A review on status and influencing factors of agricultural diversification in Bangladesh

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 the benefits of agricultural diversity, farmers' decisions and influencing factors regarding diversification in agriculture have not been well defined. This review articleaims to measure the status and influencing factors of agricultural diversification in Bangladesh. The review revealed that progress in cereal foods (rice, wheat, and maize) production increased by1.75 times and non- cereal foods (potato, vegetables, fruits, pulse, oilseeds, spices, milk, meat, and fish) production increased by 4.75 times during the period of 2000-2022. Moreover, the percentage of non-cerealfoodsconsumption increased from 46.74% in 2000 to 65.92% in 2022. The crop diversification has shown an upward trend over this time period, while overall diversification in agriculture was an increasing trend with a fluctuating nature.

There are a number of factors influencing crop and non-crop diversification that were identified by using different statistical techniques like Probit model, Tobit model, 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 assets& 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 have significant positive influence on agricultural diversification in Bangladesh. The findings of this article have significant implications for extensionfunctionaries and other development workers to find out a proper approach to motivatethe farmers towards agricultural diversification and enhance the means of livelihoodsforfarmhouseholds.

Keywords:*Agricultural diversification;adaptation strategies;crop diversification; cereal & non-cereal foods production.*

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 contributes11.61% 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, 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 is employed in this sector and about 70 percent of 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 in Bangladesh is constrained due to climate change induced hazards, e.g., drought, flood, salinity, riverbank erosion, and number of challenges such as inadequate management practices, population growth, unfair crop prices,

insufficient credit facilities, loss of arable land, and lack of investment in agricultural research" [6, 7].In addition,Karim et al. [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 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 of 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 terms 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, a variety of published and unpublished research articles, papers, books, government reports, etc., on agricultural diversification were collected through various search engines from different databases, Google Scholar, and Google. The searches included a combination of keywords and phrases such as "agricultural diversification," "crop diversification," "livelihood diversification," "agricultural production," "food consumption status," "factors of crop diversification," "farm/on-farm diversification," "determinants of agricultural diversification," and "constraintsin diversification." The review was conducted from July 2023 to June 2024 and included relevant sources published between 1991 and 2024. Through all the searches, 134 published and unpublished papers were collected. Only 54 published and unpublished papers were considered to review the paper. The decision to include or exclude particular studies was made based on the recent, relevance,and suitability of the review topic and data type. The review compiled and presented evidence and information using figures and tables obtained from reliable sources and calculated by the authors themselves.

3. RESULTS 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 level, the 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 the degradation of natural resources; and enhance exports” [12].“Horticulture and livestock products utilize a larger 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, 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[3,28,29,31,32,33,34]. 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[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].

3.2.1Trend of agricultural production: Bangladesh has made remarkable progress in domestic food production during the last 25 years due to the 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 cereal foods (rice, wheat, and maize) production increased by 1.75 times and average annual growth of 3.25% while progress in non- cereal foods (potato,

vegetables, fruits, pulse, oilseeds, spices, milk, and meat) production increased by 4.75 times and average annual growth of 16.28%. Due to this continued progress, Bangladesh has moved up to 3rdposition 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 of rice, 250 g of vegetables, 63 g of fish, 120 g of meat per day, and 104 eggs a year [43], 130 ml of milk, and 57 g of fruits per day [44]. Considering a population of 166 million in 2021, the per capita availability of rice, vegetables, 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].

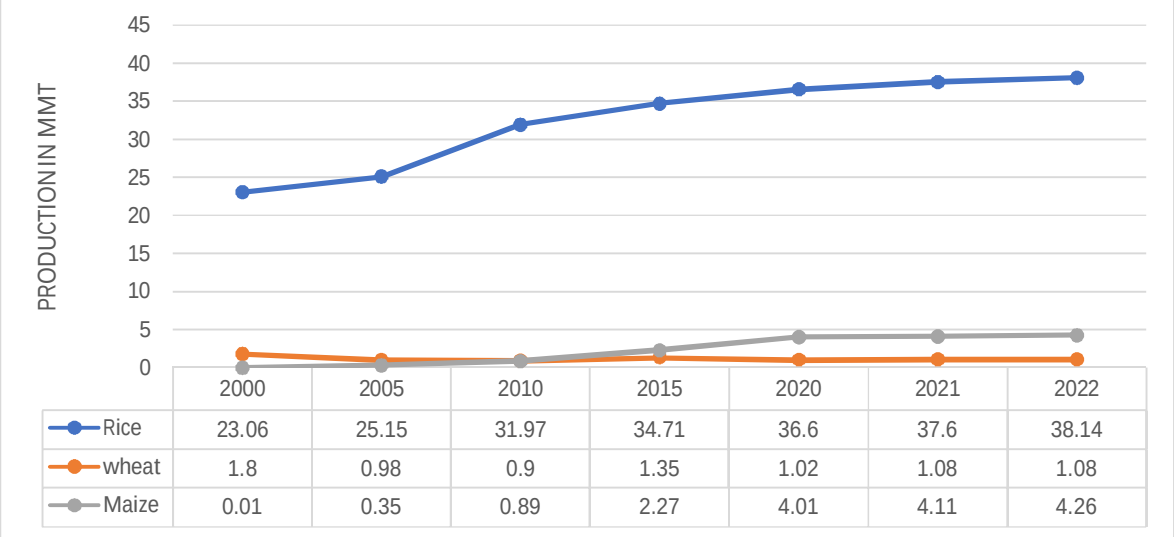
Table 1. Agricultural production of Bangladesh from 2000-2022

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: [2], [45], [76] **Number(million)*

3.2.1.1 Crop sub-sector: Food crops alone account for about 75% of the total agricultural output. Major crops in Bangladesh are cereals, jute, potatoes, fruits, vegetables, oilseeds, pulses, etc. Major industrial crops are jute, tea, tobacco, sugarcane, etc. Rice is the major crop that covers 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 [2, 45].“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 the 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

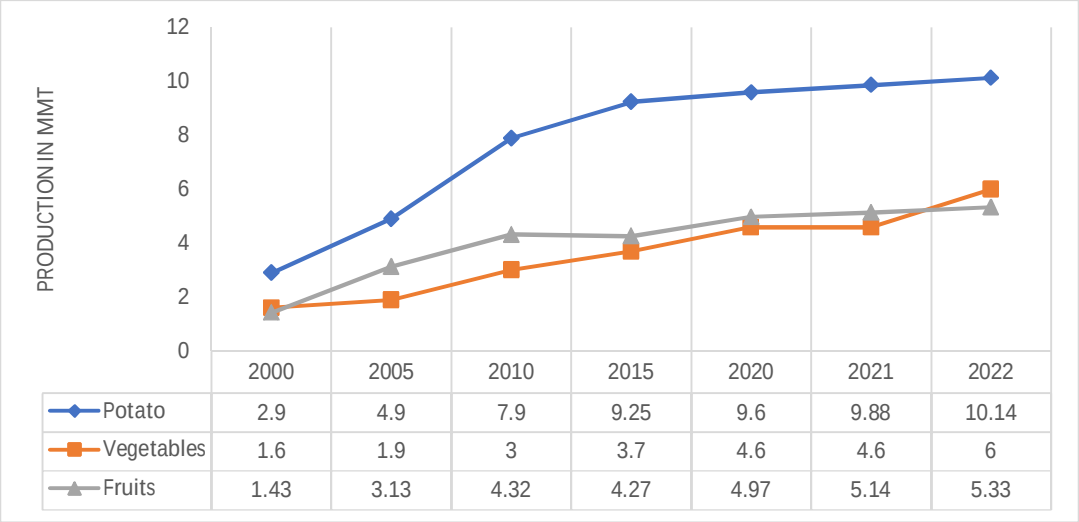
Source: [2], [45], [76]

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 the maize area increased by 160 times from 3,200 hac in 2000 to 513,270 hac in 2022 [2, 45]. 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 rice 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[2, 45]. This is a combined effect of both area expansion and high yield potato. The vegetable production depicts a similar trend to potato production, 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 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 fruit production could be attributed to technological advancement through the development of HYV, hybrids, and improved management technologies.

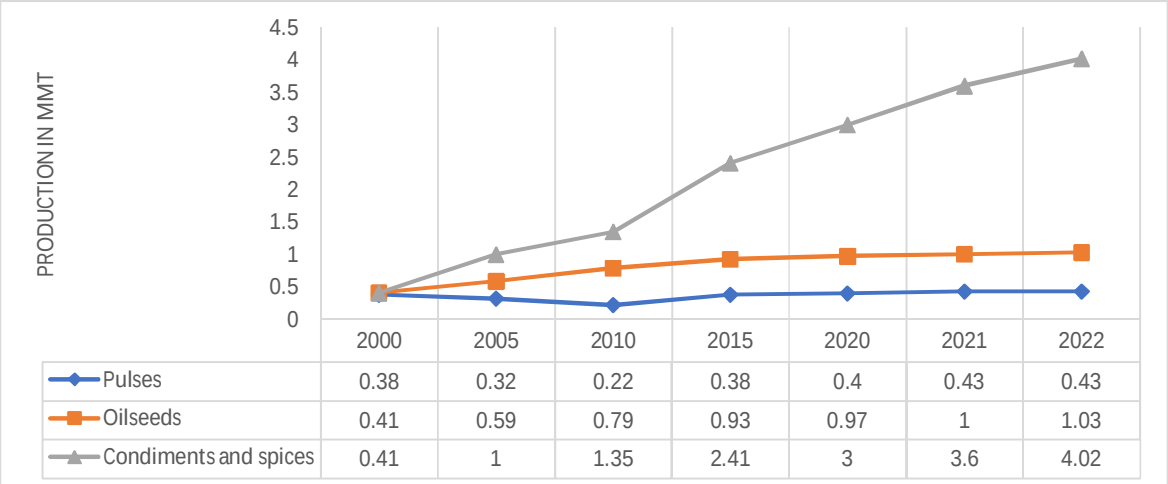


	2000	2005	2010	2015	2020	2021	2022
Potato	2.9	4.9	7.9	9.25	9.6	9.88	10.14
Vegetables	1.6	1.9	3	3.7	4.6	4.6	6
Fruits	1.43	3.13	4.32	4.27	4.97	5.14	5.33

Source: [2], [45], [76]

Figure2.Trendof Potato, Vegetables and Fruits Production inBangladesh

Pulse, Oilseed, and Spice 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 the 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.

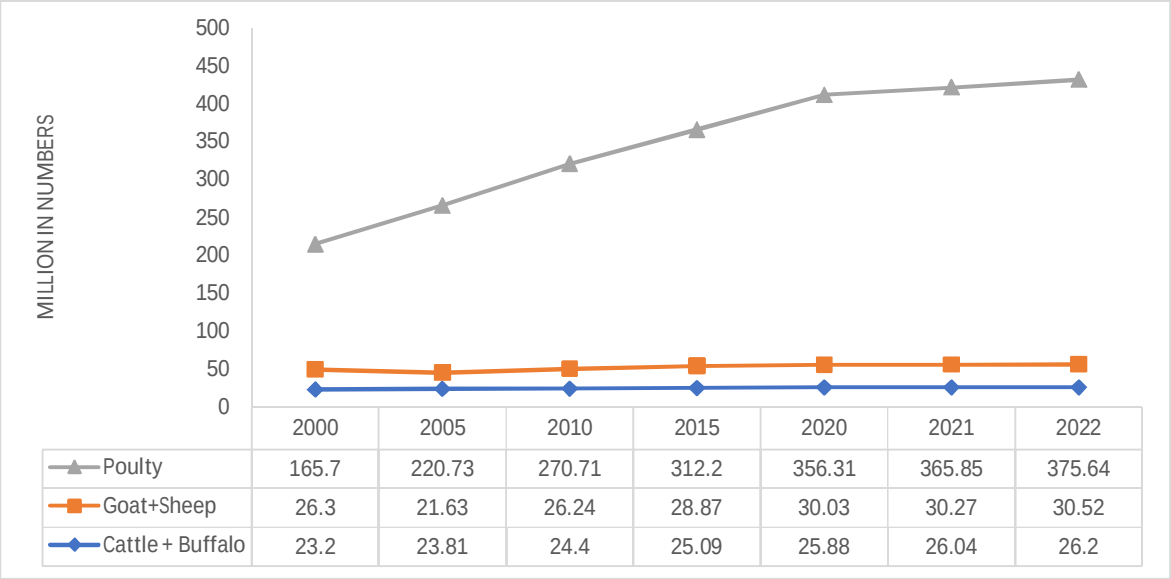


	2000	2005	2010	2015	2020	2021	2022
Pulses	0.38	0.32	0.22	0.38	0.4	0.43	0.43
Oilseeds	0.41	0.59	0.79	0.93	0.97	1	1.03
Condiments and spices	0.41	1	1.35	2.41	3	3.6	4.02

Source: [2], [45], [76]

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 eggs 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 goats and sheep was slightly upward during this period. This trend in livestock population growth is not encouraging; however, meat and milk production got a boost from technological advancements comprising cross breeding and improved management practices in respect of feeds and fodders, disease control, etc. The growth in the 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.



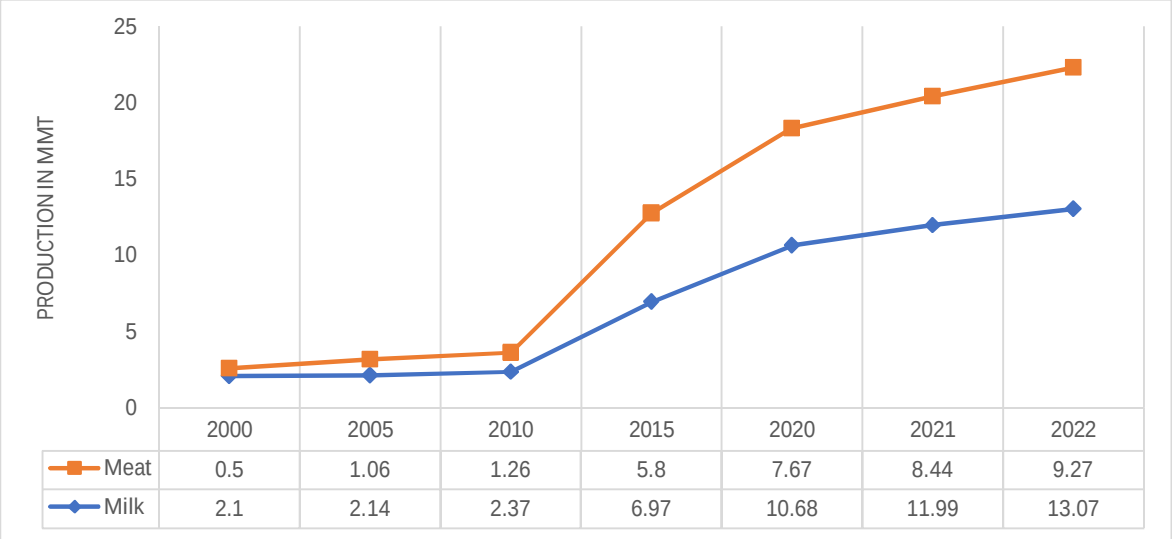
	2000	2005	2010	2015	2020	2021	2022
Poulty	165.7	220.73	270.71	312.2	356.31	365.85	375.64
Goat+Sheep	26.3	21.63	26.24	28.87	30.03	30.27	30.52
Cattle + Buffalo	23.2	23.81	24.4	25.09	25.88	26.04	26.2

Source:[2], [45], [76]

Figure4.Trendof Livestock production inBangladesh

Milk, meat, and eggs are three important products of livestock, whose production 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 of 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 [2, 45].

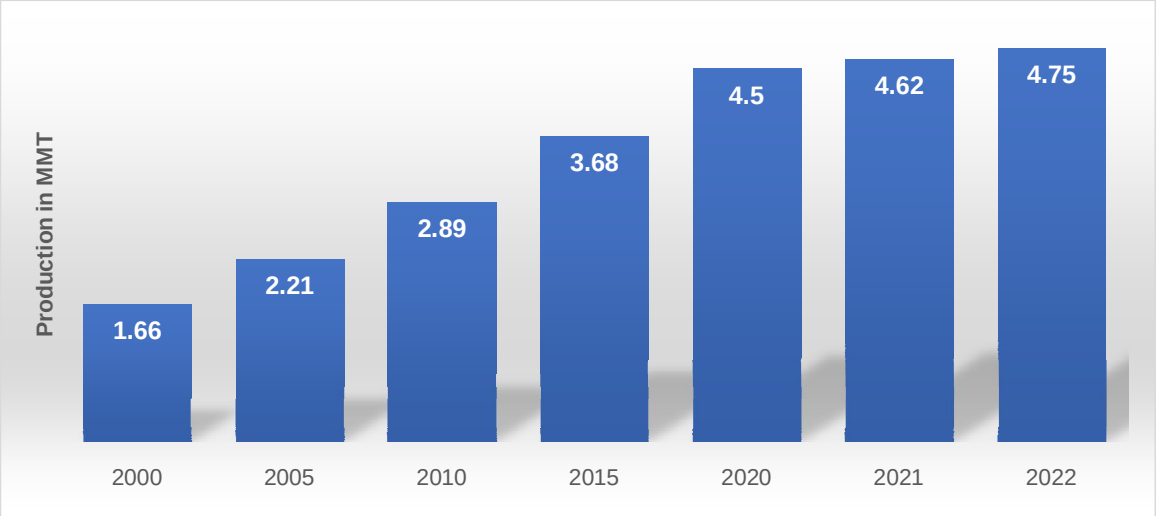


	2000	2005	2010	2015	2020	2021	2022
Meat	0.5	1.06	1.26	5.8	7.67	8.44	9.27
Milk	2.1	2.14	2.37	6.97	10.68	11.99	13.07

Source: [2], [45], [76]

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].The country today is self-sufficient in fish with a surplus of 0.09 MMT in 2015, and the surplus continued to increase to 0.68 MMT in 2021 due to a higher level of fish production than its requirement during this period [45].



Source: [2]

Figure6. Trend of fish production in Bangladesh

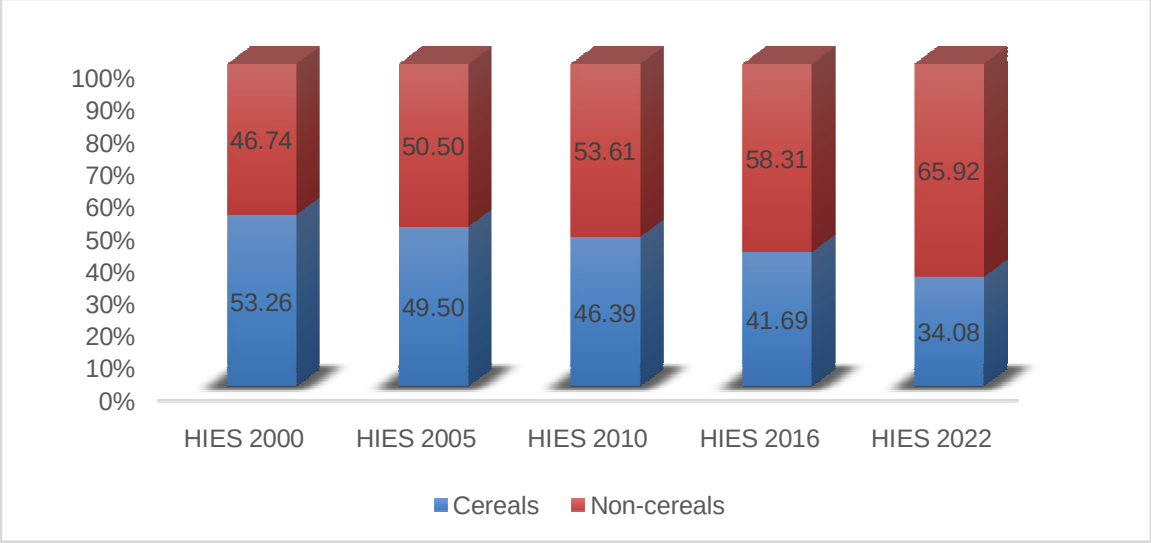
3.2.2 Trend of food consumption: The household consumption patterns in Bangladesh, as well as in other South and Southeast Asian countries, are heavily dependent on cereals, as food consumption diversity in these regions is not yet widespread. When households engage in more diverse agricultural activities, 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].The average daily per capita intake of major food items has been summarized from the last five surveys (2000, 2005, 2010, 2016,& 2022) to understand the food consumption pattern and its diversity that is 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: [2],[50],[76],[77]

The table indicates that the per capita daily intake of cereal groups 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, Figure 7 shows that the consumption level of non-cereal food items like vegetables, pulses, potatoes, milk & milk products, fruits, edible oils, meat, poultry, fish, sugar, and gur increased gradually, with 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-cereal foods has increased from 35.68 % in 2016 to 42.34 % in 2022 [50]. These findings indicate that food consumption patterns have changed over the time period as households engage in more diverse agricultural activities, change in consumption behaviour, and increased purchasing power.



Source: [2],[50],[76],[77]

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

3.3.3Measurement of diversification: Very little research on the measurement of agricultural diversification (crop and non-crop diversification) in Bangladesh has been conducted. Most research in relation to diversity in agriculture is focused on 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 the agriculture sector in Bangladesh.

Crop diversification: Metzel&Ateng [51] used the Simpson Index of Diversity (SID) as well as the 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 the Simpson Diversity Index (SDI) and found values of 0.37 in 1972-73, 0.42 in 1989-90, and 0.43 in 2001-02, which show an upward trend over time. Later on, Islam & Hossain [53] used the Simpson index and Rice Share index of crop diversification to calculate the nature and extent of crop diversity in Bangladesh from 40 years of 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 the 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 the Herfindahl index, whose value of 0.60 indicates that the cropping system is relatively diverse. Tisdell et al. [36] assessed the diversity of crop production by the adaptation of the Herfindahl-Hirschman index, whose value of 0.4479 implies low diversity of the types of crops grown in Bangladesh. Azad [55] used the Herfindahl index to measure crop diversification using Mahabub Hossain Panel Data (MHPD) and found an index value of 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. It can be concluded that crop diversification is relatively high for 64% because they are in the range of 0.2–0.4.

Zaman et al. [57] calculated crop diversity using the equation described by Kshirsagar et al. [58] and found the overall CDI of the Rangpur region 0.871. In a simultaneous study, Nasim et al. [59] found the CDI value is 0.952 at the national level, which indicates Rangpur region is relatively less diversified. Recently, Brown et al. [60] also found the 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 measure the level of crop diversity using the panel data of 17 regions of Bangladesh covering the 19-year period (1990–2008). The result revealed 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 the cropping system in the study area is relatively diverse. Uddin [63] measured crop diversification in relation to dietary diversity using the Simpson Index (SI) and 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	Determinants of	Herfindahl	0.60	Farm-level cross-section

[54]	crop choices in Bangladesh	index of crop diversificatio n		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) 0.56 during 1993-2010 by using the formula of ADI (value of non-cereal produce/ value of total agricultural produce), 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, vegetable, and fruit species produced by the household on their farm, whose value was 4.294 in 2011/12 and 5.224 in 2015, while the value of the Margalef species richness index (weights by the area grown with different crops) was 0.106 in 2011/12 and 0.324 in 2015.The results show that farm diversity is very low in Bangladesh but has increased over the years very significantly.This study used two rounds 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 the 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 datasets 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 the 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 are the production diversity score (count of food crop and animal species grown by the household), which values 5.07; the crop diversity score (number of crop species grown by the household), which values 5.17; and Simpson's Index of Crop Diversification (SID), which values 0.31. All the indicators of farm production diversity indicate that farm diversity is low in Bangladesh but has increased over time. The study was conducted using three rounds of panel data from the 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, whose value was8.049, while the Agricultural Diversification Score (ADS) was 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 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 foods 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 the 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 as one significant factor and a noteworthy determinant to enhance diversity in Bangladesh".

Nahar et al. [56] determined "the effect of different factors on crop diversification by using the binary logistic regression model and found age, farm experience, family working members, farm size, farming training; and farm income had positive effects 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 revealed that total land, access to news media, NGO membership, and number of hired labour had positive and significant effect on the extent and magnitude of crop diversification, while agricultural extension services, total fertilizer used, and number of plots had 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 increased 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 assets, 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 assets, & 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 have a significant positive influence on agricultural diversification in Bangladesh. Similar factors were also identified by Rai [68], Devi &Prasher [69], Bharadwaj [70], Bagri [71], Dudhatara [72], Kumari [73], Sen et al. [74], and Shekhar et al. [75] in their study for agricultural diversification in India, which was measured using the correlation co-efficient (r) and multiple regression 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, technical assistance, regional dummies, access to markets, and participation of women in farming	Age, farm size, access to credit, technical assistance, 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	Farm size, HH size, number of plots, annual income, non-farm income, distance of farm from road, distance	Age of the farmer, education of the farmer, extension contacts

		income, distance of farm from road, distance of market from farm, Extension contacts, Irrigation intensity	of market from farm, irrigation intensity	
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 underdevelopment of infrastructure, extension contact, share of non-agricultural income	Farm asset, proportion of land under irrigation, education of farmer, farming experience, index of underdevelopment of infrastructure, share of non-agricultural income	Amount of land owned, proportion of rented-in land, family size, extension contact

4. CONCLUSION

The trend of food production indicated that Bangladesh has made remarkable progress during the last 23 years. This progress in cereal foods (rice, wheat, and maize) production increased by 1.75 times, and non-cereal foods (potato, vegetables, fruits, pulse, oilseeds, spices, milk, meat, and fish) production increased by 4.75 times. As a result, the consumption level of non-cereal food items like vegetables, pulses, potatoes, milk & milk products, fruits, edible oils, meat, poultry, fish, sugar, and gur increased from 46.74% in 2000 to 65.92% in 2022. In the case of diversification in Bangladesh, crop diversification has shown an upward trend over this time period, while overall diversification in agriculture or on-farm is an increasing trend with a fluctuating nature.

There are a number of socio-economic, psychological, communicational, technological, infrastructural, and climate related factors that influence the process of crop and non-crop diversification at the 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 assets & 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. This study has significant learning and implications for extension functionaries and other development organizations to find out a proper approach to convince the farmers for agricultural diversification and augment the means of livelihoods for farm households thereby.

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 levels. 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 is inadequate. So, specific methods could be used in the future to understand the current scenario of agricultural diversification, and its influencing factors in different geographical locations. Besides, its association with livelihood security is needed to measure for further justification to better implement the diversification program in Bangladesh.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

This review article was written in collaboration among all the authors (MMR, MASM and MSR). MMR designed and wrote the first draft of the manuscript. MASM and MSR have contributed by editing as well as drafting some portion of the article. All authors read and approved the final manuscript.

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