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A Review on Status and Influencing Factors of Agricultural Diversification in Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. Author MMR designed and wrote the first draft of the manuscript. Authors MASM and MSR have contributed by editing and drafting some portions of the article. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Agricultural diversification has been recognized as one of the important adaptation strategies for maintaining 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 agricultural diversification have not been well defined. This review article aims 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

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increased by1.75 times and non-cereal foods (potatoes, vegetables, fruits, pulse, oilseeds, spices, milk, meat, and fish) production increased by 4.75 times from 2000 to 2022. Moreover, the percentage of non-cereal foods consumption increased from 46.74% in 2000 to 65.92% in 2022. Crop diversification showed an upward trend during this period, while overall diversification in agriculture was an increasing trend with a fluctuating nature.

There are several factors influencing crop and non-crop diversification that were identified in this review article by using different statistical techniques like the Probit model, Tobit model, correlation co-efficient (r), multiple regression, etc. Among these, age, education, farm size with the number of plots, farming experience, family working members, availability of irrigated land, availability of hired labor, family income, farm assets & infrastructure, the share of non-agricultural income, access to markets, credit facility, training received, extension linkage, membership in social organizations, and participation of women in farming were the key factors that have a significant positive influence on agricultural diversification in Bangladesh. The findings of this article have significant implications for extension functionaries and other development workers to find a proper approach to motivate the farmers towards agricultural diversification and enhance the means of livelihood for farm households.

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

1. INTRODUCTION

The agriculture sector plays a vital role in the economy of developing countries because it provides food for the people & raw materials for industry, and also creates employment for rural populations. Agriculture's share of global gross domestic product (GDP) has remained steady at around 4% since 2000, with 873 million people employed in 2021, or 27% of the worldwide workforce, compared to 1027 million (40%) in 2000 [1]. In Bangladesh, agriculture is an important part of overall economic development, which contributes 11.61% to the GDP. The agriculture sector is divided into the sub-sectors of crops, livestock, fisheries, and forests, accounting for 47.00%, 16.45%, 21.75%, and 14.80% of agricultural GDP, respectively [2]. The relative contributions of agricultural sub-sectors in GDP have changed significantly over time, even though the overall share of agriculture in GDP has decreased. The crop subsector's growth potential has diminished, and its annual growth rate has decreased. In contrast, the growth rates of the sub-sectors of livestock, fisheries, and forestry increased. As a result, non-crop agriculture has grown at a much faster rate than crop agriculture during the past few years [3].

The economy of the rural sector of Bangladesh is mostly driven by agricultural activities, where approximately 50% of Bangladesh's workforce is involved in this sector, and 70% of the country's population depends on agriculture for their livelihood [4]. Rural households rely 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 rural households in Bangladesh [5]. But agriculture in Bangladesh is embarrassed due to climate change-induced hazards, e.g., drought, flood, salinity intrusion, riverbank erosion, and also some challenges such as inadequate management practices, population growth, unfair price of agricultural products, inadequate credit facilities, loss of arable land, and lack of investment in agricultural research [6, 7]. In addition, Karim et al. [8] indicated that the availability of high-quality seed, access to markets, lack of storage facilities, and slow pace of technology transfer and adoption are some of the factors that slow down the process of agricultural development.

Agricultural diversification is regarded as a crucial approach to addressing these challenges encountered by farmers in many developing countries, as it provides opportunities for risk mitigation, addressing uneven production circumstances, and increased income generation by venturing into untapped markets [9]. It implies a transfer of resources from cereals to non-cereal crops, from rice to other cereal crops, and from crops to non-crop agriculture (livestock, fisheries, and forestry) [3]. Agricultural diversification toward higher value-added products has accelerated the growth of agricultural revenue and could contribute to the creation of jobs locally by encouraging small

farmers to participate in the market. Diversity in production is likely to lead to diversity in consumption, which is required for more well-balanced and healthy diets. As a result, the government is putting a lot of effort into encouraging agricultural diversification involving high-value crops, fruits, vegetables, livestock, and fisheries through suitable packages of seed, fertilizer and 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 [10-15]. Despite the huge benefits of agricultural diversification (including genetic resources and management practices) to agricultural production, natural resources, and rural livelihoods, farmers' decisions about diversification in agriculture have not been fully understood [16, 17, 18]. Therefore, rural policymakers and developers must have an adequate understanding of the social, economic, and ecological factors of smallholder diversification strategies to improve agricultural and livelihood resilience in rural areas [18].

The majority of literature that has been written 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 in Bangladesh are few. The studies conducted on the topic lack consistency in terms of measurement techniques and findings. So, this review aims to (1) summarize the status of agricultural diversification and (2) review the influencing factors of agricultural diversification in Bangladesh.

2. METHODOLOGY

This paper is prepared 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 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 “constraints in diversification.” The review was conducted from July 2023 to June 2024 and included relevant sources published between 1994 and 2024. A total of 134 published and unpublished papers were gathered from all of the searches. To review the work, only 54 published and unpublished papers were taken into consideration. Based on the review topic's suitability, recentness, and relevance, as well as the data type, specific research was either included or excluded. 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 term “diversification” has been derived from the word ‘diverge’, which means to move or extend in a direction different from a common point [19]. A common understanding of diversification is that it entails moving resources from low-value crops to high-value crops, shifting resources from farm to non-farm activities, and utilizing resources in a wider variety of complementary and diverse agricultural activities. In other words, diversification means expanding the rural income source by shifting the production portfolio from low-value to high-value commodities like vegetables, milk, meat, eggs, and fish in response to market demand [20].

Agricultural diversification can be explained in terms of the shift from the cultivation of a single crop dominating a region to the cultivation of multiple crops to meet increasing demand. Vyas [21] defined agricultural diversification as a shift from one crop to another crop or from one enterprise to another. Singh [22] defined agricultural diversification as the process through which producers distribute their productive resources among a greater range of economic endeavors, allowing farmers to be perceived as entrepreneurs. Joshi et al. [23] described agricultural diversification as the process of increasing household income and profit through crop, enterprise, and activity mix selection at the household level. In the context of Bangladesh, agricultural diversification is the process of moving away from rice production and engaging in non-rice crop cultivation and/or non-crop agriculture such as livestock, poultry, and fisheries [41].

From a broader point of view, agricultural diversification is the process of gradually shifting from a variety of market-oriented income crops

with a higher potential for returns on land to subsistence food crops, especially staple foods [24]. At the conceptual level, the diversification of agriculture could be classified into the following three categories [21, 25]:

1. The shift of resources from farm to non-farm activities;
2. The shift of resources within agriculture from less profitable crops or enterprises to more profitable crops or enterprises;
3. Utilizing resources in various activities that complement one another.

A diversification in favor of horticulture and livestock products is preferable to increase farm returns and employment, close time and distance gaps, and halt the loss of natural resources [12]. A greater labor force is employed in horticulture and livestock products than in conventional crops. In addition to its impact on direct employment, diversification opens up opportunities for indirect employment creation by fostering the agro-processing sector [26]. Diversification can be divided into two categories: vertical diversification and horizontal diversification. Horizontal diversification is one of the most common phenomena, which occurs when more crops are added to the current cropping system to improve the overall productivity of a farm or region's farming economy or when a farm shifts from subsistence to high-value crops, whereas vertical diversification refers to the addition of value to the current cropping system through processing, packaging, branding, or other initiatives to increase the value of the finished product [27].

3.2 Status of Agricultural Diversification in Bangladesh

Agricultural diversification is comparatively low in Bangladesh, where most of the farmers are involved in the mono-cropping system [28, 29, 30]. The reason is that the Green Revolution program and the Grow More Food program were launched in the 1970s to increase rice production with the support of critical inputs to farmers [3, 28-34]. These initiatives aimed to make Bangladesh self-sufficient in rice production. 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]. However, the steady growth of agriculture in Bangladesh is cereal-dominated, which is reflected by the prime dependence on rice cultivation and consumption [36]. However, the continued growth of per capita income in Bangladesh has been changing the consumption pattern toward non-rice crops such as fish, meats, milk, fruits, and vegetables.

These non-rice food crops are highly valuable and more profitable [37-40]. So, it is expected that farmers will have an interest in diversifying their agricultural outputs at the farm level due to the increasing demand and profitability of non-rice products. Furthermore, the government has taken several policy measures to promote greater agricultural diversification [30].

3.2.1 Trend of agricultural production

Bangladesh has achieved notable progress in domestic food production during the last 25 years due to the adoption of modern agricultural 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 with an average annual growth of 3.25% while progress in non-cereal foods (potatoes, 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 3rd position in terms of global rice production; after China and India in 2020.

Bangladesh has achieved additional milestones in the frontiers of diverse crops in global rankings: second in jute, sixth in potatoes, and eighth in mangoes, and guavas. Moreover, Bangladesh is also ranked first in hilsa fish capturing, third in inland open water & fifth in closed water fish capturing, and fourth in the world in number of goats and meat production [42]. At least 496 g of rice, 250 g of vegetables, 63 g of fish, 120 g of meat per day, and 104 eggs annually [43], 130 ml of milk, and 57 g of fruits per day should be consumed by a healthy person [44]. Taking into account a population of 166 million in 2021, the per capita availability of rice, fruits, vegetables, fish, milk, meat, and eggs has 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].

3.2.1.1 Crop sub-sector

Major crops in Bangladesh are cereals, jute, potatoes, fruits, vegetables, oilseeds, pulses, etc.

while commercial crops are jute, tea, tobacco, sugarcane, etc. Rice is the major crop that covers around 75% of the total cropped area and accounts for approximately 70% of the value of the overall crop output [46], while wheat, potato, pulses, and oilseeds are the other principal food crops of Bangladesh.

Rice, Wheat, and Maize: The crop sub-sector is dominated by rice, which almost assures a stable production structure. The rice growing area reported an increase from 10.7 million hectares to 11.69 million hectares from 2000 to 2022 [2,45]. Concerning rice area coverage, the volume of rice output has increased by 1.65 times from 23.06 MMT in 2000 to 38.14 MMT in 2022, representing a yearly growth rate of 2.84%. Despite a slow growth rate of rice area increase being attributed mainly to the transfer of agricultural land to infrastructure; massive growth of rice production was possible by the introduction of high-yielding varieties, improved management practices, and inputs like irrigation, seeds, fertilizers, pesticides, credit assistance, etc. [45].

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

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)*

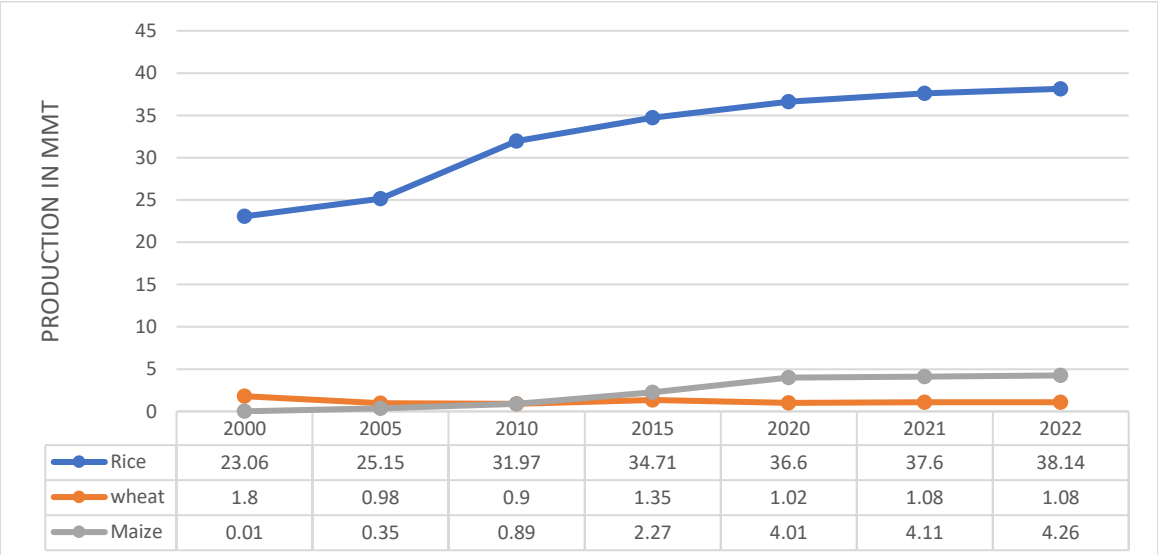


Fig. 1. Trend of rice, wheat, and maize production in Bangladesh
Source: [2,45,76]

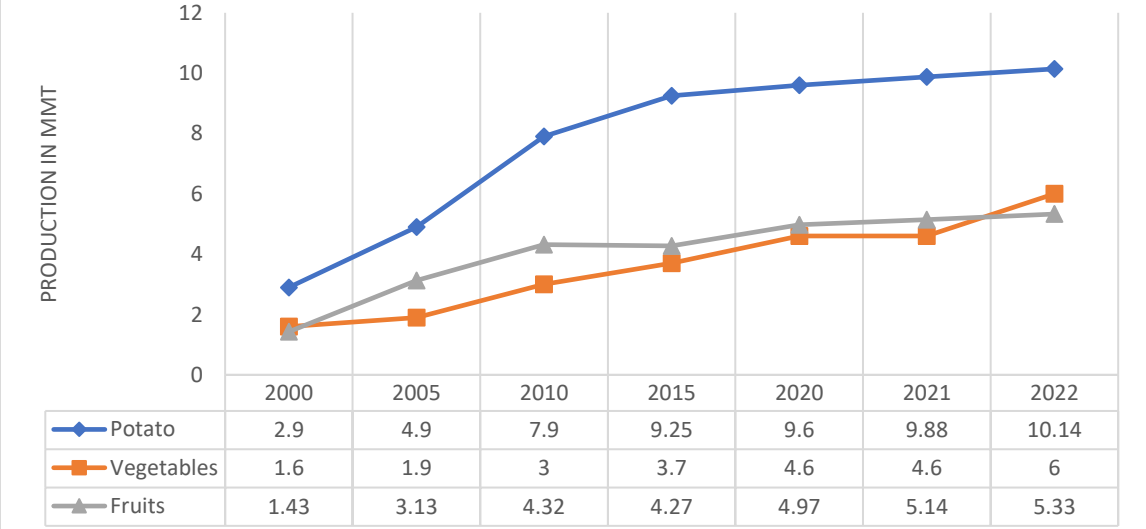
increased significantly from 0.01 MMT to 4.26 MMT during this period (Fig. 1). This decrease in wheat area might have been the result of an aggressive boro rice and maize expansion on wheat lands and also gained better outputs from these crops.

Potato, Vegetable, and Fruits: The area under potatoes increased by 1.91 times from 243,000 ha in 2000 to 464,327 ha in 2022, while production of potatoes increased by 3.5 times from 2.90 MMT in 2000 to 10.14 MMT in 202 2[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 (Fig. 2). 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 from 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.

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) from 1972 to 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) from 1972 to 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 from 1972-2000 resulting in spices surplus after 2005 [45]. Expansion of cultivated areas coupled with HYVs and other technological interventions helped increase spice production.

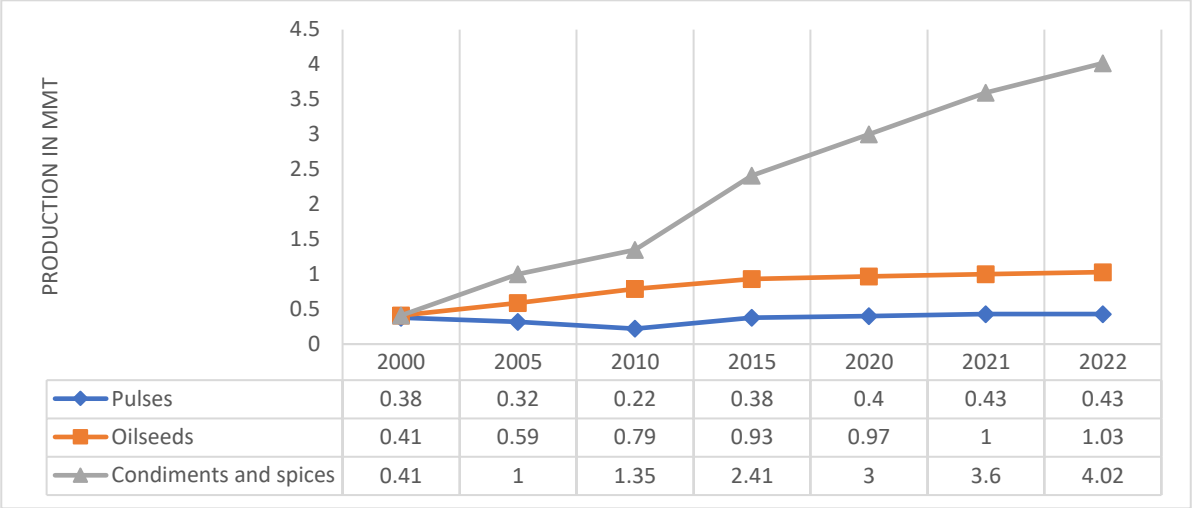
3.2.1.2 Livestock sub-sector

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 Fig. 4.



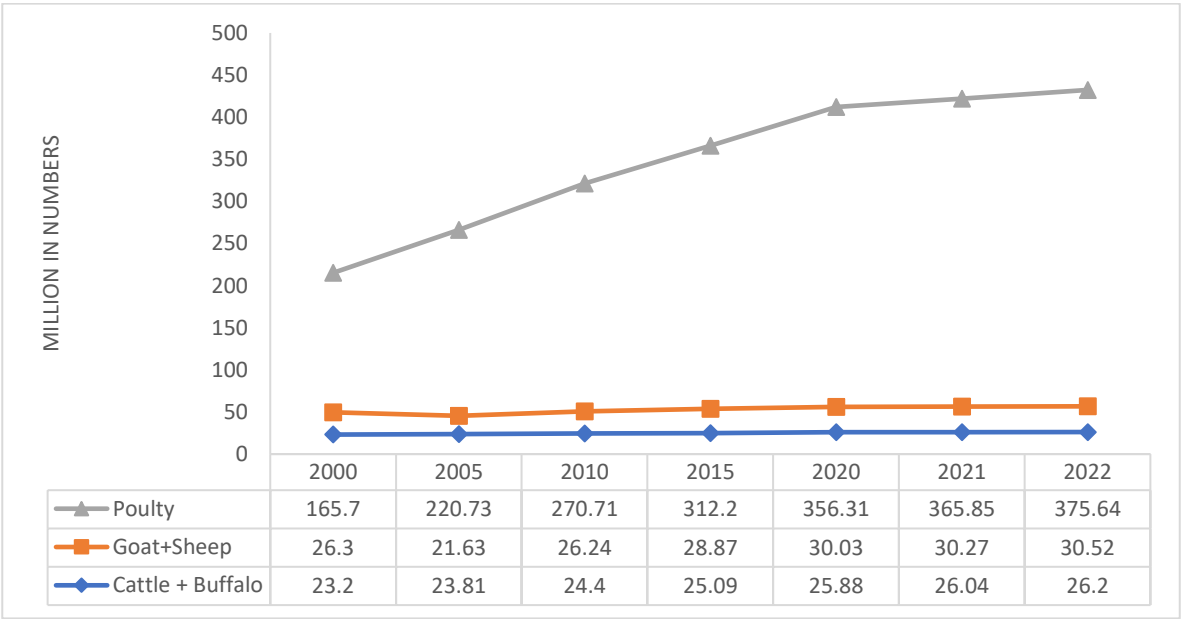
	2000	2005	2010	2015	2020	2021	2022
Potato	2.9	4.9	7.9	9.25	9.6	9.88	10.14
Vegetables	1.6	1.9	3	3.7	4.6	4.6	6
Fruits	1.43	3.13	4.32	4.27	4.97	5.14	5.33

Fig. 2. Trend of potato, vegetables, and fruit production in Bangladesh
Source: [2,45,76]



	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

Fig. 3. Trend of pulses, oilseeds, and condiments & spices crops production in Bangladesh
Source: [2,45,76]



	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

Fig. 4. Trend of Livestock production in Bangladesh
Source: [2,45,76]

It is revealed that the progress of 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 for 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.

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 an overall increase of 6.48 times

and an average annual growth of 23.85% over 23 years [2,45].

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 (Fig. 6). Bangladesh has become fish self-sufficiency; whereas the per capita consumption of fish was 7 kg/year in 1990, now it is approximately 30 kg/year [47]. The country is currently 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].

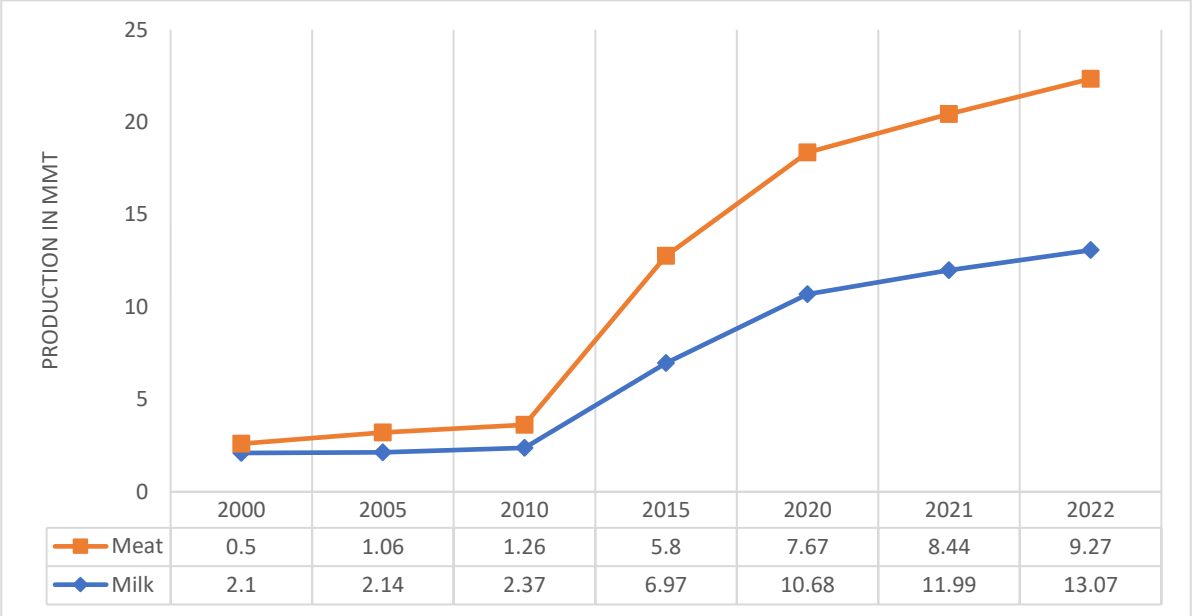


Fig. 5. Trend of milk and meat production
Source: [2,45,76]

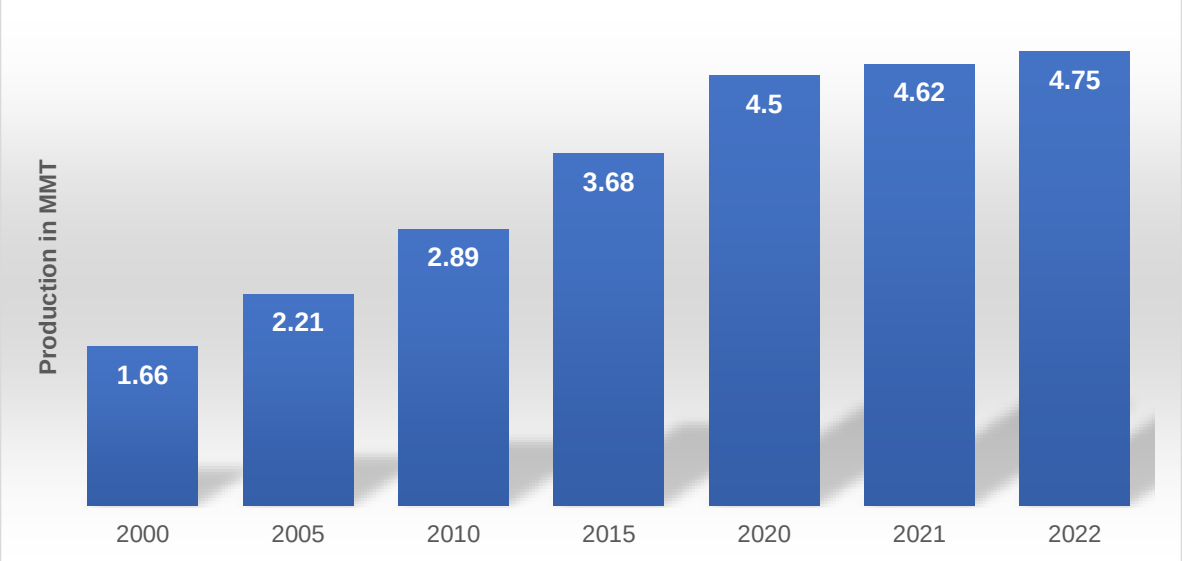


Fig. 6. Trend of fish production in Bangladesh
Source: [2]

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 due to the lack of diversity in food consumption in these areas. A wider range of foods is consumed in households when there is higher involvement in diverse agricultural activities, such as farming different crops, rearing various livestock, and engaging in fisheries [48,49]. The average daily per capita intake of main food items has been compiled from the last five surveys (2000, 2005, 2010, 2016, & 2022) to understand the food consumption pattern and its diversity that is presented in Table 2.

Based on the data presented in the table, the national average daily consumption of cereal categories was 385.0 grams in 2022. It was noted that the consumption of cereals declined by 23.55% in 2022 compared to 2000. Besides, Fig. 7 shows that the consumption level of non-cereal foods 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 period as households engage in more diverse agricultural activities with changes in consumption behavior and increased purchasing power.

Table 2. Average per capita consumption of food items (grams/day)

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]

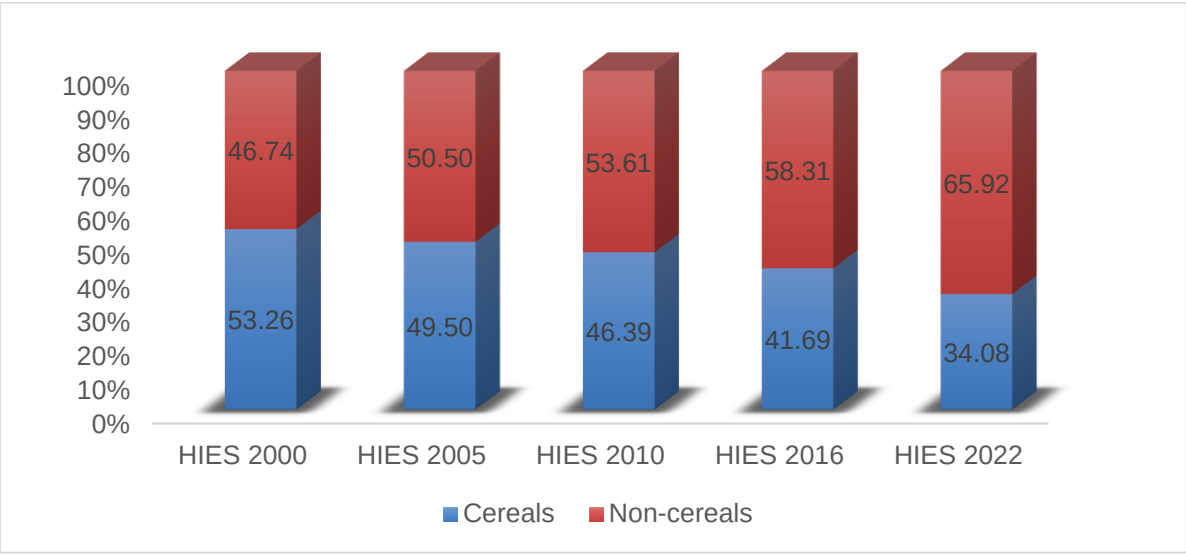


Fig. 7. Percentage of cereals and non-cereals items in average per capita daily food intake

Source: [2,50,76,77]

3.2.3 Measurement of diversification

A few studies on the measurement of agricultural diversification (crop and non-crop diversification) in Bangladesh have been conducted. Most research about 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. Subsequently, Islam & Hossain [53] determined the nature and extent of agricultural diversity in Bangladesh using the Simpson index and the Rice Share index from 40 years of time series data on crop acreage, yield, and production. They 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 crop diversification has been progressively rising in scale.

Rahman [54] measured overall crop diversification by using the Herfindahl index, whose value of 0.60 indicates that the cropping system is comparatively diverse. The data was collected from farm-level cross-section data for the crop year of 1996 in three agroecological regions of Bangladesh. Tisdell et al. [36] assessed the diversity of crop production by the adaptation of the Herfindahl-Hirschman index, whose value of 0.4479 suggests that Bangladesh grows a limited variety of crops. 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 have a moderate level of diversity. Similarly, Nahar et al. [56] measured the crop diversification of 609 farmers in five northern districts in Bangladesh and found that the majority of farmers' Herfndahl index values fall between 0.2 and 0.6. According to the study's findings, 64% of respondents had a comparatively high level of crop diversification because they fell between 0.2 and 0.4.

Zaman et al. [57] calculated crop diversity using the equation of 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 the Rangpur region is relatively less diversified. Recently, Brown et al. [60] also found the lowest crop diversification in Rangpur, where farmers have grown an average of 2.9 crops while the regional average was 3.8 crops. The average number of crops ever grown by each respondent from different locations was used to measure cropping diversity.

Rahman & Kazal [61] used the Shannon index to measure the level of crop diversity using the panel data of 17 regions in Bangladesh covering the period of 1990–2008. The data indicated that crop diversity levels varied significantly between the regions and declined in 2008 relative to 1990 levels except for Faridpur, Khulna, and Sylhet. Islam & Hossain [62] used the Entropy index (EI) to measure crop diversification with a value of 0.56 indicating that the cropping system in northern Bangladesh is relatively diverse. Uddin [63] examined crop diversification in relation to dietary diversity using the Simpson Index (SI) & Entropy Index (EI) and found that crop diversification has increased nationally over the period from 2011/12-2015, but this positive change is not significant. All seven administrative divisions of Bangladesh, except for the Sylhet division, have relatively stable crop diversification in terms of divisional estimations of SI and EI.

Agricultural Diversification: So far as we know, the only study on agricultural diversification in Bangladesh has been conducted by Miah et al. [3] in recent times. The study was primarily focused on agricultural diversity, which was measured by the formula ADI (value of non-cereal produce/ value of total agricultural produce). This study found the average value of the Agricultural Diversification Index (ADI) is 0.56 from 1993 to 2010. The highest agricultural diversification took place in Chittagong and Barisal regions, while Rangpur and Rajshahi regions experienced the lowest AD over the years. Islam et al. [64] measured farm diversification by counting the number of crop, vegetable, and fruit species that the household produced on the 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 study's findings

demonstrate that farm diversity is very low in Bangladesh but has increased significantly over time. This study employed two rounds of nationally representative panel data from the Bangladesh Integrated Household Survey (BIHS), conducted in 2011–12 and 2015. Similarly to this, Rehan [65] used the Simpson Index of Diversity (SID) to quantify farm diversity in relation to household food security. The mean SID values for diversified farms and non-diversified farms were 0.43 and 0.25, respectively. This finding indicates that the diversified farms had significantly a higher level of consumption diversification than non-diversified farms. Additionally, Abedin & Haque [66] tested the relationship between agricultural diversification and food security outcomes using panel datasets from the Bangladesh Integrated Household Survey (BIHS) 2015 and 2018–19. The aggregated diversification index is calculated as the total number of commodity groups produced from eight crops and five animal-source food groups. The study revealed that the combined measure of agricultural diversity increased significantly from 5.10 in 2015 to 5.64 in 2018/19. Besides, Khandoker et al. [67] measured agricultural production diversity using a variety of methods, including the production diversity score (count of food crops 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. These results show that although farm variety is low in Bangladesh, it has been rising 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 data from 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 that each household produced, whose value was 8.049, while the Agricultural Diversification Score (ADS) was measured by the number of different food groups produced, which score was 3.806. According to these findings, the total PDS shift between 2012 and 2018 was positively significant, and the ADS values demonstrate that agricultural diversification expanded with each wave and that the changes were highly significant.

3.3 Factors Influencing the Implementation of Agricultural Diversification

Several studies have been carried out 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.

Miah et al. [3] employed an empirical Probit model to determine the factors influencing agricultural diversification at the household level using farm-level data from 960 farmers in Bangladesh. The findings demonstrated that the probability of increasing AD at the household level is significantly influenced by land under irrigation facility, 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] used the Probit model to identify the factors that influence on-farm diversification. The results indicated that factors such as farm size, age of the head of the household, credit availability, technical support, availability of regional dummies, and market accessibility all had a favorable impact on the adoption of on-farm diversification. The active participation of women in farming activities was identified as one significant factor and a noteworthy determinant of enhancing diversity in Bangladesh.

Nahar et al. [56] determined the effect of various 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 HH total land, access to news media, NGO membership, and number of hired laborers had positive and significant effects on the extent and magnitude of crop diversification, while agricultural extension services, total fertilizer used, and number of plots had negative effects. Similarly, Islam & Hossain [62] found from the marginal effects of the Tobit Model that the number of plots, annual family income, and infrastructure affect the probability of crop diversification positively, whereas irrigation intensity and farm size affect it

Table 3. 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	Primary data from 400 Samples were selected randomly from 12 districts
Islam & Hossain [53]	Present situation of crop diversification	Simpson Index	0.35 in 1971-72 and 0.42 in 2011-12	40 years-time series crops acreage, yield and production data of Bangladesh
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	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	Herfindahl index (HI)	0.2-0.6	609 HHs of five northern districts
Zaman et al. [57]	Crop diversification	Kshirsagar et al. (1997)	0.871	Secondary data from DAE in 2014-15
Nasim et al. [59]	Distribution of crops and cropping patterns	Kshirsagar et al. (1997)	0.952	Secondary data from DAE in 2014-15
Rahman & Kazal [61]	Determinants of crop diversity	Shannon index	1.27	Panel data of 17 regions of Bangladesh during 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 HH
Brown et al. [60]	Farm diversification of EGP	Number of crops	3.8	Primary data of more than 5000 HHs in EGP

Table 4. 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 household head, farm size, access to credit, technical assistance, regional dummies, access to markets, and women's participation in farming	Age, farm size, access to credit, technical assistance, regional dummies, access to markets, and women's participation in farming	-
Nahar et al. [56]	Binary logistic regression model	Age, sex, education, farm experience, working members of family, farm size, farming training, farm income, and off farm income	Age, farm experience, working members of family, 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 labor, and total number of plots	Total land, agri extension services, access to news media, NGO membership, total used fertilizer, number of hired labor, 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, education, annual income, non-farm income, distance of farm from road, distance of market from farm, extension contacts, and 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, education of the farmer, extension contacts
Rahman & Kazal [61]	Generalized Least Squares (GLS) Random Effects model	Labor 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, and temperature variability	Labor 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,	Farm asset, proportion of land under irrigation, education of farmer,	Amount of land owned, proportion of rented-in

Researchers	Specified Model	Selected variables	Significant (Positive or negative impact)	Non-significant (No impact)
		proportion of rented-in land, education, farming experience, family size, infrastructure, extension contact, and share of non-agricultural income	farming experience, infrastructure, share of non-agricultural income	land, family size, extension contact

negatively. Rahman & Kazal [61] used the Generalised Least Squares (GLS) Random Effects model to identify the determinants of regional crop diversity and revealed that an increase in the relative prices of vegetables and urea fertilizer, extension expenditure, labor 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, and share of non-agricultural income were all significantly and positively influencing the decision to adopt a diversified cropping system.

These studies revealed that age, education, farm size with number of plots, farming experience, family working members, availability of irrigated land, availability of hired labor, 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.

4. CONCLUSION

The trend in 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 foods 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 revealed an upward trend over this period, while overall diversification in agriculture or on-farm was an increasing trend with a fluctuating nature.

Several socio-economic, psychological, communicational, technological, infrastructural, and climate-related factors 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 labor, 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 a proper approach to convince the farmers towards agricultural diversification and augment the means of livelihoods for farm households.

The effect of identified factors for agriculture diversification from limited studies in Bangladesh was not 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 the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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