FACTORS ASSOCIATED TO CHANGES IN FOOD SECURITY DURING COVID-19: INSIGHTS FROM FARM HOUSEHOLDS IN BANGLADESH

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Abstract. The COVID-19 pandemic has instigated substantial disruptions in global economic activities and food systems, prompting concerns regarding food security worldwide. However, a knowledge gap persists regarding the specific alterations in food security and the underlying factors associated to these changes. This study delves into the shifts in food security status among farm households in North-western Bangladesh in the wake of COVID-19, alongside an examination of the factors associated to these shifts. Drawing on survey data from 498 households, we employed paired sample T-tests and multinomial logit models to scrutinize variations in food consumption patterns and the Food Security Index (FSI). Our analysis unveils significant transformations in food security status, as households curtailed consumption of essential food items such as meat, fish, pulses, milk, and sugar, resulting in diminished nutrient intake. Intriguingly, while 31.9% of households exhibited food security in 2019, only 11.8% maintained food security by 2022. We identify several factors associated with changes in FSI, including the presence of migrated household members, household income, and household size. Moreover, our study sheds light on previously overlooked determinants such as the value of livestock, compliance with dietary guidelines, engagement in off-farm work, and knowledge of food elements as significant factors associated to FSI variations. In light of these findings, we underscore the imperative for targeted interventions to address food security challenges. This entails implementing agricultural projects, providing microenterprise support, and offering training programs aimed at enhancing production diversity, augmenting farmers' income, and bolstering food security. Additionally, we advocate for the implementation of social programs focusing on dietary guidelines, food nutrition education, and the facilitation of off-farm activities to alleviate food security vulnerabilities among farm households.
Keywords: *food consumption pattern, food security index, vulnerability assessment, household resilience*

Introduction

The COVID-19 pandemic has wrought enduring effects on global food systems (Ruszczyk et al., 2021). Particularly in developing countries, such as Bangladesh, the impact has been pronounced, exacerbating existing challenges in food security (FAO and UN, 2020). These challenges threaten to reverse the progress made in poverty alleviation over the past decades, pushing many families into food insecurity (UNDP, 2020). Alarmingly, global starvation rates surpassed expectations in 2021 (WFP et al., 2022). Economic disruptions and rising unemployment associated with the pandemic have led

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to adverse impacts on household incomes and food consumption habits, including a loss of dietary diversity (Eftimov et al., 2020; Kundu et al., 2021a).

Despite significant strides in reducing extreme poverty and achieving self-sufficiency in food grains by 2016, Bangladesh continues to face significant shortfalls in meeting the demand for essential nutritional items such as milk, vegetables, eggs, and fruits (Hassan, 2022). Malnutrition remains a critical issue, with one-third of Bangladeshi children under five years old suffering from moderate to severe malnutrition (NIPORT et al., 2016). Moreover, in 2019, approximately 35 million Bangladeshis were affected by levels 3 and 4 of IPC, with 11.7 million experiencing severe chronic food insecurity (IPC, 2022).

Bangladesh reported its first COVID-19 case on March 7, 2020, prompting the implementation of movement restrictions through a "public holiday" on March 26. By August 18, 2020, the country had recorded 282,344 COVID-19 cases and 3,740 deaths (MIS and DGHS, 2020). The pandemic's impact on employment and income has led to a surge in poverty and economic vulnerability (Rahman et al., 2022). The Asian Development Bank projected a 1.1% decline in GDP and the loss of 894,930 formal jobs in Bangladesh in 2020 (Abiad et al., 2020). Inflation in food prices soared to 11.36% in urban areas and 11.21% in rural areas in January 2022, accounting for over 60% of total household expenditures (The Daily Star, March 4, 2022). Additionally, the International Food Policy Research Institute (IFPRI) reported a surge in food insecurity among rural families, from 15% in early 2020 to 45% in January 2021 (Mamun et al., 2022).

Moreover, studies have highlighted the disproportionate impact of COVID-19 on low-income households in Bangladesh (Ruszczyk et al., 2021). Bidisha et al. (2021) found that households with younger children and/or older adults are particularly vulnerable to food insecurity, with COVID-19-induced economic downturns pushing a significant proportion of food-insecure families below the dietary poverty line (Bidisha et al., 2021). The pandemic has also altered consumption patterns, with residents reducing both the quantity and quality of their meals (Islam et al., 2022). Severe COVID-19 effects have been associated with food stress, decreased income, and increased food costs (Rabbi et al., 2021). Anxiety surrounding access to food has immediate effects on consumption and purchasing behaviors, with a significant percentage of households reducing their daily meals to three or fewer (Chakrobarty et al., 2020).

While several studies have examined the pandemic's impact on food consumption habits and nutritional well-being in Bangladesh, a comprehensive understanding of changes in food security and the factors associated with these changes is still lacking. Therefore, this study aims to systematically assess changes in the food security index and analyze the factors associated with either the decrease or increase in FSI.

This study makes a significant contribution in two key areas. Firstly, it provides valuable insights into the challenges and vulnerabilities unique to farm households during the COVID-19 pandemic, a perspective often overlooked in previous research. By focusing specifically on agricultural communities, the study sheds light on the distinct impacts of the pandemic on rural livelihoods and food security, enhancing our understanding of the broader socioeconomic dynamics at play.

Secondly, the study delves into the multifaceted factors influencing changes in food security among farm households, including household demographics, income levels, and dietary habits. This nuanced analysis adds depth to our understanding of the underlying determinants of food security dynamics in the context of the pandemic. By identifying these factors, the study offers actionable insights that can inform targeted policy interventions aimed at mitigating the adverse effects of the pandemic on food security

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and promoting resilience and sustainability within agricultural communities in Bangladesh and beyond.

Overall, the findings of this study contribute not only to academic scholarship but also have practical implications for policymakers, enabling more informed decision-making and effective strategies to address the complex challenges facing rural communities amidst the ongoing COVID-19 crisis.

Literature Review

The COVID-19 pandemic has brought about profound disruptions to dietary patterns and food security, particularly in low-middle-income, developing, and least-developed nations. The upheaval has reverberated through farming practices, market systems, and supply chains, leading to shifts in consumption behaviors and food security outcomes among regional producers. Numerous studies have examined the impact of COVID-19 on the Food Security Index (FSI) and associated policy responses, offering insights into the global economic implications and regional variations in food security dynamics. For instance, Balistreri et al. (2022) conducted a comprehensive analysis of the COVID-19 impact on FSI across 80 low and middle-income countries, using a global economy-wide model to evaluate associated policy responses. Their findings highlight the exacerbation of existing food security challenges, particularly in Asian countries, driven by income shocks rather than price effects.

Food security outcomes are influenced by a multitude of factors, as evidenced by studies across different regions. Sarkar et al. (2021) examined the determinants of food security in China during the COVID-19 epidemic, revealing positive associations between efficient food utilization, availability, and access. Similarly, Matavel et al. (2022) identified household attributes, geographical positioning, and agricultural output as critical determinants of food security in Mozambique.

In the United States, Nelson et al. (2022) explored the effects of COVID-19 on food security in Massachusetts, focusing on factors such as education level, economic hardships, and the food environment. Meanwhile, Saboori et al. (2022) conducted a comprehensive analysis of worldwide food security amidst the pandemic, considering aspects such as affordability, availability, quality, safety, natural resources, and resilience.

Previous research has underscored the importance of understanding these determinants of the food security index (Barrett et al., 2001; Hoddinott and Kinsey, 2001; Sahn and Stifel, 2002; Barrett, 2010; Vermeulen et al., 2012; Dizon et al., 2019; Ahmed et al., 2022). Factors such as household demographics, migration, land size, access to credit, income diversity, livestock ownership, compliance with dietary guidelines, and off-farm activities have been found to significantly influence food security outcomes.

Drawing on insights from the literature, the present study carefully considers these influential factors in analyzing the changes in food security index among farm households in Bangladesh amidst the COVID-19 pandemic (Bashir and Schilizzi, 2013; Mutea et al., 2019; Kundu et al., 2021). By systematically examining these factors, the study aims to contribute to a deeper understanding of the complex interplay between socioeconomic dynamics and food security in agricultural communities.

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Materials and Methods

Study Area and Data

The study was conducted in the northwest region of Bangladesh, specifically in Natore and Pabna. These areas are known for their susceptibility to seasonal droughts, floods, and riverbank erosion, as documented by the Climate Change Knowledge Portal (2021). Natore is characterized by its dry and hot climate, while Pabna faces greater vulnerability to floods (Sarker et al., 2017). However, the precise impact of these climatic extremes on food production and consumption during the study period could not be quantified.

A multi-stage sampling approach was employed to select the study sample. Initially, purposive random sampling based on levels of food insecurity was utilized to identify suitable study areas. Subsequently, two villages were randomly selected from each chosen district using village lists. Finally, 130 farm households were randomly chosen from each selected village to participate in the study. Face-to-face interviews were conducted with the same farm households in both 2019 and 2022. The questionnaire was tailored to local conditions following a pilot survey and administered to consenting farm households.

Ethical approval for the study was obtained from the Research Ethics Committee of Pabna University of Science and Technology (PUST) under reference number "ECO/22/8". Written informed consent was obtained from all participants prior to data collection. Enumerators assisted respondents in recalling their food consumption history and translated the questionnaire from English to Bangla, the local language, for clarity. Given the low levels of education among Bangladeshi farmers, respondents completed the questionnaire with the assistance of enumerators. Thirteen stratified focus group discussions (FGDs) were conducted with farmers to gain insights into their coping strategies, following the methodology outlined by Maxwell and Caldwell (2008). Finally, 22 samples were excluded from the analysis due to the presence of contrived outliers.

Conceptual Framework

Building on the framework established by Mutea et al. (2019), this study posits that farm households meeting all five Food Security Index (FSI) indicators are classified as food secure. The study endeavors to construct a Composite Food Security Index for farming households, integrating various dimensions of food security with equal consideration.

The conceptual framework, depicted in *Figure 1*, encapsulates the hypothesized association of the COVID-19 pandemic to the Composite FSI. It is conjectured that the pandemic has introduced significant disruptions to the food security landscape, influencing the overall Composite FSI score among farm households.

By examining the multifaceted effects of COVID-19 on food security, encompassing factors such as changes in food consumption patterns, household demographics, income dynamics, and external environmental factors, the study seeks to elucidate the nuanced interplay between the pandemic and food security outcomes.

Furthermore, the conceptual framework underscores the importance of understanding the complex factors associated to food security. Through a comprehensive analysis of these interrelated factors, the study aims to contribute to a deeper understanding of the evolving dynamics of food security in the context of global crises.

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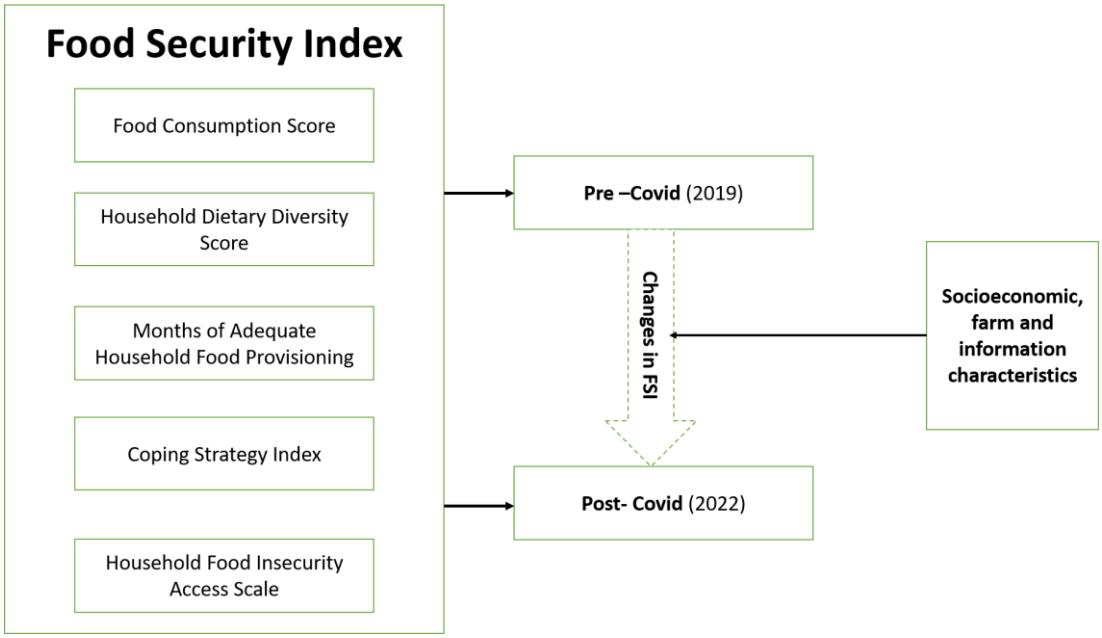

Figure 1. *Conceptual Framework*

Empirical Analysis

This section begins by delineating the composition of food consumption patterns, delineating the variations observed before and after the onset of the COVID-19 pandemic across different food groups. Subsequently, the Composite Food Security Index (FSI) is elucidated, offering an assessment of the changes observed for each indicator. Finally, the application of multinomial logistic regression is outlined to analyze the intricate relationships between shifts in FSI and their underlying factors.

Food Consumption Pattern

To compute the percentage of various food groups on per capita food availability, this study evaluated the following major categories of food: (i) cereals, (ii) vegetables, (iii) pulses, (iv) meat, (v) fish, (vi) fruits, and (vii) oils or fats. Each category was carefully assessed to discern any changes in consumption patterns before and after the onset of the COVID-19 pandemic.

To measure the shifts in food consumption patterns, a paired sample t-test was employed. This statistical method enabled a robust examination of differences in food consumption between pre-pandemic and post-pandemic periods, providing valuable insights into the association of the COVID-19 crisis with dietary habits and food preferences.

Composite FSI

The composite Food Security Index (FSI) comprises several key indicators: Food Consumption Score (FCS), Household Dietary Diversity Score (HDDS), Coping Strategy Index (CSI), Months of Adequate Food Provisioning (MAHFP), and Household Food Insecurity Access Scale Score (HFIAS). These indicators are calculated following the guidelines established by the World Food Programme (WFP) and the Food and Nutrition Technical Assistance (FANTA) community (Coates et al., 2007; Maxwell and Caldwell,

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2008; WFP and VAM, 2008; Bilinsky and Swindale, 2010). Information obtained from the survey is utilized in computing these indicators.

To ensure consistency and comparability, each original indicator score is normalized into a Z-score for every household before constructing the composite food security index (Song et al., 2013). Subsequently, the composite FSI is determined using the formula proposed by Mutea et al. (2019) (*equation 1*). In this formula, higher scores correspond to higher levels of food security, providing a comprehensive assessment of food security status among farm households amidst the COVID-19 pandemic.

$$Y_i^{FSI} = ZSc_i^{HDDS} + ZSc_i^{FCS} + ZSc_i^{MAHFP} + \left(-ZSc_i^{CSI}\right) + \left(-ZSc_i^{HFAIS}\right) \quad \text{(Eq.1)}$$

where, Y_i^{FSI} is the Composite Food Security Index for i^{th} household;
ZSc_i^{HDDS} = Z-score of HDDS;
ZSc_i^{FCS} = Z-score of FCS;
ZSc_i^{MAHFP} = Z-score of MAHFP;
ZSc_i^{CSI} = Z-score of CSI;
and ZSc_i^{HFIAS} = Z-score of HFIAS.

Multinomial Logistic Regression

To identify the factors associated with changes in the composite Food Security Index (FSI), a comparative analysis of FSI scores for farm households in 2019 and 2022 was conducted. The changes in FSI were categorized into three groups: $Y_1 = 1$, when increase; Y_2 = 0, when non-change; and Y_3 = -1, when decrease, which were adopted as the dependent variable in the model to elucidate the underlying associated factors.

Given the potential asymmetry in the positive and negative impacts on FSI, it was recognized that the group experiencing a decrease in FSI may exhibit substantial variability compared to both the group with increased FSI and the group with unchanged FSI. To capture these nuances, a multinomial logistic regression model was employed to model the relationships between changes in FSI and their determinants.

Following the approach outlined by Luce (1959), the multinomial logistic regression model with three categorical dependent variables can be expressed using *Eq. 2* and *Eq. 3*, facilitating a comprehensive analysis of the factors associated with changes in food security status among farm households amidst the COVID-19 pandemic.

$$logitP_{1/0} = ln\left(\frac{P(Y_1=1|X)}{P(Y_2=1|X)}\right) = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \cdots + \alpha_n X_n \quad \text{(Eq.2)}$$

$$logitP_{-1/0} = ln\left(\frac{P(Y_3=1|X)}{P(Y_2=1|X)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \quad \text{(Eq.3)}$$

$P(Y_1)$, $P(Y_2)$, and $P(Y_3)$ are the probabilities that the dependent variable will take on each of the three potential values (increase, non-change, decrease). Variables X_i are the independent variables (age and education of household head, household size, household dependency ratio, migrated member of household, land size, amount of credit, annual income, livestock and compliance, off-farm activities, following dietary guidelines, knowledge of food elements, and area dummy). α_i and β_i are the coefficients to be estimated.

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Results

Descriptive Statistics

Table 1 provides a summary of the descriptive statistics of the variables under study. The analysis revealed that the average age dependency ratio and average household size stood at 54.93% and 4.74, respectively, with approximately 47% of households comprising more than four members. Furthermore, the survey indicated a predominance of male household heads, accounting for 97% of farm households, with an average educational attainment of 4.82 school years. Within this demographic, 3.2% of household heads had attained a graduate degree, while 63.45% had completed primary and high school education. Additionally, 3% had achieved a college education, with over 30% lacking any institutional educational background. It's important to note that educational attainment in this context adheres to the categorization used in the Bangladesh education system, which classifies educational levels as follows: 0 years for no formal education background; 1-5 years for primary education; 6-10 years for high school education; 11-12 years for college education; and 13-16 years for graduate studies.

Table 1. *The variables and descriptive statistics*

Variables	Definition	Mean (SD)	Freq(percent)
Age of Household Head	Number of years	48.65 (12.37)	
Education of Household Head	Number of years	4.82 (4.09)	
Household Size	Number of people in the household	4.74 (1.59)	
Dependency Ratio	(Number of active member/Number of dependent member) *100	54.93 (46.38)	
Migrated Members	Numbers of family members living outside	0.30 (0.62)	
Land Size	Size of own land in Bigha[1]	3.37 (3.55)	
Amount of credit	Amount of loan in USD	320.52 (978.61)	
Annual income	Amount of yearly income in USD	1661.57 (1541.24)	
Livestock & Compliance	Price of livestock and compliance in USD	1617.36 (1670.97)	
Off-farm Activities	Participation in off-farm activities (1=Yes)		44.18%
Area	District location of the respondents (1=Pabna)		63.07%
Following Dietary Guidelines	Follow dietary guideline (1=Yes)		13.45%
Knowledge of Food Elements	Knowledge of food elements (1=Yes)		15.3%

Note: 1. The land area 1 hectare = 7.4749 Bigha 2. The income is 1 USD = 105 taka in Dec. 2022. The standard deviations (SD) are provided in parentheses. Source: Author's field survey 2022

The average size of owned land was 3.37 Bigha, suggesting that a majority of households were characterized as smallholders. Notably, 55.8% of farm households reported no engagement in off-farm activities. Disparities in income distribution were observed, as evidenced by the slight difference between the mean value and standard deviation of income among farm households.

Furthermore, the survey highlighted low levels of understanding regarding food elements, with only 15.3% of households demonstrating reasonable comprehension.

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Similarly, adherence to dietary guidelines was limited, with only 13.5% of households reported to consistently follow these guidelines.

Impacts of COVID-19 on Food Consumption Patterns and Food Security

Changes in Food Consumption Pattern

To elucidate the changes in food consumption patterns within the study area, enumerators adhered to the Food Consumption Score (FCS) guidelines outlined by the World Food Programme (WFP) and the Vulnerability Analysis and Mapping (VAM) initiative (2008). Respondents were presented with a list of food items and queried about their family's consumption frequency over the preceding week. Specifically, enumerators inquired, "Please indicate the number of days your family consumed each of the following foods last week."

Figure 2 presents the distribution of food consumption, with the Y-axis representing the percentage of households and the X-axis delineating different food groups. Notably, a discernible trend of decreasing percentages of consumers was observed across almost all food groups within the study area. This trend suggests that respondents adjusted their food consumption patterns, potentially reducing or omitting certain food items to mitigate expenditure amidst the COVID-19 pandemic.

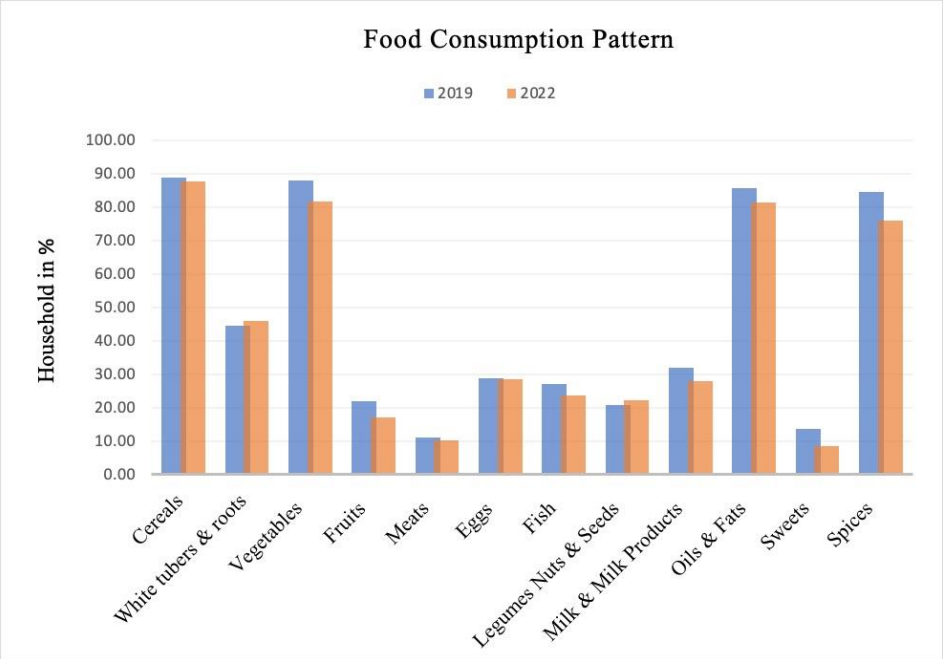

Figure 2. *Food consumption pattern based on the HDD*

Table 2 presents the mean differences in food consumption patterns between 2022 and 2019, along with the results of the paired sample t-test. The findings indicate a notable decrease in food intake, with households significantly reducing their consumption of meat, fish, pulses, milk, and sugar, leading to a decline in nutrient intake within the study area. Despite pulses being an alternative and affordable source of protein, their utilization remained limited. In conclusion, the table highlights a concerning downward trend in the Food Consumption Score among households in the study area.

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Table 2. *Paired t-test on Food Consumption Changes during COVID-19 over 7-Day Recall period*

Food Groups	2019 Mean (SD)	2022 Mean (SD)	Mean Difference	SD	P value
Staples	6.78(0.92)	6.77(1.07)	-0.018	0.35	0.257
Vegetables	5.93(1.68)	5.98(1.56)	0.042	0.81	0.247
Fruits	1.81(1.84)	1.75(1.83)	-0.064	0.98	0.147
Meats & Fish	2.54(1.48)	2.43(1.62)	-0.110 ***	0.93	0.009
Pulses	2.78(2.3)	2.71(2.3)	-0.072 **	0.72	0.027
Milk	3(2.49)	2.89(2.49)	-0.105 **	0.04	0.016
Oils	6.5(1.47)	6.47(1.53)	-0.024	0.54	0.324
Sugar	2.15(2.24)	2.05(2.18)	-0.100 ***	0.84	0.008
Condiments	1.18(1.95)	1.07(1.95)	-0.102 ***	0.58	<0.001

Note: 1. The standard deviations (SD) are provided in parentheses. 2. Levels of statistical significance: *** 1%, ** 5%, * 10%. Source: Author's field survey 2022

Food Security Measurements and Changes in the FSI

The present study utilized established food security measurements outlined in previous literature (Swindale and Bilinsky, 2006a; Coates et al., 2007; Maxwell and Caldwell, 2008; Bilinsky and Swindale, 2010). Following the guidelines provided by the World Food Programme (WFP), Food and Nutrition Technical Assistance (FANTA), and Food and Agriculture Organization (FAO), five key indicators were employed to calculate the composite Food Security Index (FSI): Household Dietary Diversity Score (HDDS), Food Consumption Score (FCS), Months of Adequate Household Food Provision (MAHFP), Household Food Insecurity Access Scale (HFIAS), and Coping Strategy Index (CSI), as detailed in *Table 3*.

Table 3. *Distributions of food security indicators in 2019 and 2022*

FSI indicators	Description	2019 Freq (percent)	2022 Freq (percent)
HDDS	Low (HDDS≤3)	115(23.3)	72(14.6)
	Medium (4≤HDDS≤5)	195(39.1)	205(41.1)
	High (HDDS≥6)	188(37.7)	221(44.3)
FCS	Poor (0≤FCS≤21)	27(5.6)	154(31.1)
	Borderline (21<FCS≤35)	135(27.1)	61(12.2)
	Acceptable (FCS>35)	336(67.3)	283(56.7)
MAHFP	Low (0≤MAHFP≤3)	22(4.6)	93(18.8)
	Medium (4≤MAHFP≤6)	45(9)	84(16.8)
	High (7≤MAHFP≤9)	110(22)	122(22.1)
	Very high (10≤MAHFP≤12)	321(64.3)	199(39.9)
HFIAS	Food-secure (HFIAS=1)	328(65.9)	218(43.9)
	Mildly food-insecure (HFIAS=2)	116(23.2)	123(24.6)
	Moderately food-insecure (HFIAS=3)	32(6.4)	54(10.8)
	Severely food-insecure (HFIAS=4)	22(4.4)	103(20.6)
CSI	Food-secure (0≤CSI≤2)	325(65.3)	123(24.6)
	Mildly food-insecure (3≤CSI≤12)	164(32.9)	176(35.5)
	Severely food-insecure (CSI≥13)	9(1.8)	199(40)
FSI	Food-insecure (FSI=0)	137(27.5)	168(33.7)
	Vulnerable to food-security (1≤FSI≤4)	202(40.6)	271(54.5)
	Food-secure (FSI=5)	159(31.9)	59(11.8)

Note: Percentage is provided in parentheses. Source: Author's field survey 2022

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The HDDS was determined based on FANTA guidelines (Swindale and Bilinsky, 2006a,b), with household food consumption data collected using a 24-hour recall method. Household dietary diversity was assessed by enumerators who inquired about foods consumed in the previous day, assigning a score of 1 for each food item and 0 otherwise. Household dietary diversity scores were classified as poor (<3), medium (4–5), or high (6+) based on existing criteria (Swindale and Bilinsky, 2006a,b), with an observed increase in HDDS among households during the COVID-19 period. Notably, households shifted towards consuming cheaper foods such as vegetables to reduce food costs.

The FCS was calculated in accordance with WFP and Vulnerability Analysis and Mapping (VAM) guidelines (2008), considering food consumption patterns and frequencies over the previous week. FCS scores were categorized as poor (0–21), borderline (21–35), or acceptable (>35) based on international thresholds (WFP and VAM, 2008), with a decrease observed in the proportion of households with acceptable FCS in 2022 compared to 2019.

MAHFP was determined following FANTA guidelines (Bilinsky and Swindale, 2010), with enumerators assessing household experiences of food shortages over the past 12 months. The resulting MAHFP scores categorized household food security as low (0-3), moderate (4–6), high (7–9), or very high (10–12) (Bilinsky and Swindale, 2010), revealing a decrease in households categorized as having very high food security from 2019 to 2022.

Similarly, HFIAS, as per FANTA guidelines (Coates et al., 2007), assessed household food insecurity based on nine questions related to food supply, quality, nutrient intake, and health information. Responses were coded to categorize households as food secure (1), mildly food insecure (2), moderately food insecure (3), or severely food insecure (4) (Coates et al., 2007), with a notable decrease observed in the proportion of food-secure households in 2022 compared to 2019.

Lastly, the Coping Strategy Index (CSI) was employed, following established estimation processes (Maxwell, 1996; Maxwell and Caldwell, 2008). CSI scores classified households as food secure (0–2), slightly food secure (12–13), or food insecure (>13) (Maxwell and Caldwell, 2008), revealing a decrease in the proportion of food-secure households in 2022 compared to 2019.

To establish the robustness of the food security index, the composite Food Security Index (FSI) was constructed based on all five indicators (HDDS, FCS, MAHFP, HFIAS, and CSI), following established thresholds (Mutea et al., 2019). Household categorization was determined such that failure to meet at least one indicator indicated vulnerable food security, while failure to meet all indicators indicated food insecurity. Notably, our findings indicated that only 11.8% of north-western Bangladeshi farm households met all five indicators and achieved food security in 2022. Conversely, 33.7% of households failed to meet any of the composite FSI indicators, signifying food insecurity—an increase from 27.5% in 2019.

The presentation of correlations between the food security indicators and the composite Food Security Index in *Table 4* serves to underscore the consistency and reliability of the index. While it may not be surprising that strong positive correlations exist, given the non-independence of these indicators, this analysis provides empirical support for the coherence of the FSI. Spearman's correlation was employed, considering the ordinal nature of the data and the requirement for monotonic relationships between food security indicators. The statistically significant results at the 1% level suggest a

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robust association between the FSI and individual food security indicators, reaffirming the reliability of the composite index.

Table 4. *Spearman's Correlation between Composite FSI and FSI Indicators*

2019	HDDS	FCS	MAHFP	HFIAS	CSI	FSI
HDDS	1.000					
FCS	.577**	1.000				
MAHFP	.574**	.897**	1.000			
HFIAS	-.497**	-.872**	-.790**	1.000		
CSI	-.514**	-.886**	-.783**	.779**	1.000	
FSI	.790**	.470**	.497**	-.484**	-.497**	1.000
2022	**HDDS**	**FCS**	**MAHFP**	**HFIAS**	**CSI**	**FSI**
HDDS	1.000	.490**	.507**	-.489**	-.489**	.385**
FCS		1.000	.863**	-.843**	-.809**	.309**
MAHFP			1.000	-.770**	-.758**	.400**
HFIAS				1.000	.704**	-.378**
CSI					1.000	-.511**
FSI						1.000

** Correlation is significant at the 0.01 level (2-tailed)

Table 5 illustrates the changes in food security indicators and the Food Security Index (FSI) amidst COVID-19 within the study area. Employing a paired sample T-test for both the FSI and all five indicators, we observed negative and statistically significant impacts on food security, as evidenced by the mean differences between 2022 and 2019. Analysis of the changes in the FSI revealed that food security deteriorated for 42.17% of surveyed households in north-western Bangladesh, while remaining unchanged for 51.4% of households.

Table 5. *Changes in food security indices during COVID-19 and the paired sample T test*

Composite FSI	2019 Mean (SD)	2022 Mean (SD)	Mean Difference	SD	P value
HDDS	5.46(2.04)	5.1(2.02)	-0.35 ***	1.7	<0.001
FCS	49.67(20.04)	43.55(22.47)	-6.12 ***	11.23	<0.001
MAHFP	9.76(2.71)	8.14(3.53)	-1.62 ***	2.07	<0.001
HFIAS	1.49(0.8)	2.08(1.17)	0.59 ***	0.89	<0.001
CSI	3.49(4.28)	10.66(9.77)	7.17 ***	7.75	<0.001
FSI	3(2.05)	2.09(1.84)	-0.91 ***	1.31	<0.001
Changes of FSI			**Frequency**	**Percent**	
FSI increased			32	6.43	
FSI decreased			210	42.17	
FSI nonchanged			256	51.4	

Note: 1. The standard deviations (SD) are provided in parentheses. 2. Levels of statistical significance: *** 1%, ** 5%, * 10%. Source: Author's field survey 2022

Determinants of Change in FSI

To explore the factors associated with changes in the FSI, a multinomial logistic regression model was utilized, with the non-change FSI group serving as the baseline. The model exhibited a significant likelihood ratio, with a chi-square value of 63.11 and a

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p-value < 0.001, indicating a robust fit for the data. The empirical findings are summarized in *Table 6*.

Table 6. *Determinants of changes in FSI using a multinomial logistic model*

Change in FSI	**Increased (Y= 1)**		**Decreased (Y= -1)**	
Non-change FSI=0 as the baseline	**Coefficient (SE)**	**dy/dx (SE)**	**Coefficient (SE)**	**dy/dx (SE)**
Education of household head	-0.0235	-0.0004	-0.0344	-0.0072
	(0.0533)	(0.0029)	(0.0273)	(0.0060)
Household size	-0.3527**	-0.0193**	-0.0272	0.0031
	(0.1565)	(0.0089)	(0.0662)	(0.0146)
Dependency Ratio	0.0025	0.00007	0.0028	0.0005
	(0.0043)	(0.00023)	(0.0021)	(0.0004)
Migrated members	0.8261***	0.0400**	0.2606	0.0374
	(0.2907)	(0.0161)	(0.1716)	(0.0368)
Land Size	0.0180	0.0007	0.0102	0.0018
	(0.0541)	(0.0029)	(0.0340)	(0.0075)
Amount of credit	2.5e-06*	1.0e-07	1.3e-06	2.3e-07
	(1.3e-06)	(6.9e-08)	(1.0e-06)	(2.2e-07)
Annual income	3.3e-06**	1.5e-07**	1.1e-06	1.8e-07
	(1.3e-06)	(7.5e-08)	(8.1e-07)	(1.7e-07)
Livestock & Compliance	-3.7e-07	2.5e-08	-1.7e-06**	-3.9e-07**
	(9.4e-07)	(5.2e-08)	(7.7e-07)	(1.6e-07)
Off-farm activities	-0.7620*	-0.0315	-0.4446**	-0.0810 *
	(0.4531)	(0.0252)	(0.2152)	(0.0472)
Area	0.3790	0.0256	-0.1545	-0.0451
	(0.4085)	(0.0227)	(0.1982)	(0.0436)
Follow dietary guidelines	-0.3368	0.0026	-0.6242**	-0.1331**
	(0.5778)	(0.0322)	(0.3022)	(0.0669)
Knowledge of food elements	-0.6593	-0.0168	-0.7829***	-0.1607**
	(0.5463)	(0.0301)	(0.2983)	(0.0651)
Cons.	-1.650		0.4977	
	(1.033)		(0.4864)	
Log likelihood	-410.9974			
Number of obs.	498			
LR chi square (24)	57.04			
Prob > chi square	0.0002			
Pseudo R square	0.0649			

Note: 1. The standard errors (SE) are provided in parentheses. 2. Levels of statistical significance: *** 1%, ** 5%, * 10%. Source: Author's field survey 2022

The analysis uncovered that migrated household members and annual income are significantly and positively associated with FSI improvement. Conversely, as family size increases, the likelihood of belonging to the increased FSI group decreases. Moreover, an increase in livestock and compliance value, along with households engaged in off-farm activities, diminishes the likelihood of belonging to the decreased FSI group.

During the food crisis, farmers increasingly resorted to cultivating vegetable gardens and raising various animals for consumption, highlighting adaptive strategies amid adversity. Additionally, adherence to dietary guidelines and knowledge about food elements were identified as factors linked to a reduced probability of belonging to the decreased FSI group.

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Discussion

This study sheds light on the profound threat posed by the COVID-19 pandemic to food security among farming households in north-western Bangladesh. Our findings reveal a concerning trend, as the majority of households experienced deteriorating food security indicators during the pandemic. Notably, only a small fraction of households managed to meet all composite Food Security Index (FSI) indicators, underscoring the severity of the situation.

Comparing our results with existing literature, we find alignment with the findings of FAO (2022) and Roy et al. (2022), which similarly reported worsening food security conditions during the pandemic. However, our study contributes to this body of knowledge by providing nuanced insights into the specific factors related to food security dynamics in the context of agricultural communities in Bangladesh.

Consistent with previous research by Ali (2005), Amjath-Babu et al. (2020), and Roy et al. (2022), our study identifies credit availability, household size, and income as significant determinants of composite FSI among farming households. This reaffirms the crucial role of socioeconomic factors in shaping food security outcomes, particularly in times of crisis.

Our analysis unveils a notable shift in dietary patterns during the pandemic, with households turning to cheaper food alternatives such as vegetables to cope with declining income. While this diversification increased dietary variety, it also led to a reduction in food quality, as evidenced by the decrease in Food Consumption Score (FCS). Moreover, the increase in Months of Adequate Household Food Provisioning (MAHFP) suggests heightened food scarcity among farm households.

Both the Household Food Insecurity Access Scale (HFIAS) and Coping Strategy Index (CSI) indicate a surge in food insecurity among farm households compared to pre-pandemic levels. This underscores the urgent need for targeted interventions to address the growing food insecurity crisis in the study area and ensure the resilience of agricultural communities.

Interestingly, our findings highlight the potential of off-farm activities in mitigating food insecurity risks. While the availability of off-farm work was associated with a decreased probability of belonging to the decreased FSI group, the nature and compensation of such activities warrant further investigation. Many farmers engaged in low-paid off-farm jobs, which, while providing some financial relief, may not be sufficient to ensure adequate food intake.

However, in addition to the observed changes in food consumption patterns, it is crucial to consider the potential impact of reduced physical activity and mobility during the pandemic on nutritional changes among farm households. The COVID-19 pandemic led to widespread restrictions on movement and social distancing measures, which may have curtailed access to physical activity opportunities and outdoor spaces. Studies have demonstrated that prolonged periods of lockdown and reduced mobility can contribute to sedentary lifestyles and decreased energy expenditure (Rahman et al., 2022). Consequently, individuals may undergo changes in dietary habits and nutrient intake due to altered energy requirements.

While our study primarily focused on assessing changes in food security indicators, including the Household Dietary Diversity Score (HDDS) and Food Consumption Score (FCS), we acknowledge the potential influence of reduced physical activity on nutritional changes. The observed decline in nutrient intake among farm households during the pandemic may be partly attributed to shifts in dietary patterns in response to changes in

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lifestyle and physical activity levels. Future research could explore the interplay between physical activity, dietary behavior, and nutritional status among rural populations to provide a more nuanced understanding of the complex factors influencing food security outcomes during crises.

In conclusion, our study illuminates the multifaceted challenges faced by farming households in north-western Bangladesh amidst the COVID-19 pandemic. By identifying key associated factors and trends in food security dynamics, we aim to inform targeted interventions and policy initiatives aimed at promoting sustainable food security and resilience in agricultural communities.

Conclusions and Policy Implications

This study investigated the nuanced dynamics of food security amidst the COVID-19 pandemic among farm households in north-western Bangladesh. Employing a comprehensive approach, we meticulously crafted a Food Security Index (FSI) by integrating indicators such as HDDS, FCS, MAHFP, HFIAS, and CSI.

Our analysis unearthed significant negative impacts on food security during the pandemic, characterized by reduced consumption of key food items and worsened nutrient intake. Moreover, our multinomial logit model identified several pivotal factors associated with changes in FSI. Notably, migrated household members and higher annual income were positively linked to FSI improvement, while larger household sizes exerted a negative influence. Additionally, factors such as livestock ownership, compliance with dietary guidelines, engagement in off-farm work, and knowledge of food elements were found to mitigate the likelihood of worsened FSI outcomes.

In response to these findings, it is imperative for policymakers in developing countries to prioritize targeted interventions aimed at supporting farm households and bolstering food security. Initiatives such as "one house, one farm" projects can substantially augment farmers' income and foster microenterprises through microcredit programs. Encouraging off-farm activities and small-scale businesses can effectively diversify income sources, thus reducing vulnerability to food insecurity. Furthermore, educational campaigns disseminating information on dietary guidelines and nutrition play a crucial role in empowering farm households to make informed food choices and enhance dietary consciousness. Additionally, promoting self-consumption production through backyard vegetable gardening and livestock breeding can significantly fortify food security, especially among smallholder farmers.

Government policies should proactively prioritize support for agricultural inputs such as seeds, fertilizer, and irrigation electricity, thereby enhancing farmers' resilience in mitigating food crises. By addressing these multifaceted issues, policymakers can effectively contribute to the resilience and sustainability of food systems in the face of future challenges.

Despite the invaluable insights gleaned from this study, it is imperative to acknowledge several limitations. Firstly, due to our focus on developing a composite FSI, information was primarily gathered from women in households, potentially limiting the assessment of income status. Future research endeavors should delve deeper into income dynamics to attain a more comprehensive understanding of household economic conditions. Additionally, exploring the role of informal farming practices and their implications for food security could significantly enrich our understanding of resilience strategies in agricultural communities. Acknowledging the susceptibility of regions like

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Natore and Pabna to climatic extremes, future research should systematically assess the impact of climatic factors on food production and consumption. Moreover, investigating environmental and social factors influencing food consumption behavior could provide further nuanced insights into food security outcomes.

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