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Longitudinal Trends, Inequalities, and Progress Towards Achieving Food Security Across Bangladesh

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ABSTRACT

Food insecurity remains a persistent global challenge, particularly in Global South countries such as Bangladesh. Despite being a long-standing policy priority, no study has explored the longitudinal trends and inequalities of food security across Bangladesh. Thus, this study assesses the trends and inequalities in food security across Bangladesh by analyzing the Household Income and Expenditure Surveys (HIES) from 2005, 2010, 2016, and 2022. The findings indicate that, while food security has improved by approximately 7% at the national from 2005 to 2022, the most recent data analysis reveals that nearly 39% of households were food insecure in 2022. In addition, inequality in food security is evident across Bangladesh. Nationally, rural areas exhibited higher food security (62%) compared to urban areas (59%). Regionally, Khulna and Rajshahi divisions recorded highest food security (around 69%), while Barishal division has the lowest (48.78%). At the agroecological level, the Ganges River Floodplain showed the highest food security (69.35%), while the Hill agroecological zone and the Southwest Coastal and Tidal Ecosystem had the lowest (55%). Socioeconomic disparities were also evident: Households headed by women (66.37%), as well as those that were smaller (70%) and had upper level incomes (63.77%), demonstrated higher food security levels. Conversely, households with access to microcredit (59.47%) and social safety net programs (58.21%) had lower food security levels. Addressing these inequalities can enable policymakers to design effective policies aimed at achieving the zero-hunger goal (SDG 2) and moving beyond SDGs.

1 | Introduction

Food security has been recognized as a fundamental human right since 1948, as articulated in the United Nations (UN) Universal Declaration of Human Rights (UN 2015a). The Food and Agriculture Organization (FAO) defines food security as a state in which "all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO 1996; Das et al. 2020). Over the past decades, numerous global initiatives, including the World Food Summit (WFS) of 1996, the Millennium Development Goals (MDGs) of 2000, and the Sustainable Development Goals (SDGs) of 2015, have sought to ensure food security (Mutea et al. 2022). Among these, SDG 2 specifically aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture by 2030 (UN 2015b). While these global efforts have led to positive trends in food security, substantial challenges remain (Britwum and Demont 2022; Mutea et al. 2025). For instance, in 2022, an estimated 2.4 billion people (29.6% of the global population) experienced moderate or severe food insecurity, with 900 million (11.3%) of them facing severe food insecurity (FAO 2023; Militao et al. 2023).

Food security is mainly challenged by extreme weather events, economic shocks, and poverty (FSIN 2022; IFPRI 2022). These challenges have been exacerbated by the COVID-19 pandemic,

ongoing conflicts (e.g., the war in Ukraine), and growing inequalities (FAO 2023; Lin et al. 2023). Among these drivers, the role of inequality in food insecurity is critical (FAO 2023). Nobel laureate Amartya Sen argued that inequality extends beyond differences in average living standards, reflecting the ethics of social arrangements (Sen 1992). Osberg (2001) further defined inequality as the variation in individuals' access to and control over social and economic resources. Addressing inequality has long been a global priority. The Rome Declaration of the WFS emphasized addressing inequalities by committing to policies aimed at eradicating poverty and improving physical and economic access to safe, sufficient, and nutritious food for all (FAO 1996, 8, Commitment 2). Similarly, SDG 10 (reducing inequalities) pledges to address inequalities while leaving no one behind (UN 2015b). Food security is deeply linked to inequalities (Nicholson et al. 2021) and significantly affected by social and economic inequalities (Wesselbaum et al. 2023). Although global food production is sufficient to meet demand, notable inequalities persist in food consumption across and within nations (Otero et al. 2015; Maxim et al. 2022). Addressing these inequalities is critical for achieving sustainable and equitable food security.

Ensuring food security remains a particular challenge in developing countries (Slimane et al. 2016). Asia, despite being a major contributor to global agricultural output, accounts for nearly half of the global moderately or severely food insecure population (1.14 billion), and more than half of the severely food insecure population (489 million) (Khan and Ali 2023; Oluwole et al. 2023). Within Asia, Southern Asia is the most affected region, with 809 million people facing moderate or severe food insecurity; 389 million of them are in the severe category (FAO 2023). In South Asia, Bangladesh has made commendable progress in achieving the MDG target of halving the number of undernourished people (Rahman 2017); nevertheless, it faces substantial food security challenges (Rahman et al. 2019). One in every four households faces food insecurity (Rocky et al. 2016) in this densely populated country (1119 people/km^2) of 170 million people living in 147,570 km^2 of land area (BBS 2021). The State of Food Security and Nutrition in the World 2023 report revealed that in 2022, approximately 52.70 million (31%) Bangladeshis faced moderate or severe food insecurity, while 18.7 million of them (11%) experienced severe food insecurity (FAO 2023). That same year, Bangladesh ranked 80th out of 113 nations in the Global Food Security Index (Economist Impact 2022) and 84th out of 121 nations in the Global Hunger Index (Concern Worldwide 2022).

Food security has been a major policy priority in Bangladesh since its independence in 1971. However, existing studies have predominantly examined food security trends through the lens of agricultural production, particularly rice production, without actually measuring food security (Karmokar and Imon 2008; Karim et al. 2012; Shahe and Islam 2013; Amin et al. 2014; Sarker et al. 2014; Mainuddin and Kirby 2015; Rahman 2017). Additionally, agroecology-based studies are very rare; in fact, no study has used the latest available data to explore food security (Hossain et al. 2024). Exploring spatial and temporal trends in food security can provide valuable insights into its heterogeneity and disparities across the country and over time (Lv et al. 2022). Understanding both the spatial and temporal dimensions of food security is crucial for evidence-based policy planning (Alemu 2010), considering the scientific and policy imperatives tied to agroecology and the geographical context (Kerr et al. 2021). For example, Maxim et al. (2022) identified higher food insecurity in Bangladesh's peripheral regions—specifically in the north, northwest, and southeast—compared to the central parts. They suggested targeted policy interventions, such as employment generation programs, to enhance food security in these vulnerable regions. However, they examined spatial differences in diet quality across regions using cross-sectional data, without directly measuring food security or considering temporal shifts. In addition, despite the major challenge inequality poses in achieving food security (FAO 2023), it has largely remained unexplored in food security studies in Bangladesh (Hossain et al. 2024). Considering these gaps, this study assesses the spatial and temporal trends and inequalities in food security across Bangladesh and discusses policy measures to facilitate achieving SDG 2. The latest available HIES 2022 data, along with HIES 2005, 2010, and 2016 data, from the Bangladesh Bureau of Statistics (BBS), are used for the analysis.

The rest of the paper is structured as follows. In the methodology section, we explain the HIES 2005, 2010, 2016, and 2022 datasets; define key variables; describe the data analysis method; and establish a clear indicator to measure food security. In the results section, we analyze food security across geographical, agroecological, and socioeconomic characteristics. Finally, we discuss the observed trends and inequalities in food security before concluding with actionable policy implications for achieving SDG 2 in Bangladesh.

2 | Methodology

2.1 | Overview of the Datasets

This study utilized BBS's HIES data. Since its inception in 1971, the BBS has conducted 17 rounds of household surveys at 5-year intervals (BBS 2021). The HIES serves as a comprehensive source of socioeconomic data at both individual and household levels (Hasan and Mozumder 2017). As a nationally and divisionally representative survey (Szabo et al. 2022), the HIES remains the primary source of information on Bangladeshi households (Romano and Traverso 2020). These survey datasets include a wide range of socioeconomic data, including age, gender, education, and income of household members, along with family size, landholding, remittances, access to microcredit, and social safety net programs across Bangladesh.

The HIES employs a standard two-stage stratified random sampling design, covering all eight administrative divisions and 64 districts (Hossain et al. 2020). Using an integrated multipurpose sampling framework, the BBS first selects primary sampling units (PSU) and then randomly samples households within each PSU (Hossain et al. 2016). This study analyzed household food security using data from four survey rounds: 2005, 2010, 2016, and 2022. The number of surveyed households in these years totaled 10,080, 12,240, 46,080, and 14,400, respectively. Owing to missing values related to calorie consumption, 8, 4, 270, and 405 observations from the

respective years were excluded from the analysis. The analysis was limited to the 2005 and 2022 datasets, as these surveys were consistent in their methodology and included comparable indicators, ensuring a robust analysis.

The BBS collects daily and weekly food consumption data through interviews conducted over 14 consecutive days. The daily consumption modules of HIES 2005 and 2010 included data on the quantity, value, and origin of 126 different food items from 15 categories: foodgrains, pulses, fish, eggs, meat, vegetables, milk and dairy, sweetmeat, oil and fats, fruits, drinks, sugar and molasses, miscellaneous food, dining out, tobacco, and tobacco products. Conversely, the daily consumption module of HIES 2016 included data on 130 food items from the same 15 categories. In 2022, the daily consumption module was expanded to include 220 food items distributed across 30 categories. Among these, the foodgrain category remained dominant, encompassing all types of rice, wheat, flour, vermicelli, bread, biscuits, and cakes (BBS 2016). The weekly consumption modules of HIES 2005, 2010, and 2016 covered 19 food items across two categories: spices and betel leaf-chew goods. By contrast, HIES 2022 expanded this coverage to 45 food items within nine food categories. To estimate the per capita calorie intake, the quantity (in grams) of food items consumed by the households was converted into energy consumption (kcal) using the BBS food energy conversion tables. The calculated average per capita calorie intake per day was 2241.38, 2357.19, 2209.81, and 2437 kcal in 2005, 2010, 2016, and 2022, respectively.

2.2 | Outcome and Explanatory Variables

Following the International Food Policy Research Institute (IFPRI) approach (Smith and Subandoro 2007), household-level food security was used as the outcome variable to examine spatial and temporal trends, as well as inequalities in food security. To emphasize inequalities and obstacles to food entitlement, daily per capita calorie intake was employed to measure the access dimension of household food security (Nicholson et al. 2021). Recent reviews have confirmed that access to food remains the most significant dimension (Oluwole et al. 2023). Likewise, in Bangladesh, access is one of the persistent and unresolved challenges that threaten food security (Roy et al. 2019; Panezai et al. 2022). To calculate household food security, the IFPRI classifies a household as food secure if its daily total reported energy intake exceeds the calorie requirements. For Bangladesh, the per capita daily calorie requirement is set at 2122 kcal/day (Hossain et al. 2020; Szabo et al. 2022). Therefore, a household is considered food secure if its daily per capita calorie intake surpasses this threshold. Per capita daily energy (calorie) intake is calculated by dividing the household's total daily food energy availability by the number of household members.

This study incorporates a range of socioeconomic variables (e.g., age, gender, education, and income of household head, family size, landholding, remittance, and access to microcredit and social safety nets) as explanatory variables to examine the trends and inequalities in household food security across regions over time. These variables are considered essential for explaining the outcome variable's response (Islam et al. 2022). To facilitate analysis, some variables were categorized into groups. For income, the HIES datasets were divided into three quantiles: the upper quantile was labeled as the "upper-income group," the middle quantile as the "middle-income group," and the lower quantile as the "lower-income group." Furthermore, based on education level, household heads were classified into five categories, including no education, primary (class 1–5), secondary (class 6–10), college (class 11–12), and higher (beyond class 12) education groups. Food categories were also reorganized into five major food groups: food group 1 (cereals), food group 2 (fish, meat, egg, and milk), food group 3 (vegetables), food group 4 (fruits), and food group 5 (pulses). Household heads were grouped by age: Those below 35 years of age were classified as young-aged, those between 36 and 50 years as middle-aged, and those above 50 years as old-aged. Similarly, families were categorized into three groups: families with fewer than four members were classified as small, those with between four and seven as medium, and those with more than seven as large. Households were also grouped by landholdings as landless (less than 0.049 acres), marginal landholders (between 0.049 and 0.49 acres), smallholders (between 0.49 and 2.47 acres), medium landholders (between 2.47 and 7.41 acres), and large landholders (more than 7.41 acres). A detailed list of the socioeconomic variables used in this analysis is attached as Supporting Information S1.

2.3 | Data Analysis

This study analyzed the HIES 2005, 2010, 2016, and 2022 datasets using descriptive statistics and following a quantitative approach. Each HIES dataset includes several data files. For instance, HIES 2022 contains separate data files of household basic information (e.g., household size, members' ages, gender, and occupation), household education, household income, expenditure, and food consumption. We first generated a unique household identification number (HHID) by combining two values (e.g., household number and primary sampling unit) in every data file; then, using the HHIDs, we combined these files into one dataset (e.g., HIES 2022) by merging (e.g., one-to-one). Subsequently, we extracted the necessary information (e.g., household head's age, household income, and household calorie consumption) from each dataset (e.g., HIES 2022) and compared it with the same information in the other datasets (e.g., HIES 2005, 2010, and 2016) to determine food security trends. Using a similar process, we investigated inequalities across Bangladesh's eight administrative (Dhaka, Chattogram, Rajshahi, Khulna, Sylhet, Barisal, Rangpur, and Mymensingh) and eight agroecological regions over time. As Rangpur was declared a division in 2010 (it was previously part of the Rajshahi division), its data were not available in HIES 2005. Similarly, Mymensingh was part of the Dhaka division until it was separated in 2015; thus, the relevant data became available only after 2016.

Based on cropping patterns, soil types, seasons, physiography, hydrology, and tidal activity, the country is divided into 30 agroecological zones (AEZs) (Rahaman et al. 2019) (Figure 1). These 30 AEZs are combined into 12 agroecological regions by assessing crop production (Quddus 2009). The 12 regions are then grouped into eight agroecological regions to maintain similarity with the eight administrative divisions. The list of

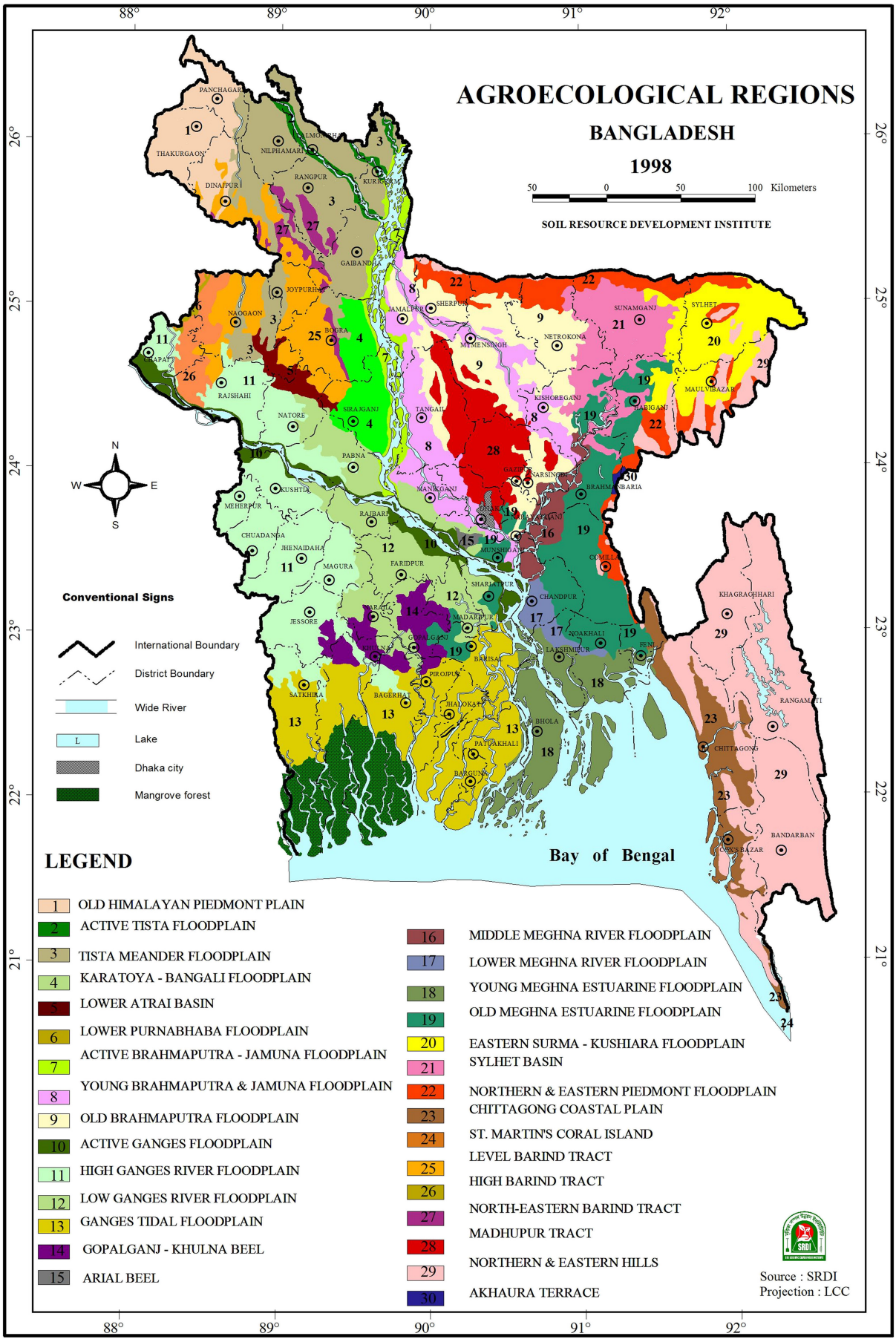

FIGURE 1 | Map of Bangladesh showing administrative areas and 30 agroecological zones (*Source:* SRDI 2024).

administrative regions and rearranged agroecological regions, including districts, is provided in Supporting Information S2 and S3.

All data were analyzed using the statistical software package Stata version 17 and Microsoft Excel. For the graphical presentation, RStudio was also used.

2.4 | Study Limitations

This study's limitations should be considered when interpreting its findings. First, the HIES datasets used in the study are representative only at the national and division levels (Hossain et al. 2016). Therefore, we could only examine food security trends at the division level and were unable to analyze trends at the district and sub-district levels. Examining the trends at more refined levels can provide a more comprehensive understanding of local-level inequalities in food security across the country. Second, the study faced challenges related to the unavailability of long-term regular data for temporal trend analysis. Tracking trends over time is inherently difficult without access to time-series data (Mustafa et al. 2023). As HIES data are collected every 5 years, establishing and constructing yearly time series datasets can provide a more accurate depiction of food security trends. Third, the calorie-based (IFPRI) approach used to measure food security in this study (e.g., daily per capita calorie intake) has some limitations. Although considered a standard indicator for measuring household-level access to food (Hoddinott and Yohannes 2002), it does not capture other critical aspects of food security, such as food quality, vulnerability, temporal shifts, and individual food security (Maxwell et al. 2013; Smith and Subandoro 2007). However, the IFPRI approach also has some significant advantages. It is a direct and systematic method for measuring household food security (Huang et al. 2015) and relies on household expenditure survey data that are scientifically collected, nationally representative, and directly derived from surveyed households (Smith et al. 2006). Moreover, the calorie-based approach is a reliable indicator for monitoring a country's food security status (Smith and Subandoro 2007). Despite these limitations, this study successfully utilized the calorie-based indicator and obtained meaningful results, contributing valuable insights into food security trends and inequalities in Bangladesh.

3 | Results

3.1 | National and Regional Trends in Food Security

Table 1 and Figures 2, 3, and 4 describe the spatial and temporal trends in food security across Bangladesh from 2005 to 2022. Over this period, food security improved at the national level and across all eight administrative divisions, despite a temporary decline in 2016. Nationally, the number of food secure households increased by 6.89%, rising from 53.46% in 2005 to 60.35% in 2022. Similarly, all eight regions demonstrated improvements in food security, with increases ranging from 1.53% to 17.65%. Among the regions, Dhaka experienced the slightest improvement (1.53%), while Rajshahi recorded the most substantial gain (17.65%). At the national level, throughout the study period, rural households consistently exhibited higher levels of food security compared to urban households. At the regional level, five divisions—Barisal, Khulna, Mymensingh, Rajshahi, and Rangpur—mirrored this rural advantage. However, three divisions—Chattogram, Dhaka, and Sylhet—displayed mixed trends. In Dhaka, rural households were less food secure in 2010 and 2016, while lower rural food security was observed in Chattogram in 2010 and 2022. Rural households in Sylhet consistently reported lower food security, with rates declining between 9% and 14% across all survey periods. In 2022, Barisal emerged as the least

TABLE 1 | Trends of household food security at national and division (urban and rural) level.

Geographic location	Level	Food security status (%)			
		2005	2010	2016	2022
National	Average	53.46	58.55	49.3	60.35
	Urban	49.26	56.07	45.78	59.07
	Rural	56.26	60.26	50.83	61.62
Divisions					
1. Barisal	Average	41.95	54.08	37.22	48.78
	Urban	37.5	48.12	36.2	43.44
	Rural	44.26	56.97	37.56	54.11
2. Chattogram	Average	52.9	59.59	44.95	56.14
	Urban	52.57	63.3	37.1	56.89
	Rural	53.11	56.83	47.19	55.39
3. Dhaka	Average	58.15	53.45	51.85	59.68
	Urban	52.45	54.19	52.32	58.13
	Rural	61.61	52.82	51.48	61.22
4. Khulna	Average	54.1	58.78	54.18	69.5
	Urban	46.5	49.03	46.85	67.78
	Rural	59.52	65.3	58.03	71.22
5. Mymensingh	Average	N/A	N/A	47.43	60.37
	Urban	N/A	N/A	47.79	64.07
	Rural	N/A	N/A	47.28	56.67
6. Rajshahi	Average	51.33	59.81	50.76	68.98
	Urban	42.27	52.06	41.1	64.63
	Rural	56.31	65.66	54.29	73.33
7. Rangpur	Average	N/A	66.25	54.18	58.11
	Urban	N/A	61.9	46.3	53
	Rural	N/A	68.37	56.67	63.22
8. Sylhet	Average	57.96	68.49	52.81	61.22
	Urban	68.64	72.04	52.97	64.67
	Rural	50.62	66.78	52.76	57.78

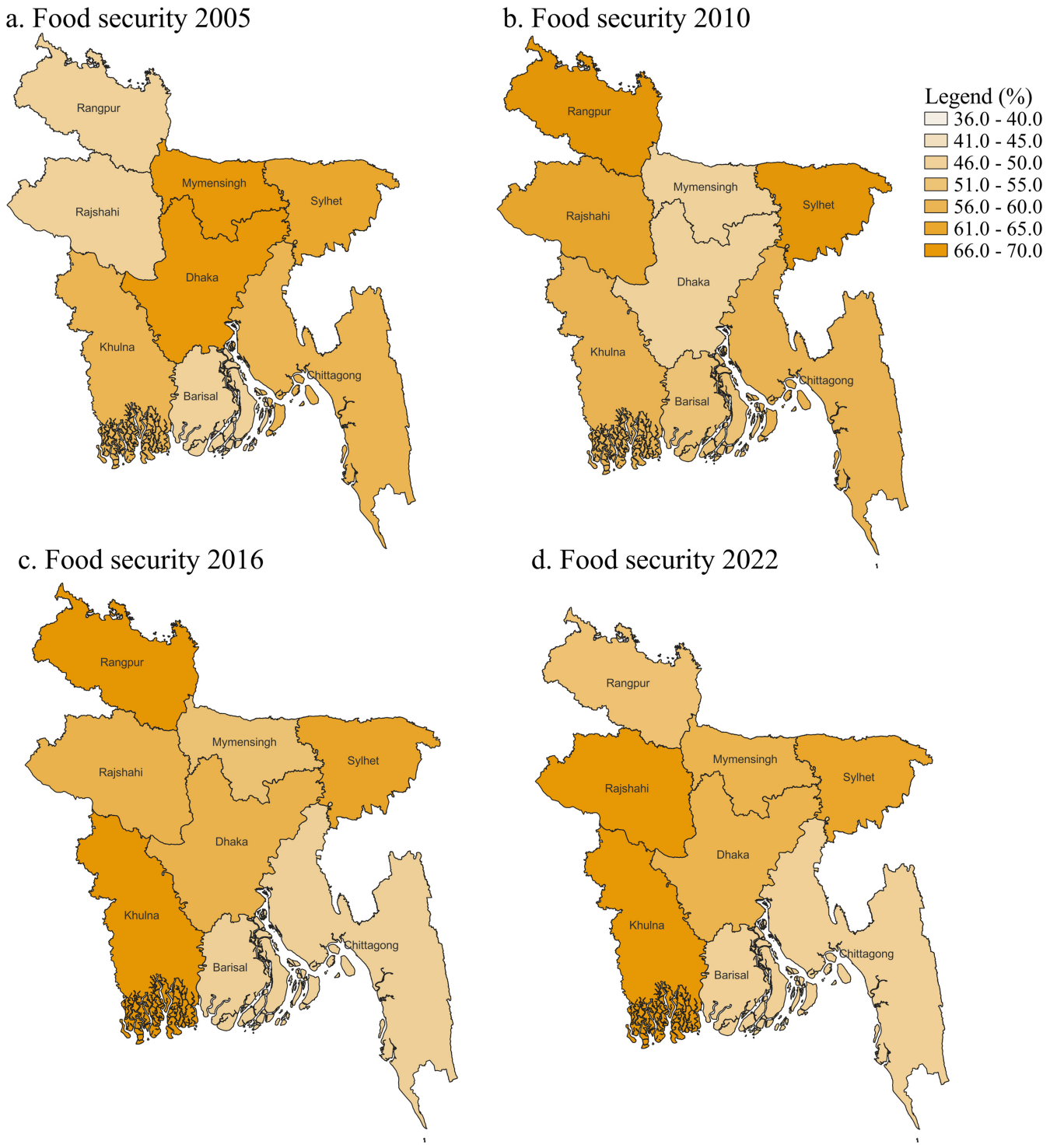

FIGURE 2 | Food security status across eight divisions in Bangladesh from 2005 to 2022. Rangpur was part of Rajshahi in 2005 and Mymensingh was part of Dhaka in both 2005 and 2010; their data are presented under the respective parent divisions for those years.

food secure (48.78%), while Khulna recorded the highest food security levels (69.50%).

3.2 | Agroecological Trends in Food Security

Table 2 and Figure 5 describe the trends in food security across agroecological regions from 2005 to 2022. During this period, household food security improved at different levels across all eight agroecological regions, excluding the Hill agroecological region. The Karatoya Floodplain and Atrai Basin (KFAB) experienced the most substantial improvement, with food security increasing by 17.66% over the period. Conversely, the Surma-Kusiyara Floodplain region exhibited the slowest progress, with an increase of only 3.2%. The Southwest Coastal and Tidal Ecosystem (SWCTE) remained the least food secure region in

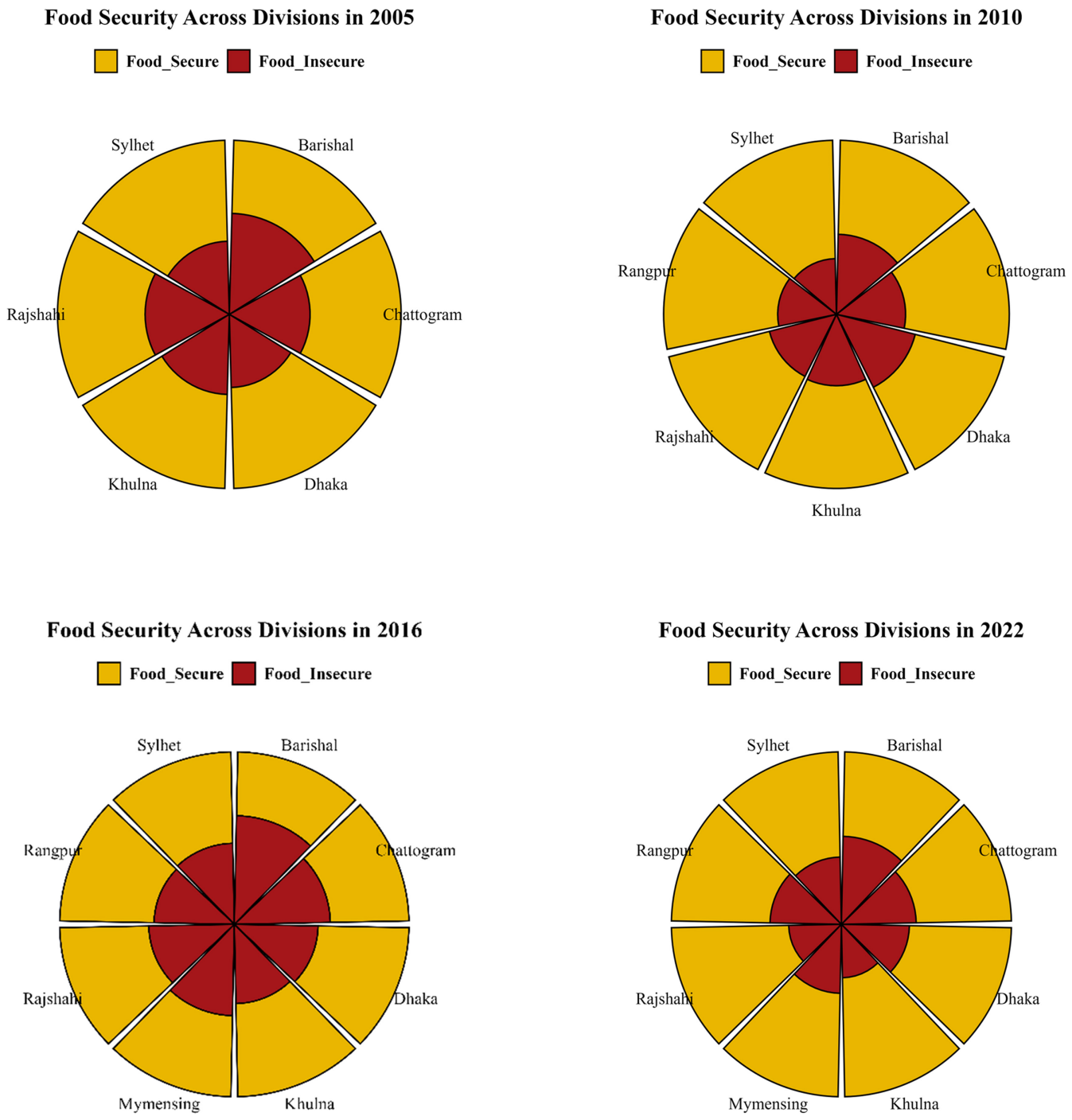

FIGURE 3 | Food security progress towards achieving SDG zero-hunger goal across divisions in Bangladesh.

2005, 2010, and 2016. In 2005, approximately 42% of households in this region were food secure, with the proportion rising to 54.92% by 2022. Conversely, the Hill agroecological region was the most food secure in both 2005 (61.66%) and 2010 (70.85%). However, it experienced a substantial decline, becoming the least food secure in 2022 (54.53%). In both 2016 and 2022, the Ganges River Floodplain (GRF) emerged as the most food secure region. Unlike other regions, the GRF's food security remained stable until 2016, with a modest increase of 3%, followed by a sharp rise of 13.44% in 2022.

3.3 | Trends in Calorie Intake From Major Food Groups

Table 3 and Figure 6 describe the national level energy consumption from major food groups such as cereals; fish, meat, egg, and milk; vegetables; fruits; and pulses. Our findings reveal that the contribution of cereals to daily calorie intake remained significantly higher than those of all other food groups in all regions across all survey years. Per capita daily calorie intake from cereals was recorded as 1611.63, 1639.14,

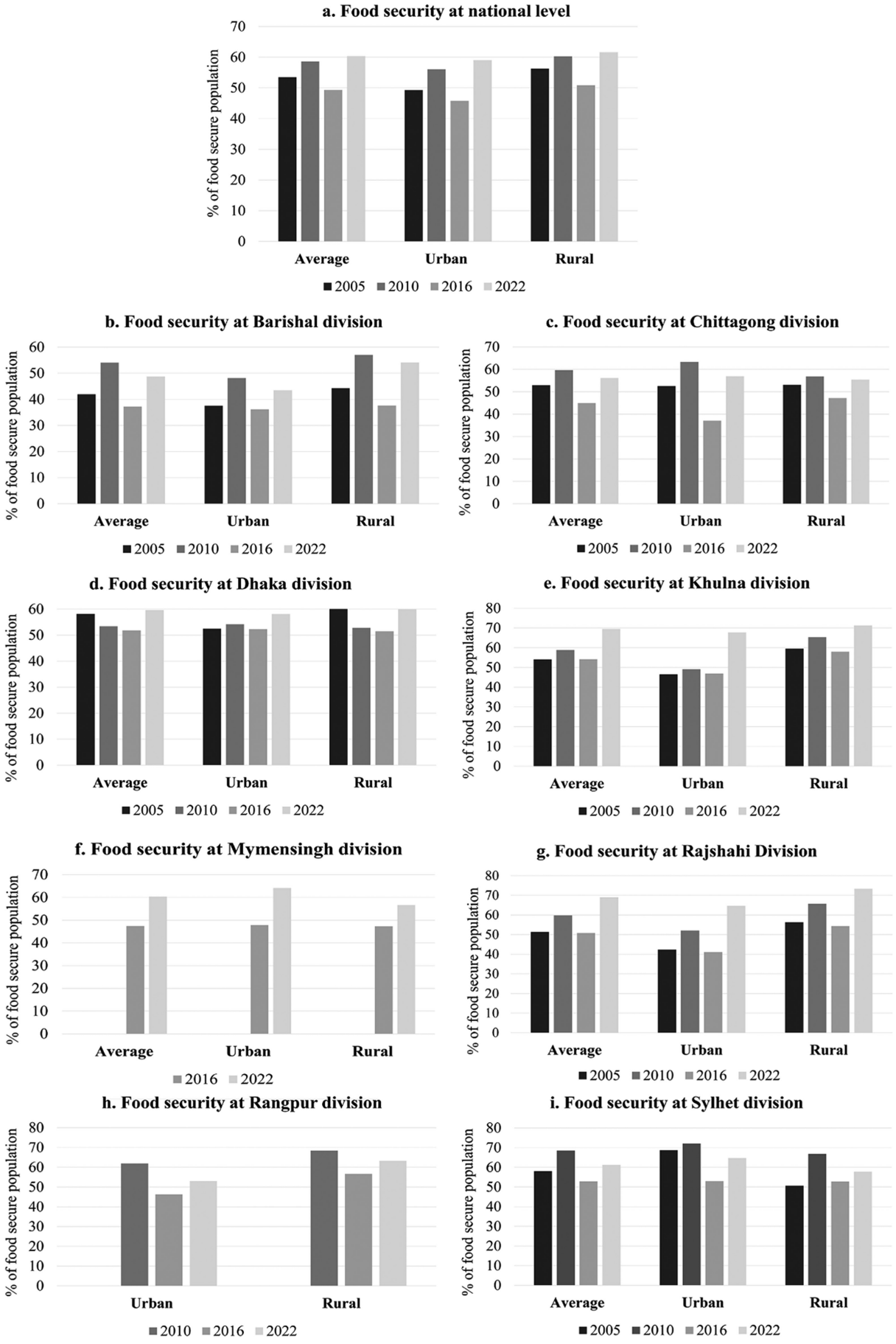

FIGURE 4 | Spatial and temporal trends of food security across Bangladesh from 2005 to 2022.

1437, and 1315.42 kcal in 2005, 2010, 2016, and 2022, respectively. While cereal consumption showed a slight increase of 27.51 kcal in 2010 compared to 2005, a substantial decline was observed in subsequent years, decreasing by 174.63 and 296 kcal in 2016 and 2022, respectively. In 2005, the caloric contribution from cereals was 1611.63 kcal, whereas other major food groups contributed considerably fewer kcal: 108.62 from eggs and milk, 157.88 from vegetables, 38.36 from fruits, and 57.34 from pulses. Despite the gradual decline in caloric intake from cereals since 2005, energy consumption from all other major food groups has shown a steady increase.

TABLE 2 | Trends of household food security at agroecological regions.

Agroecological region (AER)	2005	2010	2016	2022
AER 1: Old Himalayan Piedmont Plain and Tista Floodplain (OHPTF)	53.14	66.25	53.85	58.11
AER 2: Karatoya Floodplain and Atrai Basin (KFAB)	48.85	63.31	50.7	66.51
AER 3: Brahmaputra-Jamuna Floodplain (BJF)	56.67	52.95	47.86	60.11
AER 4: Ganges River Floodplain (GRF)	59.07	59.17	55.91	69.35
AER 5: Southwest Coastal and Tidal Ecosystem (SWCTE)	41.88	51.04	40.16	54.92
AER 6: Surma-Kusiyara Floodplain (SKF)	57.96	68.26	52.65	61.22
AER 7: Middle and lower Meghna River Floodplain (MLMRF)	45.82	49.83	44.46	57.61
AER 8: Hill Agroecological Region (HAR)	61.66	70.85	44.78	54.53

3.4 | Social Inequalities in Food Security

Table 4 and Figure 7 describe household food security across Bangladesh based on social characteristics. From 2005 to 2022, household food security improved across household heads' gender, age, education, marital status, and family size, with increases ranging from 1.98% to 14%. However, exceptions were observed at certain sub-category levels, particularly among medium and large families. As with the national and regional trends, food security across all these categories experienced a decline in 2016 compared to 2010. At the national level, food security among female-headed households increased by 9.54%, while male-headed households witnessed an increase of 6.46%. Female-headed households consistently demonstrated higher food security than male-headed households across the national, urban, and rural levels, except 2010 in rural areas.

Food security also improved across all household heads' age groups (young, middle, and old) by 1.98%–8.83% between 2005 and 2022, despite a temporary decline in 2016. Among all these groups, households headed by older individuals remained the least food secure throughout the survey period.

Households headed by literate individuals (those who can read and write) consistently demonstrated higher food security

TABLE 3 | Food security trends based on calorie intake.

Food group	2005	2010	2016	2022
Cereals (Food group 1)	1611.63	1639.14	1437	1315.42
Fish, meat, egg, milk (Food group 2)	108.62	121.40	128.47	150.45
Vegetables (Food group 3)	157.88	168.18	162	170
Fruits (Food group 4)	38.36	45.33	39.48	48.46
Pulses (Food group 5)	57.34	58.34	58.73	63.90

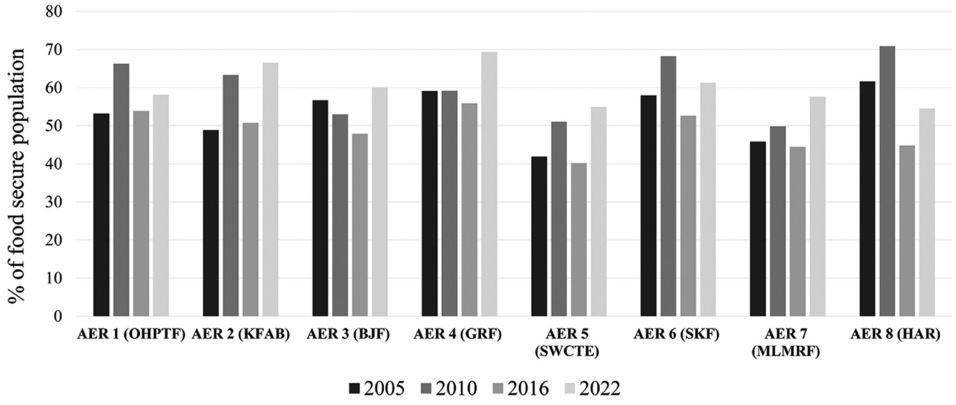

FIGURE 5 | Food security trends across eight agroecological regions from 2005 to 2022.

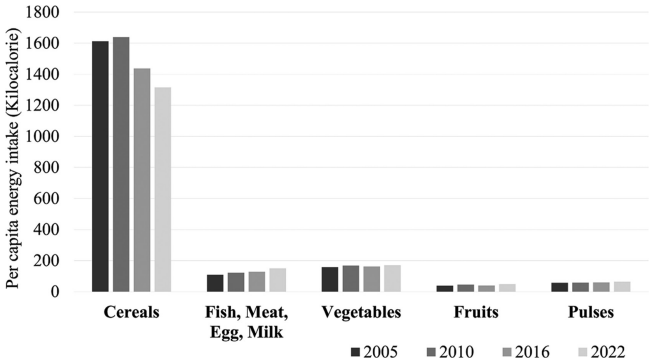

FIGURE 6 | Trends of food energy consumptions from major food groups.

levels in 2005 (56.33%), 2010 (59.81%), and 2016 (48.43%). However, in 2022, households headed by individuals with no education became the most food secure (60.97%) with a marginal difference (< 1%). Between 2005 and 2022, household food security improved by 3.09% to 10.91% across most education groups. By contrast, during the same period, households headed by college-educated heads experienced a 1.1% decline, despite being the most food secure in 2005 (59.18%) and 2010 (68.28%). By 2022, households headed by highly educated individuals emerged as the most food secure. Interestingly, in 2016, households headed by individuals with no education became the most food secure (51.52%) despite being the least food secure in 2005 (49.80%) and 2010 (47.30%). From 2005 to 2022, household food security improved across households headed by married, unmarried, widowed, and separated individuals, with increases ranging from 2.12% to 13.97%. However, during the same period, households headed by divorced individuals experienced a 3.71% decline. Throughout the survey years, households headed by unmarried individuals consistently demonstrated the highest levels of food security, while those headed by married individuals remained the least food secure. Furthermore, households headed by unmarried, widowed, divorced, and separated individuals consistently experienced better outcomes compared to those headed by married individuals.

From 2005 to 2022, food security among small families increased by 9.74%, while it decreased by 12.23% for large families. Specifically, food security rates for small families were 60.26% (2005), 65.36% (2010), 56.42% (2016), and 70% (2022). Conversely, food security among large families was lower at 45.17% (2005), 43.93% (2010), 28.15% (2016), and 32.94% (2022).

We found contrasting trends for food security based on mobile phone usage. Among households that used mobile phones, food security showed a declining trend, while among households that did not use mobile phones, the trend was upward, except in 2016. Specifically, over the survey years, food security declined by 1.47% for households using mobile phones but increased by 8% for those not using mobile phones. In 2005 and 2010, households using mobile phones were more food secure (61.74% and 60.73%) than nonuser households (52.34% and 54.53%). However, in 2016 and 2022, this trend reversed, with households not using mobile phones reporting higher food security (53.52% and 61.17%) than user households (48.34% and 60.27%).

3.5 | Economic Inequalities in Food Security

Table 5 and Figure 8 describe household food security status in relation to key household economic characteristics. Between 2005 and 2022, food security for households headed by income earners and households with access to microcredit, social safety net programs, remittances, and landholdings increased by 1.45%–11.26%. However, consistent with the national and regional food security trends, these households experienced a decline in 2016.

Between 2005 and 2022, food security improved for both households headed by income earners (1.45%) and those headed by non-income earners (7.22%), despite declines in 2016. While households headed by income earners demonstrated higher food security in 2005 (59.02%) and 2022 (60.47%), they became less food secure compared to non-income earners in 2010 (58.34%) and 2016 (48.85%). Food security for all three income groups (lower, middle, and upper) improved from 3.36% in 2005 to 10.57% in 2022, despite experiencing declines in 2016. The upper income group demonstrated the highest levels of food security compared to the other two groups.

Throughout the years, households with access to microcredit consistently exhibited lower levels of food security compared to those without such access, although the difference was marginal (< 2%). Between 2010 and 2022, food security improved slightly for both household groups by 1% and 2.82%, respectively, with notable declines in 2016 (10% and 8.64%). Household status in 2005 could not be assessed owing to the unavailability of microcredit data in HIES 2005.

Similar to households with access to microcredit, those with access to social safety net programs consistently exhibited lower levels of food insecurity compared to households without such access across all survey years. Between 2005 and 2022, food security for both household groups increased by 10.85% and 7.33%, respectively; however, both groups experienced declines in 2016. By contrast, households receiving remittances showed mixed results over the survey years. While in 2005 and 2022 they were less food secure compared to non-recipient households, they exhibited higher food security in 2010 and 2016.

Food security among households across all landholding categories fluctuated over the survey period. From 2005 to 2022, food secure households increased significantly among landless (11.26%) and marginal households (11%), while smallholders experienced a modest increase of 2.88%. Conversely, food secure households decreased slightly among medium landholders (1.15%) and drastically declined among large landholders (40.38%). Households with larger landholdings were the most food secure in 2005 (80.72%), 2010 (63.84%), and 2016 (58.22%). However, they became the least food secure in 2022 (40.34%), while medium landholders emerged as the most food secure (69.30%). Landless households had the lowest food security in 2005 (43.12%) and 2016 (43.53%), while small landholders were the least food secure in 2010. No marginal landholders were recorded in the HIES 2010 survey.

TABLE 4 | Inequalities in food security based on household social characteristics.

Household characteristics		Food security status (%)			
		2005	2010	2016	2022
Household head's gender					
Male	National	53.11	58.53	48.58	59.57
Female		56.83	59.07	56.35	66.37
Male	Urban	48.37	55.43	44.94	58.19
Female		54.32	60.91	53.63	66.04
Male	Rural	56.06	60.73	50.15	60.96
Female		58.10	58.02	57.53	66.67
Household head's age group					
Young age (≤35)		44.66	48.72	42.23	53.49
Middle age (>35 and ≤50)		51.98	58.19	48.24	60.14
Old age (>50)		62.84	66.59	58.21	64.82
Household head's literacy level					
Can read and write		56.33	59.81	48.43	60.07
Cannot read and write		50.85	57.42	50.92	60.97
Household head's education level					
No education (= 0)		49.8	57.3	51.52	60.71
Primary (≥1 and ≤5)		53.55	59.83	47.7	58.74
Secondary (≥6 and ≤10)		57.46	58.17	48.74	60.55
College (>1 and ≤14)		59.18	68.28	49.33	58.08
Higher education (>14)		52.3	62	50.98	61.63
Household head's marital status					
Married		52.78	58.24	48.64	59.74
Never married		69.83	76.62	64.52	71.95
Widowed		56.77	59.19	56.96	65.32
Divorced		66.67	63.16	59.49	62.96
Separated		53.45	64.38	55.38	67.42
Household family size					
Small family (≤4)		60.26	65.36	56.42	70
Medium family (>4 and ≤7)		47.61	51.33	36.51	47.53
Large family (>7)		45.17	43.97	28.15	32.94
Household head's mobile phone use					
Mobile phone user		61.74	60.73	48.34	60.27
Not mobile phone user		52.34	54.53	53.92	61.17

4 | Discussion

4.1 | Trends in Food Security Across Bangladesh

Our findings indicate that food security in Bangladesh has improved by approximately 7% since 2005, despite experiencing a decline in 2016, which may be attributed to changes in consumption behavior (BBS 2016). As cereals contribute significantly to the daily calorie intake, the declining trends in cereal consumption likely resulted in reduced calorie intake, negatively impacting food security. Factors such as low foodgrain stocks, reduced rice imports, and extreme rainfall might

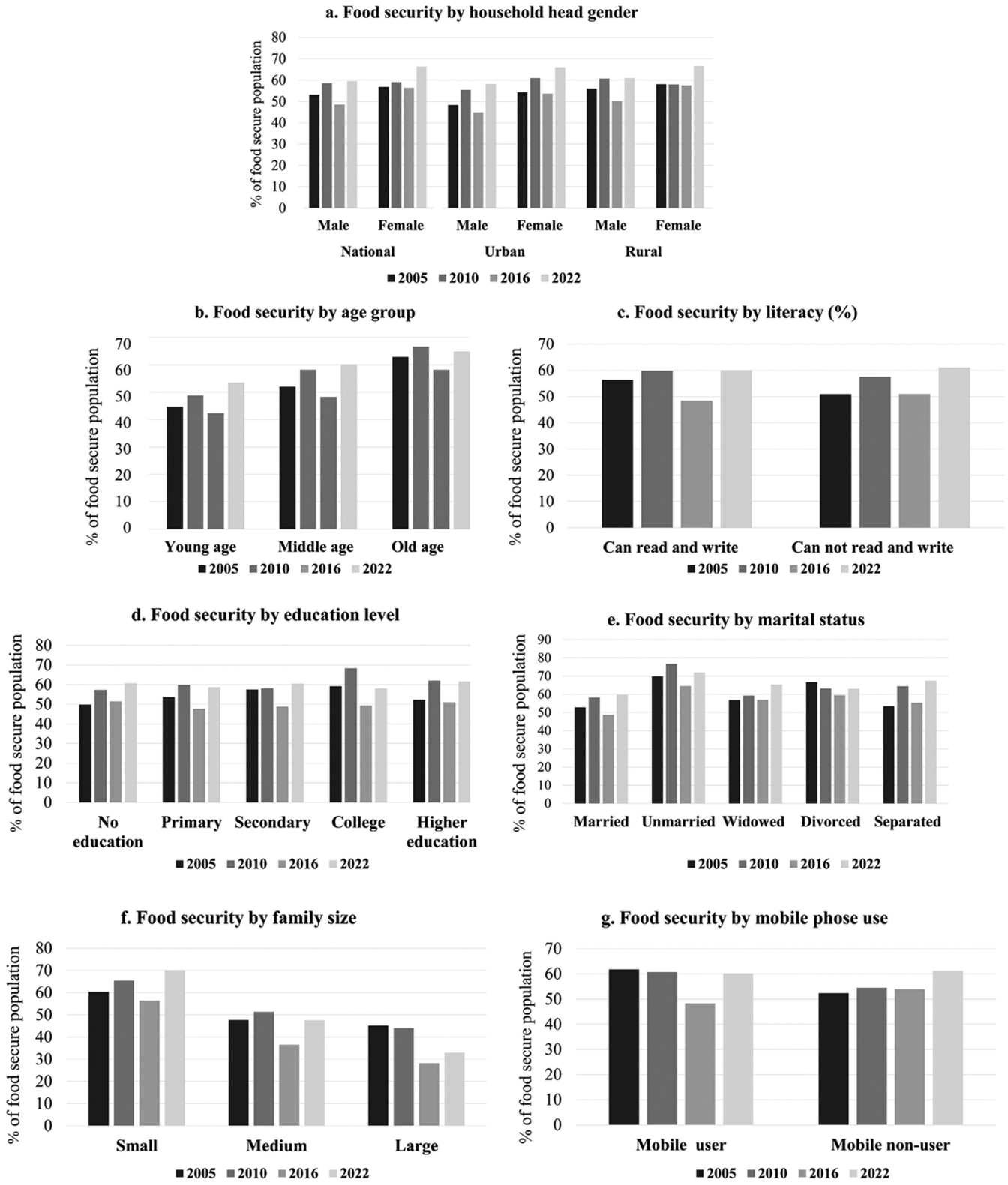

FIGURE 7 | Inequalities in food security based on household's social characteristics across Bangladesh from 2005 to 2022.

have constrained food availability during this period (Szabo et al. 2022; Ahmed 2024). These findings underscore the multifaceted nature of food security challenges, emphasizing the need for integrated strategies that address both socioeconomic vulnerabilities and environmental risks to ensure sustainable food security.

The results reveal that food security was consistently higher among rural than urban populations in all survey years. This could be due to rural households' increased access to agricultural land, which enables them to produce food for their own consumption, thereby enhancing their food security. Our finding aligns with that of Das et al. (2020), who measured food

TABLE 5 | Inequalities in food security based on household economic characteristics.

Household characteristics	2005	2010	2016	2022
Household head's earning status				
Earner	59.02	58.34	48.85	60.47
Not earner	52.63	59.84	53.16	59.85
Household head's income group				
Lower income group	48.44	53.75	51.35	59.01
Middle income group	51.61	57.07	47.52	58.5
Upper income group	60.41	64.78	48.87	63.77
Household's access to microcredit				
Having access to microcredit	NA	58.39	48.36	59.47
Without access to microcredit	NA	58.65	50.01	61.47
Household's access to social safety net				
Access to social safety net	47.36	57.88	46.64	58.21
No access to social safety net	54.38	58.68	50.53	61.71
Household's remittance receipt				
Remittance-receiving	52.15	65.99	56.83	59.35
Remittances non-receiving	55.5	57.74	49.24	60.43
Household's landholding				
Landless (< 0.049)	43.12	52.83	43.53	54.38
Marginal (≥ 0.049 and ≤ 0.49)	51.33	NA	49.26	62.36
Small holder (≥ 0.49 and ≤ 2.47)	63.33	46.52	58	66.21
Medium (> 12.47 and ≤ 7.41)	70.45	54.78	58.4	69.3
Large (> 7.41)	80.72	63.84	58.22	40.34

security using the Household Food Insecurity Access Scale (HFIAS). However, it contrasts with that of Maxim et al. (2022), who argued that rural areas are more food insecure compared to urban areas. Their study relied solely on HIES 2016 data and assessed food security based on the percentage of food expenditure rather than a calorie consumption-based indicator. These contrasting findings highlight the importance of methodological differences in measuring food security and underscore the need to conduct context-specific analyses.

At the regional level, food security improved at varying rates across all eight divisions since 2005, despite experiencing declines in 2016. In seven divisions, rural populations consistently demonstrated higher food security levels than urban populations. However, in the Sylhet division, the rural population exhibited lower food security. This disparity may be attributed to the impact of remittances, which predominantly benefit urban households in Sylhet (Islam et al. 2021). Among all divisions, Barisal emerged as the least food secure, while Khulna ranked as the most food secure. Barisal's high vulnerability to environmental challenges, including riverbank erosion, droughts, floods, cyclones, and storm surges (Akter et al. 2015), may explain its persistently low food security levels.

Our findings reveal that household food security varies significantly across agroecological zones in Bangladesh. While the Hill agroecological region was the most food secure in earlier years (2005 and 2010), it became the least food secure in 2022. This shift could be due to rising food prices, particularly in Cox's Bazar district, which experienced an 8% increase in food prices due to the influx of approximately 1 million Rohingya people who had fled from Myanmar (Alam et al. 2022; UNHCR 2022). Overall, the GRF emerged as the most food secure agroecological region, while the SWCTE region consistently recorded the lowest food security levels. The GRF is a high-production region owing to its fertile alluvial soil, deposited by the Ganges River and its tributaries. The SWCTE region's vulnerability can be attributed to its disaster-prone nature and status as one of the most salinity-affected regions worldwide (Lam et al. 2022), which significantly impairs cereal production. These findings contradict those of Rahman (2017), who reported higher (lower) food security in the KFAB (GRF) regions. However, Rahman (2017) used relatively old panel data (1948–2008), which may not fully reflect the current dynamics and challenges of food security in these regions. Our findings underscore regional disparities and highlight the persistent vulnerabilities of specific regions, emphasizing the need for region-specific policies and interventions in achieving equitable food security.

In terms of food energy intake, our results reveal a decline in per capita energy consumption from cereals, while energy consumption from other food groups, such as fish and meat, vegetables, fruits, and pulses, increased consistently over the study period. These results are similar to those of Harris-Fry et al. (2015), who observed that calorie consumption from cereals was highest in 2011, followed by consumption of fish and meat, vegetables, fruits, and pulses. This trend suggests that people in Bangladesh, likely driven by steady economic growth, are gradually becoming more conscious of maintaining a balanced and nutritious diet. Bangladesh has experienced consistent GDP growth since 2005 (Ferdousi and Dehai 2014), which might have contributed to improved purchasing power and greater dietary diversity. Similarly, Li and Shangguan (2012) found that in China, rising GDP influenced consumption behavior, which resulted in a decline in cereal consumption but an increase in consumption from other food groups. To ensure balanced and nutritious diets for the population, the National Food and Nutrition Policy 2020 needs to incorporate targeted interventions and strategic instruments that align with evolving food consumption patterns and address the nutritional needs of diverse population groups.

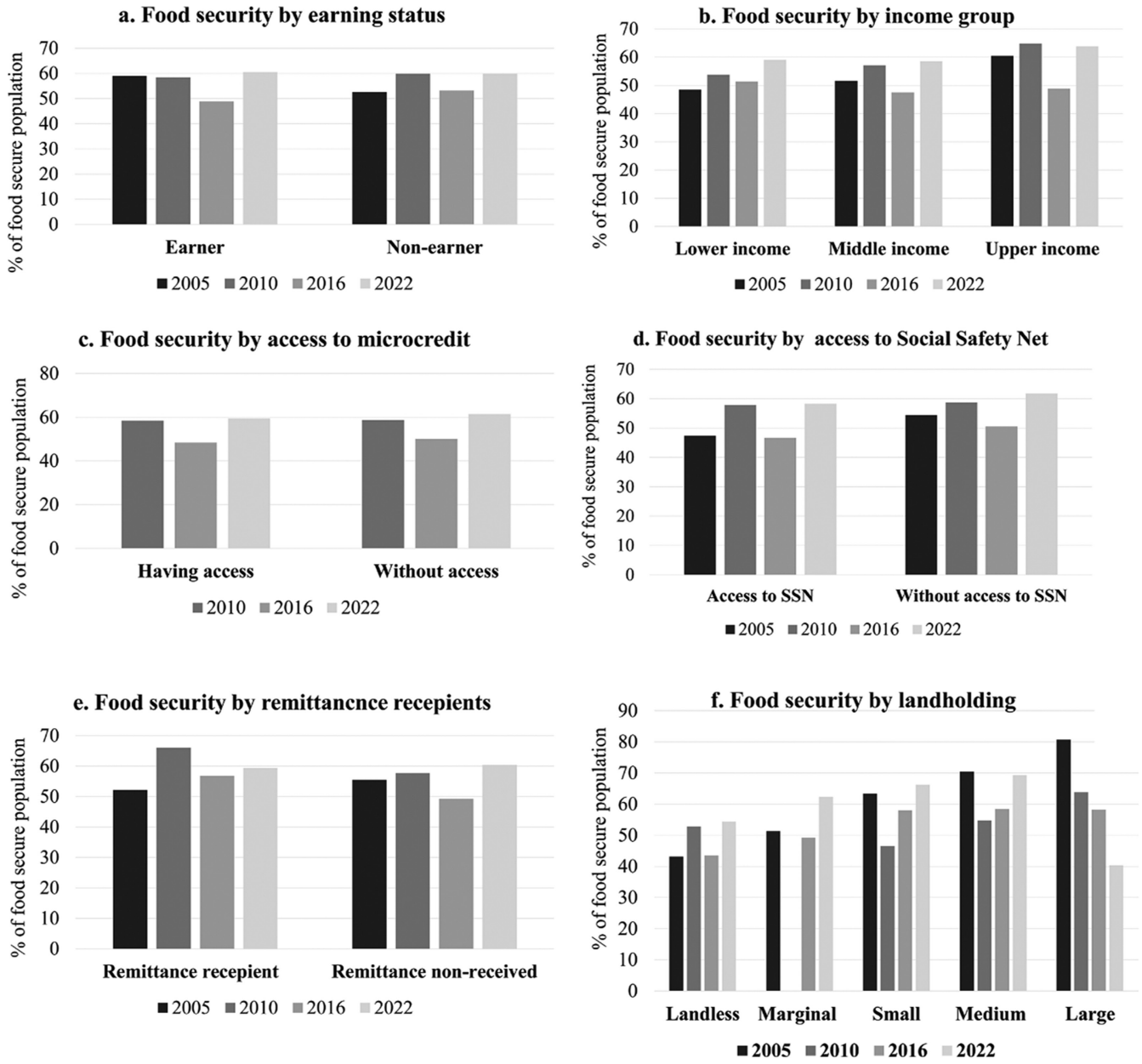

FIGURE 8 | Inequalities in food security based on the household's economic characteristics across Bangladesh from 2005 to 2022.

4.2 | Inequalities in Food Security Across Bangladesh

4.2.1 | Inequalities in Food Security Based on Household Social Characteristics

This study reveals that at the national level (both urban and rural), female-headed households were consistently more food secure than male-headed households over the survey period. These results contradict the conventional perspective that female-headed households are inherently more prone to food insecurity (Mallick and Rafi 2010). However, our results align with Quisumbing et al. (2001) findings, who used household survey data across six developing countries and reported that female-headed households were more food secure. One possible explanation for these results is that female-headed households often allocate a larger portion of their income for food, contributing to enhanced food security (Duflo and Udry 2004; Mutea et al. 2022). These findings highlight women's crucial role in improving household food security. Therefore, policymakers should prioritize initiatives aimed at women's economic participation, as such measures have a positive and sustained impact on household food security (Sraboni et al. 2014).

Furthermore, our findings reveal that households headed by older individuals consistently exhibited higher food security levels, while those headed by younger individuals remained the least food secure over the study period. Previous studies have supported these observations, indicating that the age of the household head positively impacts food security (Rahman et al. 2019). This finding suggests that food security tends to improve as the household head's age increases (Ahmad and Khonker 2010). A plausible explanation for these trends is that older household heads accumulate greater experience

and knowledge over time, enabling them to make better decisions regarding resource allocation, food procurement, and overall household food management. These findings indicate the importance of experience and maturity in enhancing resilience to food insecurity and suggest that targeted support for younger household heads could help effectively manage food resources.

Our findings indicate that in all survey years, the household head's literacy does not significantly contribute to household food security. While households headed by literate individuals were more food secure in earlier years, they became less food secure in later years. Moreover, in 2022, households headed by highly educated individuals demonstrated high levels of food security, whereas in 2016, those headed by non-educated individuals reported the highest food security levels. An explanation may be that highly educated household heads are more likely to secure better employment opportunities and income sources (Mutisya et al. 2016), enabling them to spend more on food. Conversely, non-educated individuals often rely on farming for their livelihoods, allowing them to produce food for their own household's consumption, thus improving food security. However, households headed by college-educated individuals exhibited better food security, while those with primary and secondary-educated heads demonstrated average but consistent results. Our findings suggest that education alone may not guarantee improved food security if other socioeconomic factors, such as income, employment opportunities, and family size, remain unaddressed. This conclusion diverges from those of previous studies by Ahmad and Khonker (2010) and Rahman et al. (2019), which reported a significantly positive impact of education on household food security. However, these studies relied on cross-sectional data with relatively small sample sizes and were confined to specific districts, which may limit the generalizability of their conclusions.

Households headed by unmarried individuals consistently demonstrated the highest level of food security, while those headed by married individuals remained the least food secure across all survey years. This could be because unmarried individuals have fewer dependents and better control over income, allowing them to prioritize food security. These findings contradict those of Shah et al. (2022), who reported that households headed by married individuals are more food secure. They used the Bangladesh Integrated Household Survey (2018–2019) and assessed food security using FAO's Food Insecurity Experience Scale (FIES), which may account for the variation. This result provides important insights into the dynamics of household food security across marital status groups. While it may not be prescriptive, understanding these trends could inform decisions regarding the timing of marriage and its potential impact on household food security.

A considerable disparity was observed across households of varying sizes, with smaller households consistently exhibiting higher levels of food security compared to larger households. This difference can be attributed to higher dependency ratios in larger families, which impose greater pressure on household resources and limit the ability to effectively meet food requirements (Amrullah et al. 2019). Our findings are consistent with those of previous studies conducted in Bangladesh. For example, Harris-Fry et al. (2015) conducted a cross-sectional study in rural areas and similarly reported that smaller households are more food secure. Farzana et al.'s (2017) cross-sectional survey of 23,374 households led to the same conclusion, while Kundu et al. (2021) observed a decline in food security as household size increased. This study's finding emphasizes that population management plays a critical role in ensuring food security and underscores the need to strengthen family planning initiatives in addressing this issue. Although Bangladesh has achieved remarkable progress in family planning (Alam et al. 2018), continued investment in population control is required to improve household food security.

4.2.2 | Inequalities in Food Security Based on Household Economic Characteristics

Our findings provide evidence that the income status of household heads does not appear to be a critical determinant of household food security. While households whose heads earned income were more food secure than those with non-income-earning heads in 2005 and 2010, they were less food secure in 2016 and 2022. These findings differ from those of Rahman et al. (2019), who surveyed 600 rural households and found that the household head's income status positively impacted food security. Similarly, Kundu et al. (2021), in a more recent survey of 1876 participants, found that household head income had a positive impact on food security. However, these studies were based on relatively small samples from specific areas, which limit their generalizability to the broader population. Our findings highlight the influence of other socioeconomic factors, such as household size and access to resources, indicating that further investigation is necessary to capture food security's multifaceted nature.

Looking at income groups, the results reveal that food security improved across all three categories, with the lower income group experiencing the highest rate of increase (10.57%) and the upper income group showing the lowest rate of increase (3.36%). Despite the group's slower growth rate, households in the upper income group largely remained the most food secure throughout the study period. Conversely, households in the lower income group were the least food secure in 2005 and 2010, despite becoming the most food secure in 2016. Farzana et al. (2017) found that a household's income level has a positive impact on its food security. Thus, household income seems to significantly influence food security. Higher income enables households to allocate more resources to food, thereby increasing food security. These findings signify the importance of income-generating policies for improving food security. Targeted interventions aimed at increasing household incomes, particularly for lower and middle income groups, could play a pivotal role in ensuring sustainable food security.

Consistent with Banerjee et al.'s (2015) findings, our study demonstrated that households with access to microcredit were consistently less food secure than those without access. This aligns with Islam et al. (2016), who, based on a four-round survey conducted over eight years (1997–2005), reported that microcredit access does not improve short-term food security.

These findings suggest that microcredit's benefits may require more time to manifest. We recommend that future researchers use long-term data to better understand microcredit's long-term effects on household food security. Similarly, households with access to social safety net programs were less food secure throughout the survey period. This outcome aligns with Ahmad and Khonker (2010), who conducted a primary survey in the northern part of Bangladesh. A likely explanation is that low-income households, which are the primary beneficiaries of microcredit and safety net programs, are already at higher risk of food insecurity owing to limited resources and economic constraints. These findings highlight the need to design more targeted interventions that address the underlying vulnerabilities of low-income populations, ensuring that microcredit and safety net programs effectively contribute to long-term food security.

Moniruzzaman (2022) and Romano and Traverso (2020) reported that foreign remittances enhance household food security; however, our study revealed mixed results. In 2005, we found that remittance-receiving households were less food secure than those that did not receive remittances; by 2010 and 2016, they exhibited higher food security levels than their counterparts but became comparatively less food secure again in 2022. Szabo et al. (2022) used HIES 2016 data and reported that remittance-receiving households experienced better food security than those without remittances. This variability could be attributed to how households utilize remittances; at times, it may be spent on purchasing food, thereby directly improving food security, and on other occasions, it may be used for investment in land or business ventures, not immediately contributing to food security (Szabo et al. 2022). These findings indicate that remittances' impact on food security is context-dependent and influenced by household decisions on resource allocation. Thus, policies that maximize the food security benefits of remittance inflows should be implemented.

When grouped by landholdings, landless households consistently exhibited the lowest levels of food security, while those with medium landholdings showed stable food security. However, despite being the most food secure in the early survey years, large landholder households became the least food secure in later years. This decline was attributed to the limited sample size (142 out of 14,400 in 2022), which may not capture broader reality. Similarly, Harris-Fry et al. (2015) found that land ownership significantly increased food security; this could be because landholding households have the advantage of growing food for their own consumption (Fuster et al. 2008). These findings highlight the need for policies that support land access and utilization, particularly to allow landless households to improve their food security.

4.3 | Policy Implications for Achieving the Zero Hunger Goal in Bangladesh

This study suggests that achieving SDG 2 by 2030 could be particularly challenging, as only 60.35% of households were food secure in 2022. While some administrative regions, such as Khulna (69.50%) and Rajshahi (68.98%), show impressive food security levels and a progressive trend of improvement, others, such as Barishal (48.78%), Chattogram (56.14%), and Rangpur (58.11%), remain far below expectations (Table 1, Figure 3). Similarly, certain agroecological zones, such as the GRF (69.35%), performed relatively well, while others, including the Hill agroecological region (54.53%) and SWCTE (54.92%), lagged behind (Table 2). Moreover, substantial inequalities in food security persisted across various socioeconomic dimensions, including region; household head's age, gender, education, and income; household size and landholdings; and access to microcredit, remittances, and social safety nets (Tables 4 and 5). These disparities reveal that achieving SDG 2 (ending hunger) and SDG 10 (reducing inequalities) by 2030 is unlikely unless targeted and effective measures are implemented.

To address these challenges, extra efforts are urgently required for food-insecure regions. First, interventions should focus on improving food availability through measures such as agricultural mechanization, irrigation, use of fertilizers, and introduction of saline-tolerant and high-yielding crop varieties. Such initiatives can enhance both food production and household income, contributing to improved food security (Mutea et al. 2022). Bangladesh has developed several strategic documents that emphasize the importance of achieving food security, including the National Food and Nutrition Policy 2020, Mapping the SDGs, 8th Five Year Plan, Vision 2041, Bangladesh Perspective Plan, and Delta Plan. These strategies need to be effectively implemented to meet planned targets within the specified timeline. Regular progress monitoring and evaluations are essential to assess whether these initiatives are producing the desired outcomes and to identify areas that require additional attention.

Second, our results revealed that improving food security at the national and regional levels does not necessarily translate to equitable food security for all. Substantial inequalities in food security persist among regions and within the population. Our findings underscore that targeted interventions are critical for reducing these inequalities. The government can consider implementing tailor-made initiatives to bridge socioeconomic gaps and ensure that improvements in food security benefit all population groups. To achieve Zero Hunger and other goals while ensuring that no one is left behind, integrated efforts must be strengthened to address the challenges that most affect food security. For instance, our results indicate that household income levels and size significantly impact food security. Therefore, policymakers need to focus on promoting income-generating initiatives and implementing effective family planning support, which can, in turn, significantly improve food security at both the household and national levels. These efforts must be integrated into a comprehensive strategy that prioritizes inclusive growth, aiming to ensure that the benefits of food security initiatives reach all individuals, regardless of their socioeconomic and geographic characteristics.

5 | Conclusion

Food security in Bangladesh improved from 53.46% in 2005 to 60.35% in 2022. This modest improving trend in food security is evident at the rural, urban, and national levels. However, inequalities persist both regionally and within various socioeconomic groups in terms of the household head's age, gender, income, education, and marital status; household size; landholdings; and access to microcredit, social safety nets, and remittances. Bangladesh has set a national target to reduce

food insecurity to below 12.6% by 2030 (Bangladesh Planning Commission 2020). Despite progress, currently 39% of the population remains food insecure, underscoring the substantial challenges ahead. Achieving SDG 2 appears particularly inconceivable under the present circumstances; hence, comprehensive policy measures should be established. These should include increasing food production through agricultural mechanization, promoting income-generating activities, reducing socioeconomic inequalities, empowering women economically, implementing population control strategies, and designing targeted interventions for microcredit and social safety nets. These interventions are crucial for addressing systematic issues that perpetuate food insecurity. The study's findings offer valuable insights for policymakers in Bangladesh and provide a possible foundation for evidence-based strategies to address food insecurity. Moreover, these findings have broader applicability and can serve as a reference for policymakers in other countries that are experiencing similar challenges with regional and socioeconomic inequalities in food security.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** Supporting information.