0.952	Secondary data from DAE in 2014-15
Rahman& Kazal [61]	Crop Diversity in the Regions of Bangladesh	Shannon index	1.27	panel data of 17 regions of Bangladesh covering a 19-year period (1990–2008)
Islam & Hossain [62]	Factors of crop diversification	Entropy index	0.56	Primary data of 343 farmers from four districts in Rajshahi division

Uddin [63]	Crop Diversification for Dietary Diversity and Nutrition	Simpson Index (SI) and Entropy Index (EI)	SI = 0.18 in 2011/12 & 0.19 in 2015 while EI=0.32 & 0.32	BIHS data- 1,697 (3,394 for 2 rounds in 2011/12 &2015) out of 2,200 farm households
Brown et al. [60]	Farm diversification of EGP	Number of crops	3.8	Primary data of more than 5000 HHs in Eastern Nepal, West Bengal, India and Northwest Bangladesh

Agricultural diversification: To the best of our knowledge, the only study on agricultural diversification in Bangladesh has been conducted by Miah et al. [3] in recent times whose study was primarily focused on understanding agricultural diversity which includes homestead farming as well as livestock, poultry and fisheries. This study found the average value of Agricultural Diversification Index (ADI) is 0.56 during 1993-2010 by using the formula of ADI (Value of non-cereal Produce/ Value of total agricultural produce) with indicating the highest agricultural diversification took place at Chittagong and Barisal region over the time due to the increase of the productions and prices of some non-cereal commodities mentioned above during 2007 and the lowest AD took place at Rangpur and Rajshahi region over the years. Islam et al.[64] measured farm diversification by counting the number of crop, vegetables and fruit species produced by the household on their farm which value 4.294 in 2011/12 and 5.224 in 2015 while value of Margalef species richness index Weights by the area grown with different crops was 0.106 in 2011/12 & 0.324 in 2015. This study used two round of nationally representative panel data from the Bangladesh Integrated Household Survey (BIHS), collected in 2011/12 and 2015. Similarly, Rehan[65] measured farm diversity in relation to household food security by using Simpson Index of Diversity (SID) and found the mean value of Simpson's Index of diversified farms was 0.43, whereas the mean value of SID for the non-diversified farms was 0.25, demonstrating that the diversified farms had significantly a higher level of consumption diversification than non-diversified farms. Besides, Abedin & Haque [66]used panel dataset from the Bangladesh Integrated Household Survey (BIHS) 2015 and 2018-19 to test the association between agricultural diversification and food security outcomes where aggregated diversification index is measured as the total number of commodity groups produced from eight crops and five animal-source food groups. The study revealed that aggregated measure of agricultural diversification increased significantly from 5.10 in 2015 to 5.64 in 2018/19. Besides, Khandoker et al. [67] used multiple methods for measuring farm production diversity. These methods and its value are production diversity score (Count of food crop and animal species grown by the household): 5.07; crop diversity score (Number of crop species grown by the household): 5.17 and Simpson's Index of Crop Diversification (SID): 0.31. All the indicators of farm production diversity indicate that farm diversity is low in Bangladesh but has increased over time. The study is conducted using three rounds panel data of Bangladesh Integrated Household Survey (BIHS) collected in 2011/12, 2015 and 2018/19. Similarly, Mastura et al. [41] used the same date of the Bangladesh Integrated Household Survey (BIHS) in 2012, 2015 and 2018 to calculate the Production Diversification Score (PDS) by adding up all the food crops, fish and livestock products each household produces which value was 8.049 while Agricultural Diversification Score (ADS) measured by the number of different food groups produced, (according to the 12 groups used in the HDDS), with a score of 3.806. These results indicate that the overall change of PDS from 2012 to 2018 was positively significant and the ADS values show that diversification in agriculture increased in each wave and the changes were highly significant.

3.3 Factors influencing the implementation of agricultural diversification

Some studies have been conducted to determine the factors or determinants of agricultural diversification in Bangladesh. This review has also considered related studies on crop or farm diversification in Bangladesh as well as similar studies in globally especially in India. These studies have identified a number of factors that influence the nature and extent of crop and agricultural diversification from staple food to high value commodities.

Miah et al. [3] used an empirical Probit model to identify factors affecting agricultural diversification at the household level from farm level data of 960 farmers in Bangladesh. The results presented that diversity at the farm level was positively affected by availability of irrigated land, land suitability, training received, extension linkage, family influence in production and credit facility while storage facility was found to be positive but not significant and access to market was not important. Rehan[65]identified determinants of on-farm diversification using Probit model and data showed that the age of the head of the household, farm size, access to credit, technical assistance, regional dummies and access to markets positively influenced the adoption of on-farm diversification. The active participation of women in farming activities was identified one significant factor a noteworthy determinant to enhance diversity in Bangladesh.

Nahar et al. [56] determined the effect of different factors on crop diversification by using Binary logistic regression model and found age, farm experience, family working members, farm size, farming training and farm income have positive effect on crop diversification. Azad [55] applied Cragg's alternative Tobit model to find the catalysts of crop diversification from a unique rural household level dataset. The estimated results have revealed that total land, access to news media, NGO membership, number of hired labour have positive & significant effect on extent and magnitude of crop diversification while agricultural extension services, total fertilizer used and number of plots have negative effect. Similarly, Islam & Hossain [62] found from the Marginal Effects of the Tobit Model that numbers of plots, annual family income and infrastructure affect the probability of crop diversification positively whereas irrigation intensity and farm size affect it negatively. Rahman & Kazal [61] used the Generalised Least Squares (GLS) Random Effects model to identify the determinants of regional crop diversity and revealed that among the determinants, an increase in the relative prices of vegetables and urea fertilizer, extension expenditure, labour stock per farm, average farm size, irrigation and a reduction in livestock per farm significantly increase crop diversity. Rahman [54] identified the determinants of crop choices by farmers in Bangladesh using a bivariate probit model and found that farmers' education, farming experience, farm asset as well as the share of non-agricultural income were all significantly related to the adoption of a diversified cropping system. A diversified cropping system was more likely to be adopted by owner-operators and small farmers.

These studies revealed that age, education, farm size with number of plots, farming experience, family working members , availability of irrigated land, availability of hired labour, family income, farm asset & infrastructure, share of non-agricultural income, access to markets, credit facility, training received, extension linkage, membership in social organizations, and participation of women in farming are key factors that had significant positive influence on agricultural diversification in Bangladesh. Similar factors were also identified by Rai [68], Devi &Prasher [69], Bharadwaj [70], Bagri [71],Chandubhai [72], Kumari [73] and Sen et al. [74]in their study for agricultural diversification in India which was measured using the correlation co-efficient (r) and multipleregression analysis.

Table4.Specification of the model used by different researchers to determine the factors for diversification in agriculture

Researchers	Specified Model	Selected variables	Significant (Positive or negative impact)	Non-significant (No impact)
Miah et al. [3]	Probit model	Irrigated land, land suitability, training received, extension linkage, family influence in production, credit facility, storage facility and access to market.	Irrigated land, land suitability, training received, extension linkage, family influence in production, credit facility, access to market	Storage facility
Rehan [65]	Probit model	Age of the head of the household, farm size, access to credit,	Age, farm size, access to credit, technical assistance,	-

		technical assistance, regional dummies, access to markets, and participation of women in farming	regional dummies, access to markets, and participation of women in farming	
Nahar et al. [56]	Binary logistic regression model	Age, Sex, Education, Farm experience, Family working members, Farm size, Farming training, Farm income, Off farm income	Age, Farm experience, Family working members, Farm size, Farming training, Farm income	Sex, education, Off farm income
Azad [55]	Cragg's Tobit model	Age, sex, education, HH size, total land, number of livestock, agri. extension services, access to news media, NGO membership, total used fertilizer, number of hired labour, total number of plots	Total land, agri extension services, access to news media, NGO membership, total used fertilizer, number of hired labour, total number of plots	Age, sex, education, HH size, number of livestock
Islam and Hossain [62]	Tobit model	Farm size, HH size, number of plots, age of the farmer, education of the farmer, annual income, non-farm income, distance of farm from road, distance of market from farm, Extension contacts, Irrigation intensity	Farm size, HH size, number of plots, annual income, non-farm income, distance of farm from road, distance of market from farm, irrigation intensity	Age of the farmer, education of the farmer, extension contacts
Rahman & Kazal [61]	Generalized Least Squares (GLS) Random Effects model	Labour stock per farm, land area, livestock resources per farm, crop output price, fertilizer price indices, irrigation, average farm size, average literacy rate, R&D expenditure, extension expenditure per farm, total rainfall, temperature variability	Labour stock per farm, livestock resources per farm, crop output price, fertilizer price indices, irrigation, average farm size, R&D expenditure, extension expenditure per farm, total rainfall, temperature variability	Land area, average literacy rate
Rahman [54]	Bivariate probit model	Amount of land owned, farm asset, Proportion of land under irrigation, proportion of rented-in land, education of farmer, farming experience, family size, index of	Farm asset, proportion of land under irrigation, education of farmer, farming experience, index of underdevelopment of infrastructure, share of non-	Amount of land owned, proportion of rented-in land, family size, extension contact

		underdevelopment of infrastructure, extension contact, share of non-agricultural income	agricultural income	

4. CONCLUSION

The trend of food production indicated that Bangladesh has made remarkable progress during the last 23 years where rice production increased by 4.23 times. Similarly, wheat, maize and vegetable production were also increased by 35.2, 1354 and 5.4 times, respectively. Besides, non-crop production fish, livestock, egg, meat and milk production were increased by 53.5, 8.5, 42.8, 44.1 and 11.0 times respectively. As a result, production and consumption of non- cereals has been increased compared with last 20 years. In case of diversification in Bangladesh, crop diversification shown an upward trend over the time period while overall diversification in agriculture or on-farm are an increasing trend with fluctuating nature.

There were number of socio-economic, physiological, communicational, technological, infrastructural, climate related factors that influenced the process of crop and non-crop diversification at country level. The major factors responsible for diversification reported were age, education, farm size with number of plots, farming experience, family working members, availability of irrigated land, availability of hired labour, family income, farm asset & infrastructure, share of non-agricultural income, access to markets, credit facility, training received, extension linkage, membership in social organization, participation of women in farming.

The effect of identified factors for agriculture diversification from limited studies in Bangladesh was not clearly understandable as different methods were used for diversification measurement at different level. Besides, most of the studies tried to find linkage among diversification, food & nutrition security and dietary diversity while measurement of the relationship between diversification and livelihood security are inadequate. So, specific methods could be used in future to understand the current scenario of agricultural diversification & its influencing factors in different geographical locations. Besides its association with livelihood security is needed to measure for further justification to better implementation of diversification program in Bangladesh.

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