Food and Nutrition Security in Developing Economies: An Intra-household and Gender Based Assessment

Jaweriah Hazrana
Morrison School of Agribusiness
W. P. Carey School of Business
Arizona State University
Email: jaweriah.hazrana@gmail.com
jaweriah.hazrana@asu.edu

Ashok K. Mishra
Morrison School of Agribusiness
W. P. Carey School of Business
Arizona State University
Email: Ashok.K.Mishra@Asu.edu

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Abstract

This study examines the impact of droughts on intra-household food consumption, diet diversity, and nutrition. The study provides a unique and nuanced understanding of how droughts affect the food consumption and nutrition of men, women, and children within a household. We use panel data from a nationally representative survey in Bangladesh. Findings show that after a drought, individuals spend 4.6% less on food and consume 3.4% fewer calories, 3.3% less protein, and 4.7% less fat. However, the effect is not homogeneous across all household members. Women and children, the most vulnerable groups, experience a greater shortfall in food consumption and nutrients than men. Furthermore, droughts lead to a less balanced household diet, characterized by reduced consumption of nutrient-rich animal-source and plant-based foods and increased reliance on cereals. Policymakers could support targeted interventions for vulnerable individuals to access adequate nutrition during climatic stress.

JEL classification: D12, D13, Q18, Q54

Keywords: Climate change, Food consumption, Nutrition, Gender, Bangladesh

1. Introduction

Achieving food security and improved nutrition, as outlined in the second of the United Nations' Sustainable Development Goals for 2030, remains one of the most pressing global development challenges. Despite progress in recent years, estimates suggest that in 2021, extreme poverty affected nearly 698 million people (9%), and over 923.7 million people (11.7%) experienced severe food insecurity globally (FAO, 2022). Climate change further compounds these challenges, threatening the quantity, quality, and affordability of food

(Carpena, 2019). Natural disasters, such as droughts, extreme weather events, and rising temperatures, have become more frequent and intense in recent decades. Climate models project further increases in the frequency and severity of these events, with potentially catastrophic implications for local and global food systems (World Bank, 2013).

This paper explores a critical yet understudied aspect of food security - the impacts of droughts on intra-household food utilization. Prior research has established that inadequate rainfall can reduce agricultural productivity, leading to lower farm incomes and higher food prices (Auffhammer et al., 2012; Birthal et al., 2021; Taraz, 2018). Consequently, this reduced food availability following rainfall deficits can potentially translate into poorer food consumption and nutritional outcomes. However, the downstream effects of these rainfall shocks on food utilization at the individual levels remain unclear. The conventional assumption that lower food availability directly results in poorer consumption overlooks potential coping mechanisms, such as household savings or government assistance programs, that could buffer the adverse effects of droughts on food utilization. Additionally, existing literature lacks insights into how droughts may heterogeneously impact individuals within the same household based on factors such as gender and age. This study aims to bridge these knowledge gaps by addressing three key research questions: (i) How do extreme climate events, such as droughts, impact food consumption and nutrition? (ii) Do droughts have differential impacts on the food consumption and nutrition of individuals from different sex and age groups within households? (iii) How effective are social safety nets in smoothing household food consumption post droughts?

We examine the above issues in the context of rural agricultural households in Bangladesh. Over 60% of households in Bangladesh earn income from agriculture, and rainfall patterns vary significantly across time and space (Ministry of Agriculture, 2017). Rainfed agriculture accounts for over 50% of Bangladesh's net sown area and 40% of total food production, making rural livelihoods and nutrition highly dependent on precipitation (Ministry of Agriculture, 2017). Notably, Bangladesh ranks seventh on the list of countries most vulnerable to climate change, having experienced 185 extreme weather events from 2000 to 2019, resulting in economic losses worth $3.72 billion (Global Climate Risk Index, 2021). Additionally, the recent literature highlights concern about food security and intra-household inequality in Bangladesh, with studies showing evidence of high levels of nutritional disparity within households (Brown et al., 2021; D'Souza and Tandon, 2019). Bangladesh's heavy reliance on rainfed agriculture, existing nutrition challenges, and vulnerability to climate change underscore the need to understand how droughts influence food utilization dynamics, especially among vulnerable groups within households. This study aims to provide valuable insights into these issues by leveraging Bangladesh's unique context.

Bangladesh has a comprehensive portfolio of both food- and cash-based social safety net programs to protect vulnerable populations against the impact of income shocks. These interventions can directly improve welfare by providing access to essential dietary staples or the flexibility to purchase food and other necessities, thereby maintaining purchasing power (Gadenne et al., 2021; Narayanan and Gerber, 2017; Narayanan et al., 2019). While it is recognized that addressing the impact of climate shocks on food security is critical, the mediating role of safety net programs is often overlooked. Moreover, existing literature lacks clarity on how in-kind and cash transfers interact with the effects of climate shocks on food security. This study aims to provide a comprehensive examination of how cash and food transfers mediate the link between rainfall shocks and food utilization at the intra household level. The findings can offer evidence-based guidance on optimizing social protection policies and programs to build climate resilience and food security amongst vulnerable individuals, in Bangladesh and similar contexts.

This study reveals three key findings. Firstly, droughts have a significant and negative impact on food consumption and nutrition. Importantly, the impact of droughts varies among household members, with women and children experiencing greater effects compared to prime-aged males. Second, droughts reduce dietary diversity — the consumption of nutrient-rich animal- and plant-based foods and processed foods, which are more responsive to income and price changes, is affected disproportionately compared to the consumption of staple food cereals. This analysis holds significant relevance for policymakers as it highlights specific areas where dietary deficiencies may arise post droughts, providing valuable insights for targeted interventions. Third, the findings indicate that social safety nets play a crucial role as a support system in mitigating the adverse effects of droughts' on individual food consumption and nutrition. However, it is important to note that although these safety nets assist, they do not completely restore food consumption to the levels observed before the droughts.

This paper aims to make several key contributions to the literature and policy discourse on intra-household food security in the context of climate shocks. Existing research on this topic primarily focuses on food availability and access, with limited insights on aspects of food utilization. Additionally, the existing literature on food utilization relies on household-level information, overlooking the growing body of work that highlights substantial intra-household inequality in resource distribution (Brown 2021; and D'Souza and Tandon 2019). By examining the impact of droughts on consumption, nutrition, and diet diversity – issues that encompass food utilization - of different household members, this paper provides insights that may aid policymakers and practitioners in promoting food and nutrition security in drought-prone regions. These insights may also guide the design of targeted interventions to ensure vulnerable households have access to adequate nutrition during such periods.

The rest of this paper is organized as follows: Section 2 presents the data, and Section 3 presents the descriptive statistics of key variables. The empirical strategy to assess the impact of droughts is outlined in Section 4. Section 5 presents empirical results, which are validated for their robustness in Section 6. Concluding remarks are made in Section 7.

2. Background and related literature

The impacts of climate shocks, such as droughts, on food security have been widely explored across various disciplines, including the physical and social sciences. The literature has established the adverse effects of low rainfall on crop production and the subsequent reduction in food availability (Carpena 2019; Asfaw and Maggio 2018). Droughts can result in water stress in crops, hampering their growth and development, ultimately leading to lower yields (Amare et al., 2019). The reduction in crop yields can directly impact the amount of food available for consumption, and the subsequent food price increases can exacerbate the problem of affordability, particularly for vulnerable households in areas where food prices are already high (Dell et al., 2014; Knox et al., 2012; Carleton and Hsiang, 2016). In addition to reduced yields, droughts can also lead to reduced incomes for farmers who may not have any produce to sell or may not be able to afford food due to price increases (Auffhammer et al., 2012; Jayachandran, 2006; Mahajan, 2017; Taraz, 2018). This could exacerbate the problem of food insecurity, particularly among low-income households (Adeyemi et al., 2020).

Despite the considerable amount of research conducted on the impact of climate shocks on food production and consumption, there is a significant gap in understanding how droughts affect food utilization—a critical component of food security (Lobell & Burke, 2010). Existing literature relies heavily on household-level data and provides anecdotal evidence. The majority demonstrates that by reducing yields, climate change diminishes food production and, thereby, consumption (Auffhammer et al., 2012; Birthal et al., 2021; Jayachandran, 2006; Mahajan, 2017; Taraz, 2018). However, the specific nutritional implications of such agricultural declines remain opaque (Phalkey et al., 2015). While some studies reveal potential linkages between droughts and reduced nutrition and diet diversity, these are context-specific. For example, Baez et al. (2015) demonstrate an 8.2% decline in per capita consumption following rainfall shocks in Guatemala. Similarly, Carpena (2019) finds modest rainfall effects on nutrition in India using household-level data only. Additionally, Asfaw and Maggio (2018) demonstrated a reduction in calorie intake in Malawi due to climate change. Mahapatra et al. (2021) and Rodriguez-Llanes et al. (2011) found higher child undernutrition incidence in climate-vulnerable Indian districts.

A critical question that remains unaddressed in the literature is whether droughts disproportionately affect food utilization within households. Previous studies on parallel themes show women and children are often more vulnerable to food insecurity. For instance, studies conducted in Bangladesh and India have revealed gender-related disparities in calorie intake and nutritional status that cannot be fully explained by differences in labor productivity (Behrman and Deolalikar, 1990; Pitt et al., 1990; Hill and Upchurch, 1995; Mangyo, 2008; Pillai and Ortiz-Rodriguez, 2015; D'Souza and Tandon, 2021). Furthermore, recent research in Bangladesh has revealed that nearly half of undernourished women and children reside in non-poor households (Brown et al., 2021). Other studies reinforce this vulnerability pattern (Chen et al., 1981; Thomas, 1990; Udry, 1996; de Mel et al., 2009; Martínez, 2013; Doss et al., 2018; Mason and Jayne, 2015). It is possible that droughts could exacerbate the existing nutritional inequalities by altering intra-household food allocation. The current literature provides limited insights into equitable climate resilience policies. A more detailed analysis is needed to explore how droughts impact food utilization among individuals with diverse vulnerabilities.

A parallel body of literature suggests that social safety nets can play a critical role in reducing the impact of climate shocks on various aspects of food security (Headey et al., 2018; Kilic et al., 2017). The social safety net programs aim to safeguard vulnerable populations from the adverse effects of climate shocks by providing cash or in-kind transfers, which can function as insurance against income shocks and reduce households' vulnerability to droughts (Barrett, 2002). In-kind food transfers can ensure that households have access to nutritious food. In contrast, cash transfers provide greater flexibility and agency to households, enabling them to purchase food and other essentials. However, the empirical literature lacks consensus on the effectiveness of social safety nets in promoting household resilience and mitigating the impact of droughts on food security. While some studies have shown positive effects of social safety nets on food security (Gelli et al., 2011; WFP, 2020), others have found limited effectiveness, especially in contexts of chronic poverty and inequality (Sabates-Wheeler et al., 2008). Thus, underscores the importance of assessing the effectiveness of social safety net programs in drought-prone regions and gaining a better understanding to inform evidence-based policies.

3. Data

3.1. *Food expenditure and consumption*

Food consumption and expenditure data have been extracted from the Bangladesh Integrated Household Surveys (hereafter BIHS) conducted by the International Food Policy Research Institute (IFPRI) in 2011-12, 2015-16, and 2018-19 from a panel of 6,500 households. This dataset contains detailed information on the consumption of different food commodities and on expenditures at household and individual levels. It also provides information on non-food expenditures and several household and individual characteristics.

The BIHS has several modules. For our analysis, we rely on data from three modules: (i) 24-hour recall of household food consumption, (ii) 24-hour recall of individuals' dietary intakes and food weighing, and (iii) 7-day recall of food expenditures. Data on household food consumption includes food recipes, ingredients, and raw and cooked weights of meals and snacks consumed in the morning, noon, and evening. The intra-household module contains information on individuals' food consumption[1], measured using standard-sized bowls. It also

[1] It is possible that short recall period for individual-level consumption may not accurately reflect intra-household food allocation, and such a measurement error could potentially lead to attenuation bias. Some studies, however,

contains information on the reasons for skipping meals (due to illness or fasting), food offered to guests, fed to animals, given away as alms, and leftovers. However, we do not use this information. Female heads of the households, responsible for overseeing food preparation and serving, were the respondents providing information on household food consumption or allocation to individuals.

To estimate the intake of nutrients, i.e., calories, protein, and fat, by individuals in a household, we have followed a two-step process. First, we combine individual and household food consumption data to calculate the quantity of raw ingredients of the food consumed (Bogard et al., 2016) as $\text{Weight of raw ingredient}_{\text{Individual}} = \text{Weight of raw ingredient}_{\text{Household}} * \frac{\text{Weight of composite food}_{\text{Individual}}}{\text{Weight of composite food}_{\text{Household}}}$.

To derive calorie, protein, and fat content per unit of weight of raw ingredients, we use nutritional conversion factors from the food conversion table published by the University of Dhaka and USAID (2013) (Shaheen et al., 2013). The actual nutritional consumption may vary due to cooking methods, as certain nutrients may be lost during food preparation and cooking. To address this, we incorporate information on cooking methods obtained from the BIHS and adjust the nutrient intake accordingly.

Food expenditure is derived from the 7-day recall module, which contains detailed records of more than 300 food commodities. Expenditure on each commodity is summed up to determine the total food expenditure. To value the home-produced and gifted foods, we rely on median unit-value prices obtained from the nearest geographical region, considering a minimum of three unit price observations. This ensures that estimated values accurately reflect local food prices and mitigates potential outliers in the data. Households or individuals often make food

have shown a little difference in calorie estimates obtained from 24-hour recall and 7-day recall periods (see Sekula et al., 2005).

choices in a broader economic context. Often, there are competing demands for limited resources during a drought. Hence, we also analyze droughts' impact on non-food expenditure[2]. For analytical purposes, annual non-food expenditure is converted into monthly expenditure to match the reported period for food expenditure.

The BIHS surveys also provide information on households' access to social safety nets[3]. We considered their access to such safety nets (i.e., cash transfer and in-kind food transfer) in the year before the survey.

3.2. *Climate*

Climate data have been obtained from the CRU-TS (Climatic Research Unit Time-Series) database (Version 4) maintained by the Climate Research Unit University of East Anglia. This database provides daily time series of precipitation and maximum and minimum temperatures at a 0.5x0.5 degree resolution. Climate data are integrated with household-level data using location identifiers provided in the BIHS dataset. Since our focus is on droughts, following Sekhri and Storeygard (2014), we define drought as the standardized deviation of annual rainfall, expressed in meters, from its long-term average (1980 to 2019):

$$\frac{\mathrm{Rain}_{it} - \overline{\mathrm{Rain}}_{it}}{\sqrt{E[(\mathrm{Rain}_{it} - \overline{\mathrm{Rain}}_{it})^2]}}$$

where i denotes household and t denotes year. The standardized deviations allow us to capture location-specific and exogenous rainfall shocks. To achieve a concordance between the occurrence of a drought and the survey timing (surveys have been conducted in different months throughout the year), we have considered standardized deviations for the past 12

2 Sum of expenditures on individual non-food commodities in the preceding year.
3 The BIHS reports about 90 social safety net programs operational in Bangladesh.

months preceding the survey, thus capturing the impact of recent droughts on food consumption and nutrition.

3.3. *Social safety nets*

The role of a well-functioning social safety net system in enhancing food security, especially during climate shocks, is widely recognized. An effective social safety net can improve food security by increasing real incomes for low-income rural households, particularly amid climate shocks. Our study aims to assess the effectiveness of social safety nets in Bangladesh. To do so, we extracted data on safety net participation and benefits from the BIHS dataset, which provides valuable information for our analysis. The BIHS survey collected detailed information regarding the types of social safety nets households received, such as cash transfers or in-kind assistance, including food grains like wheat. This information was collected for the year before the survey, aligning with our measure of droughts to be discussed in Section 3.1. The dataset's temporal alignment and comprehensive coverage of social safety net programs make it an ideal resource for analyzing our study's relationship between social safety nets and droughts.

Importantly, social safety net programs may have objectives beyond coping with climate shocks.[4] To account for this, we specifically identify programs that provide cash assistance and/or in-kind transfers of food grains. We define two binary indicator variables ─ one for cash assistance and one for in-kind food grain transfers. The cash variable takes a value of 1 if the household received any cash aid; 0 otherwise. Likewise, the in-kind variable is 1 if the household received food transfers; 0 otherwise. Focusing specifically on cash and food-based assistance, these measures identify programs designed to provide vulnerable groups with either direct food access or income to buy essentials. This targeted approach accounts for the diverse

[4] At the baseline survey in 2011-12, over 90 social safety net programs were operating in Bangladesh, each with distinct objectives such as disaster mitigation and livelihood support for disadvantaged groups.

objectives of social protection policies and isolates the impacts of transfers directly relevant to maintaining nutrition during droughts. Figure A3 in the appendix shows household participation in at least one social safety net program over the three survey rounds in rural Bangladesh.

4. Descriptive statistics

Figure 1 presents the trend in expenditures on food and non-food commodities as well as the combined total. Since 2011-12, the amount spent on food has increased gradually, but its share of the total expenditure has fallen by 11 percent points, from 63% in 2011-12 to 52% in 2018-19.

A disaggregated analysis of food expenditure provides important insights into food consumption dynamics (Table 1). Over time, spending on staple cereals has fallen, in absolute and relative terms. However, their share of the total food expenditure declined from 33.1% in 2011-12 to 23% in 2018-19. The expenditure share of fruits and vegetables also declined in 2018-19. On the other hand, the expenditure share of animal-source foods increased slowly to 27.4% in 2018-19. The biggest change occurred in the expenditure share of processed foods, from 18% in 2011-12 to 28% in 2018-2019. However, expenditure shares of other food commodities show no definite trend.

Table 2 presents the changes in calorie, protein, and fat intake resulting from the changes in food basket. Between 2011-12 and 2018-19, calorie intake decreased from 2,083 to 1,944 kcal/person/day. Cereals remained a primary source of calories, but their share of the total calorie intake from all sources declined from 77% to 70%. Fruits, vegetables, pulses, and animal-source foods have emerged as important sources of calories. Protein intake decreased from 52 grams/person/day in 2011-12 to 48 grams/person/day in 2018-19. Despite declining consumption, cereals have remained the most important source of protein. Edible oils have consistently contributed around 22% to the total protein intake. On the other hand, the contribution of animal-source foods and fruits and vegetables to the total protein intake increased. Fat intake experienced a noticeable increase of nearly 31% since 2011-12; edible oils accounted for 14% of the total fat intake. The contribution of animal-source foods to protein intake also increased to 3.3% in 2018-19.

Individuals in a household are classified by their age and sex into six broad categories: (i) boys (5-14 years), (ii) girls (5-14 years), (iii) adult men (15-59 years), (iv) adult women (15-59 years), (v) elderly men (60 years and above), and (vi) elderly women (60 years and above). Table 3 presents the adult male equivalent nutrient intake for different groups[5]. There are significant gender differences in nutrient intake. The average intake of any nutrients by adult males is at least 42% higher than by their female counterparts. Further, elderly males are favored over elderly females and boys over girls in food allocation decisions.

Kernel densities of consumption expenditure and nutrients for different age and sex groups are presented in Figure 2. The kernel densities of all nutrients and consumption expenditures for all except adult males skew left, confirming significant gender disparities in food consumption and nutrition. These findings reinforce the need to understand individuals' consumption behavior to better target nutritional programs.

5. Empirical strategy

To assess droughts' impact on food consumption and nutrition, we estimate a reduced-form equation. Our measure of droughts is the deviations in annual rainfall from its long-run mean. Average rainfall varies predictably from one location to another. At the same time, the deviation from its local mean is serially uncorrelated and largely unpredictable at the start of

[5] Nutrient intakes by individuals belonging to different age-sex groups are converted into adult male equivalent (AME) following Akhter and Shams (1994) and James and Schofield (1990).

an agricultural season. This allows us to consider rainfall shocks as exogenous and unpredictable factors.

We begin by estimating the following equation.

$$FS_{iht} = \beta_0 + \beta_I I_{iht} + \beta_H H_{ht} + \beta_D Drought_{ht} + \lambda_{ih} + \delta_t + \eta_{vt} + \varepsilon_{iht} \quad (1)$$

where, FS_{iht} is the natural logarithm of food expenditure (or intake of a nutrient intake) by individual i from household h at time t; I_{iht} is a vector of individuals' characteristics (i.e., literacy, gender, marital status, and employment), H_{ht} is a vector of household characteristics (i.e., household size, remittances, etc.), and ε_{iht} is an identically and independently distributed error term.

Equation (1) includes the time-fixed effects (δ_t) and village-specific time-fixed effects (η_{vt}) to control for any potential macroeconomic policy change that may influence food expenditure and nutrition. Further, to control for observed and unobserved time-invariant factors, individual fixed effects (λ_{ih}) are included in Equation (1). To address potential heteroskedasticity and correlation of errors, we have clustered standard errors at the household level. This is relevant as the households in our dataset form clusters, and accounting for such clustering adjusts for the correlation in the data. β_D captures the average effect of droughts on an individual's food consumption and nutrition. A priori, β_D is expected to be negative, as droughts lead to a reduction in food supplies and an increase in prices. Droughts can potentially alter food baskets via their effects on household income and on relative prices of different food commodities. To know their impact on dietary diversity, Equation (1) is estimated separately for each food group, i.e., cereals, pulses, edible oils, fruits and vegetables, animal-source foods, and processed foods.

Equation (1) leverages individual-level data to assess droughts' impact on the outcomes. However, it does not provide insights into droughts' disproportionate effect on the food and nutrition of different household members. To understand heterogeneity in the impact of droughts, we introduce a categorical variable for individuals belonging to different age and sex groups and interact it with droughts.

$$\mathrm{FS_{iht}} = \beta_0 + \beta_I \mathrm{I_{iht}} + \beta_H \mathrm{H_{ht}} + \beta_M \mathrm{Member_{iht}} + \beta_D \mathrm{Drought_{ht}} + \beta_{DM}(\mathrm{Drought_{ht}} * \mathrm{Member_{iht}}) + \lambda_{ih} + \delta_t + \eta_{vt} + \varepsilon_{iht} \qquad (2)$$

where Member represents the categorical variable, and the interaction term $(\mathrm{Drought_{ht}} * \mathrm{Member_{iht}})$ captures droughts' differential impact on the outcome for each specific group of individuals.

Social safety nets (such as in-kind food transfers and cash transfers) help households or individuals cope with climate-induced income shocks. To know their consumption-smoothening effects, we include a categorical variable for the household's access to in-kind and cash transfers and allow them to interact with drought and sex-age groups of individuals (Equation 3).

$$\mathrm{FS_{iht}} = \beta_0 + \beta_I \mathrm{I_{iht}} + \beta_H \mathrm{H_{ht}} + \beta_M \mathrm{Member_{iht}} + \beta_D \mathrm{Drought_{ht}} + \beta_C \mathrm{Cash\_transfer_{ht}} + \beta_I \mathrm{Inkind\_transfer_{ht}} + \beta_{DM}(\mathrm{Drought_{ht}} * \mathrm{Member_{iht}}) + \beta_{DC}(\mathrm{Drought_{ht}} * \mathrm{Cash\_Transfer_{ht}}) + \beta_{DI}(\mathrm{Drought_{ht}} * \mathrm{Inkind\_transfer_{ht}}) + \beta_{DCM}(\mathrm{Drought_{ht}} * \mathrm{Cash\_Transfer_{ht}} * \mathrm{Member_{iht}}) + \beta_{DIM}(\mathrm{Drought_{ht}} * \mathrm{Inkind\_transfer_{ht}} * \mathrm{Member_{iht}}) + \lambda_{ih} + \delta_t + \eta_{vt} + \varepsilon_{ihvt} \qquad (3)$$

where, $\mathrm{Cash\_Transfer_{ht}}$ and $\mathrm{Inkind\_transfer_{ht}}$ are binary variables that take the value of 1 if household i received a cash (in-kind) transfer and 0 otherwise. Partial derivative of Equation

(3) with respect to drought provides the marginal effect of droughts on food consumption or nutrition:

$$\text{Impact}_{\text{FS}} = \frac{\partial(\text{FS}_{\text{iht}})}{\partial(\text{Drought}_{\text{ht}})^{\text{k}}} = \beta_{\text{D}} + \beta_{\text{DM}}(\text{Member}_{\text{iht}}) + \beta_{\text{DC}}(\text{Cash\_Transfer}_{\text{ht}}) + \beta_{\text{DI}}(\text{Inkind\_transfer}_{\text{ht}}) + \beta_{\text{DCM}}(\text{Cash\_Transfer}_{\text{ht}} * \text{Member}_{\text{iht}}) + \beta_{\text{DIM}}(\text{Inkind\_transfer}_{\text{ht}} * \text{Member}_{\text{iht}}) \quad (4)$$

where, $k \in \{1, \dots, 6\}$ denotes age-sex groups of individuals. Theoretically, the impact of drought on food consumption or nutrition should be negative, i.e., $\frac{\partial(\text{FS}_{\text{iht}})}{\partial(\text{Drought}_{\text{ht}})^{\text{k}}} < 0$.

Equation (4) provides the marginal effect of droughts on food consumption in the presence of social safety nets. To know droughts' effect on food consumption in the absence of safety nets, we set both $\text{Cash\_Transfer}_{\text{ht}}$ and $\text{Inkind\_Transfer}_{\text{ht}} = 0$ and re-write Equation (4):

$$\text{Impact}_{\text{FS}} = \frac{\partial(\text{FS}_{\text{iht}})}{\partial(\text{Drought}_{\text{ht}})^{\text{k}}} = \beta_{\text{D}} + \beta_{\text{DM}}(\text{Member}_{\text{iht}}) \quad (5)$$

The impact of droughts on food consumption and nutrition in the presence of cash or in-kind transfers can be assessed as:

$$\text{Impact}_{\text{FS}} = \frac{\partial(\text{FS}_{\text{iht}})}{\partial(\text{Drought}_{\text{ht}})^{\text{k}}} = \beta_{\text{D}} + \beta_{\text{DM}}(\text{Member}_{\text{iht}}) + \beta_{\text{DC}}(\text{Cash\_Transfer}_{\text{ht}}) + \beta_{\text{DCM}}(\text{Cash\_Transfer}_{\text{ht}} * \text{Member}_{\text{iht}}) \quad (6)$$

$$\text{Impact}_{\text{FS}} = \frac{\partial(\text{FS}_{\text{iht}})}{\partial(\text{Drought}_{\text{ht}})^{\text{k}}} = \beta_{\text{D}} + \beta_{\text{DM}}(\text{Member}_{\text{iht}}) + \beta_{\text{DI}}(\text{Inkind\_transfer}_{\text{ht}}) + \beta_{\text{DIM}}(\text{Inkind\_transfer}_{\text{ht}} * \text{Member}_{\text{iht}}) \quad (7)$$

If the magnitude of the marginal effect of droughts is less in the presence of cash or in-kind transfers, then the safety nets help mitigate droughts' adverse impacts on food consumption and nutrition.

6. Results and Discussion

5.1 Impact of droughts on food consumption and nutrition

Table 4 reports estimations of Eq. (1) for individual total expenditure (column 1), food and non-food expenditure (columns 2 and 3), and macronutrient consumption (columns 4–6). We find that all drought coefficients in Table 4 are negative and statistically significant. Given that the individuals consume very low levels of calories, protein, and fat on a day-to-day basis (see table 1), the results indicate that droughts can exacerbate food security concerns.[6] [7] In addition to empirically demonstrating the direction of the effects, it is important to understand the magnitudes of the impacts. We find that total and food expenditure decrease by 9.3% and 4.6%, respectively. Similarly, Columns 4-6 shows that the adverse impact of droughts on households' food expenditure, subsequently translates into a decline in nutrient intake, with a decrease of 3.47% in calorie intake, 3.33% in protein intake, and 4.78% in fat intake. These results reinforce the hypothesis that climate risks pose a serious threat to food and nutrition security.

While household food consumption and nutrition are the primary focus of this study, we also explore the impact of droughts on non-food spending, a critical factor in determining overall household well-being, in Column 3. During periods of low rainfall, households may be compelled to reduce non-food spending to sustain their food expenditure, potentially affecting their access to essential necessities. Our findings demonstrate that the reduction is greater in non-food expenditures (13.9%), almost three times the reduction in food expenditures. These

[6] As Equation (1) is estimated in the log-linear form, the percentage changes in the outcomes due to droughts are calculated by taking the exponential of the product of the mean droughts and their respective coefficients.

[7] The nutritional needs vary among different age and gender groups, consequently influencing the allocation of food resources. However, the results in Table 5 focus on the impact of droughts on food expenditure and nutrition, independent of the absolute quantity of consumption. Consequently, in line with this reasoning, we refrain from utilizing AME adjusted outcomes. Instead, our analysis delves into the broader implications of drought-induced changes in food allocation and their impact on nutrition outcomes.

findings indicate that during a drought, despite reallocating expenditures to food, households are unable to regain their pre-drought levels of food and nutrition.[8]

5.2 Impact of droughts on food diversity and nutrition

To understand the effect of droughts' on dietary diversity and nutrient intakes, Equation (1) is estimated for different food groups, namely, cereals, pulses, edible oils, animal-sourced foods, fruits and vegetables, and processed foods. Table 5 presents the results.

We find in general, the estimates consistently indicate that droughts lead to reduced food expenditure and nutrition for all types of food items, as evidenced by negative drought coefficients across all food groups and consumption outcomes. However, the magnitude of these impacts varies among different food categories, providing important insights into the specific areas where nutritional deficiencies may be more pronounced during droughts. Cereals demonstrate the least effect of droughts, where a mean drought results in less than a 1% decrease in food expenditure (Column 1, Panel A) but 3 to 4% declines in calorie, protein, and fat intake (Column 1, Panels B–D. Processed foods experience the most significant effects of droughts, with declines of 15 to 19%. Similarly, animal-sourced foods witness an 8% decrease in spending, leading to lower consumption of calories, protein, and fat. Consumption of pulses, edible oils, and fruits and vegetables, and their nutritional contribution, also is adversely affected by droughts.

These findings suggest that droughts disproportionately affect consumption of high-value, nutrient-rich commodities and processed foods compared to consumption of staple cereals and other essential foods. Notably, the substitution away from processed and animal-based

[8] A Seemingly Unrelated Regression (SUR) also is estimated consisting two equations with food expenditure, and non-food expenditure as dependent variables; and a test of equality of coefficients is conducted.Test indicates (p-value = 0.1189) that coefficients are not equal, meaning non-food expenditure is crowded out during a drought period.

products during droughts may be attributed to their high-income elasticity. Wealthier households typically consume these products, and prior research suggests that they are considered luxury goods in rural settings, characterized by an income elasticity greater than 1 (Kumar et al., 2011).

5.3 Gendered impacts of droughts on food consumption and nutrition

The above results have demonstrated that droughts exert a statistically significant, negative impact on individual food consumption and nutrition. However, it remains imperative to explore how the effects of droughts manifest heterogeneously across different household members, namely men, women, and children, with respect to their food consumption and nutritional outcomes. Negative income shocks such as droughts may compel households to not only reduce aggregate food consumption but, consequently necessitate a redistribution of resources that could disproportionately disfavour certain members. We explore this below.

We present the differential impacts of droughts across gender and age cohorts, in Table 6. The results reveal striking disparities, particularly in the vulnerability of women to the adverse effects of droughts. Across all demographic groups, women consistently exhibit greater sensitivity to drought-induced shocks relative to their male counterparts. Adult women, for instance, experience a significant 7.7% reduction in food expenditure compared to a more modest 4.8% decrease among adult men. Consequently, this precipitates a more substantial decline in calorie, protein, and fat intake for adult women. Similarly, elderly women endure a considerable 8.14% contraction in food expenditure, while elderly men undergo a much lower 4.95% decrease. For children, the effect of droughts on their food consumption is not much different, with a reduction of 6.58% for girls and 5.58% for boys.

The reduction in consumption expenditure translates into a lower intake of all nutrients, and females are expected to experience a larger decrease than males. Fat intake is affected the most by all age-sex groups, and calorie intake is the least.

5.4 Role of social safety nets in consumption smoothening

Social safety nets, including cash and in-kind transfers, may prove instrumental in mitigating the adverse effects of droughts on household members' consumption and nutritional intake. Such programs provide targeted assistance to vulnerable households and marginalized populations, who disproportionately bear the encumbrance of drought impacts. By providing financial support and essential resources, social safety nets can alleviate the immediate economic burden caused by droughts, ensuring households can maintain sufficient food consumption levels and access nutritious food during scarcity. To analyze the impact of social safety nets on food expenditure and nutrition, we estimate Eq. (6) and Eq. (7) in this section, isolating their contribution in attenuating the effect of droughts. Additionally, we differentiate between cash and in-kind transfers to gain insights into their comparativeness effectiveness and equity in supporting vulnerable households during droughts. Panel A and Panel B of Table 7 present estimates of Eq. (6) and Eq. (7), respectively.

As expected, cash transfers and food aid help smooth food consumption during drought conditions, irrespective of age and gender. The consumption-stabilizing impacts apply to all individuals irrespective of age and sex, but the effect appears more significant in the case of females. However, the consumption-smoothing effect appears larger for in-kind food aid than for equivalent cash transfers. This likely occurs because food transfers have minimal diversion for other uses, while fungible cash transfers are more likely to be allocated to non-food essentials like school fees. Nonetheless, safety nets cannot fully restore pre-drought consumption and nutritional levels.

6 Robustness Checks

We undertake a few robustness checks to validate the results of the main model. These include using winsorized outcomes, alternative definitions of droughts, regression specifications, and seasonal effects. First, we examine the robustness of the results to the choice of dependent variable. Recall that our default dependent variable is food expenditure or nutrient intake, inclusive of outliers, which may affect the estimates of the drought effects. To examine this, we winsorize outcomes at 1% and 99% levels and re-estimate Equation (1). The results presented in Table A1 show that the effects of droughts are comparable to those reported in Table 5, which suggests the robustness of our results. Further, we evaluate the stability of our main results with standard errors clustered at the village and district levels to check for the potential impact of spatial correlation of errors within these higher geographic units. Results in Table A2 show that although standard errors generally decline, all coefficients remain statistically significant, reinforcing our main findings.

The BIHS dataset has a hierarchical structure with individuals nested in households, households nested in villages, and villages nested in districts. This implies greater similarity between randomly selected individuals/households within the same lower-level units. A standard fixed effects model cannot account for this structure and may underestimate standard errors (Raudenbush and Bryck, 2002). To address this, Equation 1 was re-estimated using a multilevel mixed effects model that explicitly incorporates the hierarchical nature of the data.[9] As shown in Table A3, the results remain consistent with the original main findings.

It is possible that our results are sensitive to the measure of drought. We construct an alternative measure of drought, the Standardized Precipitation Index (SPI), and replace the existing

[9] We have employed multilevel modelling framework, i.e., administrative division, district, village, household, and individual. For methodology, see Raudenbush and Bryk (1986) and Raudenbush (2002).

measure with it in Equation (1). The results in Table A4 show that the coefficients of SPI are negative and statistically significant, corroborating the robustness of our findings. Finally, the estimates of droughts may be influenced by seasonality in consumption, as the surveys have been conducted at different months of the year. To look for seasonality effects, Equation (1) is re-estimated incorporating survey months. There is little, if any, deviation in the results from those reported in Table 5.

7 Conclusions

Food security is a complex issue that involves multiple aspects of food availability, access, and utilization. Although past literature examines food security's dimensions of availability and access, there remains a dearth of evidence on the complex intra-household dynamics linking droughts to food utilization. Data constraints ─ such as lack of reliable intra-household data, challenges in measuring individual consumption from joint meals, and the absence of standardized methodologies for assessing individual food allocation ─ have hindered analysis of the impacts of individual-level allocation. This study helps fill the knowledge gap regarding how droughts affect key utilization metrics like personal expenditure, nutrition, and diet diversity. Additionally, it evaluates the efficacy of safety nets in mitigating consumption and nutrition declines during droughts. Unlike past small-scale cross-sectional studies, the analysis uses a large nationally representative rural Bangladesh panel to provide insights into intra-household allocation patterns during climate shocks.

The study reveals three main findings. First, drought exposure significantly reduces food expenditure (4.6%), calorie intake (3.4%), protein consumption (3.3%), and fat intake (4.7%) at the individual level. Importantly, droughts' impact varies across households, with greater nutritional declines observed for women and children than for prime-aged males. Second, although negative nutritional effects occur across food groups, the largest percentage drops arise in processed, animal- and plant-based foods critical for diet quality. In contrast, cereals, which provide carbohydrates, display the smallest changes in consumption. Finally, social safety nets mitigate but do not completely offset droughts' adverse consequences on personal nutrition.

Our results directly address the heightened vulnerability of females, especially the elderly, to drought-induced food insecurity. We find disproportionate declines in individual food expenditure and nutrient intake among women relative to men. This not only endangers their immediate well-being but has long-term public health implications. Notably, limited access to food, water, income generation, and household decision-making power may contribute to females' heightened vulnerability. Past studies confirm pre-existing intra-household consumption disparities (Behrman and Deolalikar, 1990; Haddad et al., 1996; Brown et al., 2021; D'Souza and Tandon, 2019) that droughts further exacerbate. A multifaceted approach, encompassing resource access, participation in decisions, and targeted interventions, is imperative to address the challenges and close gender gaps.

Bangladesh has implemented several safety net programs over the past few decades. These initiatives aim to alleviate hunger and provide nutritional support to vulnerable groups during climate stress. The key schemes include the Public Food Distribution System, which makes essential staple food commodities available at subsidized rates through fair-price shops nationwide. Another scheme is the Vulnerable Group Development program, which offers food and cash transfers to marginalized women and children. The Food for Work program also provides food assistance to rural communities in exchange for labor. These programs ease the financial burden on low-income households and enhance their purchasing power. Although the food security initiatives have limitations in targeting, coverage, and implementation, evidence from this study underscores their utility in helping mitigate nutrition and welfare losses that otherwise would arise due to economic shocks.

The findings highlight the importance of adopting a gender-sensitive and age-specific approach to address droughts' impacts on food security. Recognizing and addressing the unique challenges faced by vulnerable groups is crucial for implementing targeted measures that enhance adaptive capacities, safeguard nutrition, and promote sustainable development in the face of water scarcity induced by climate change. Effective policy interventions should focus on improving water management strategies, strengthening social safety nets, and promoting gender equality and women's empowerment to enhance resilience and mitigate droughts' adverse effects on food security.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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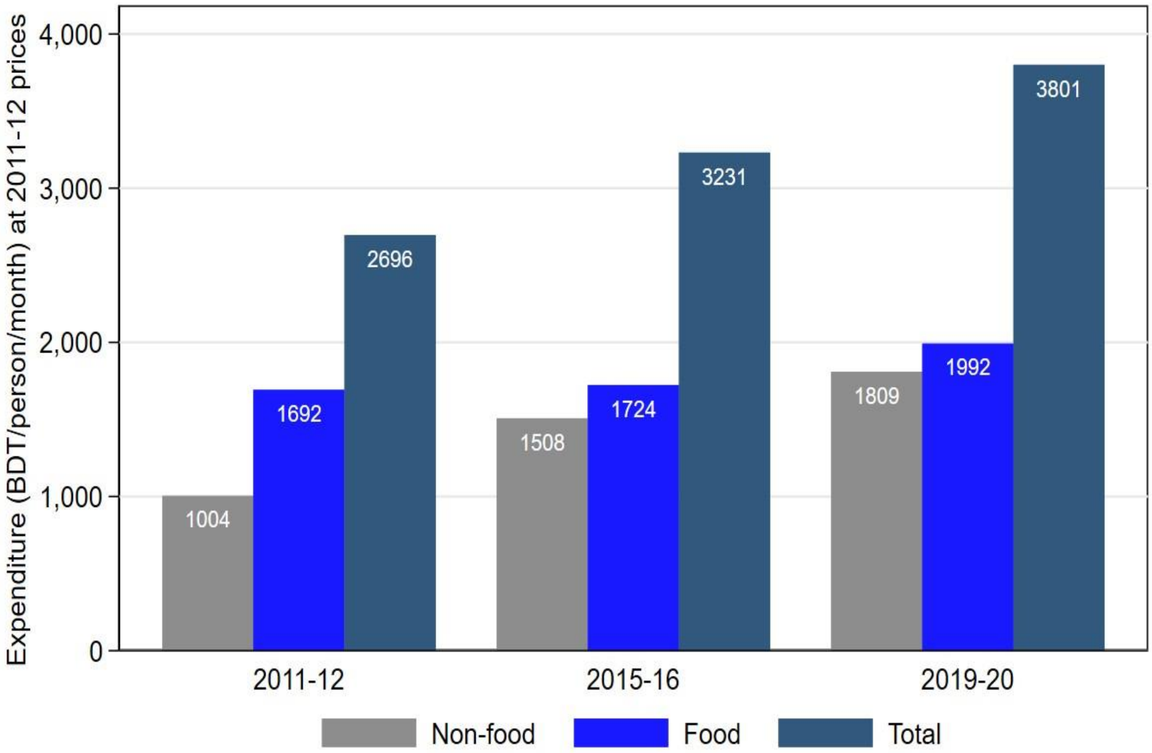
Figure 1. Trends in monthly expenditure at 2011-12 prices.



Source: Bangladesh Integrated Household Surveys (BIHS), International Food Policy Research Institute (IFPRI) 2011-12, 2015-16, and 2018-19.

Figure 2. Intra-household disparities in expenditure and nutrition

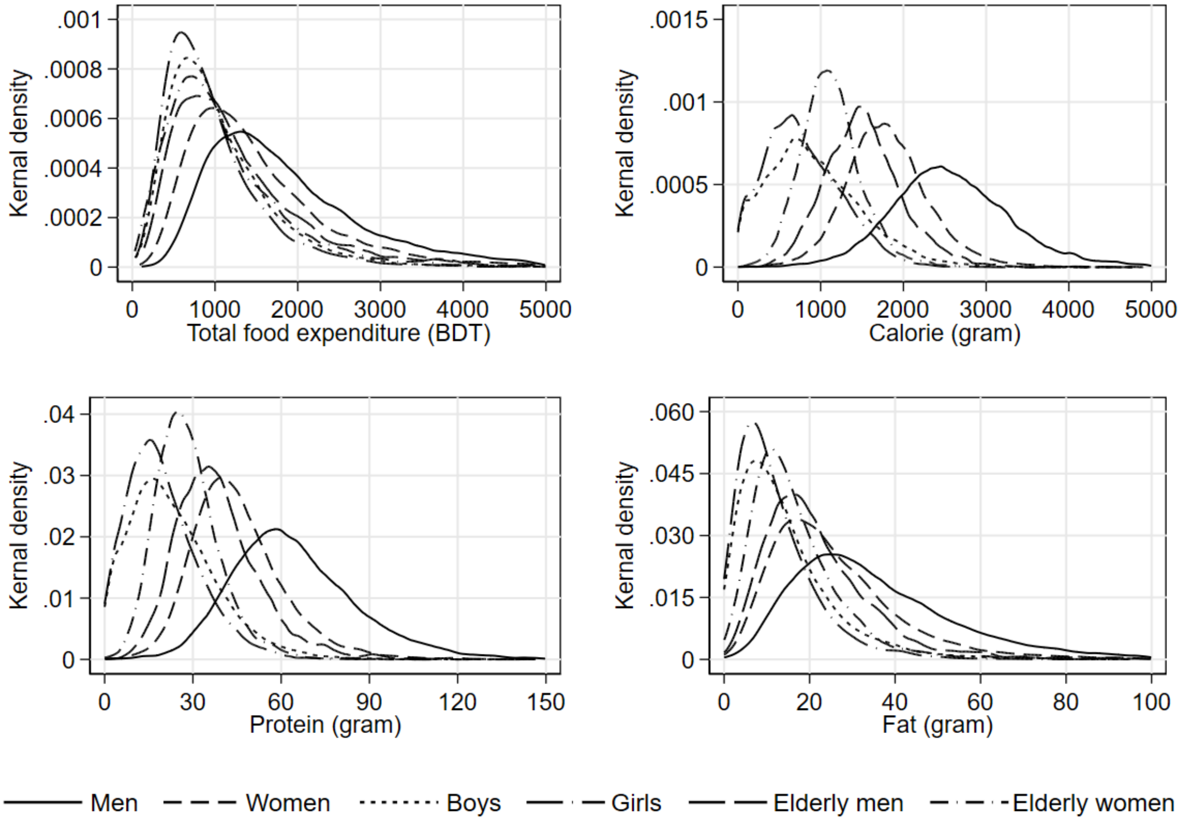


Table 1. Changes in the composition of food expenditure in Bangladesh

Year	Cereals [1]	Pulses [2]	Edible oils [3]	Fruits & vegetables [4]	Animal-source foods [5]	Processed Foods [6]	Total [7]
Food expenditure (BDT/person/month) at constant 2011-12 prices							
2011-12	559.22	23.10	150.11	222.57	432.54	304.17	1691.72
	(269.69)	(36.49)	(160.94)	(138.08)	(483.55)	(250.45)	(2172.45)
2015-16	468.85	36.03	180.49	233.42	486.12	318.69	1723.60
	(263.64)	(47.55)	(226.49)	(149.45)	(481.44)	(309.68)	(3656.63)
2018-19	457.41	29.53	187.38	218.23	546.31	553.14	1992.01
	(229.62)	(36.29)	(193.63)	(119.38)	(516.70)	(475.98)	(2813.39)
% share in food expenditure							
2011-12	33.06	1.37	8.87	13.16	25.57	17.98	100
2015-16	27.20	2.09	10.47	13.54	28.20	18.49	100
2018-19	22.96	1.48	9.41	10.96	27.43	27.77	100

Notes: Expenditure is population-weighted. Figures in parentheses are standard deviations.
Source: Bangladesh Integrated Household Surveys (BIHS), International Food Policy Research Institute (IFPRI) 2011-12, 2015-16, and 2018-19.

Table 2. Changes in composition of nutrition intake, 2012-2019

	Cereals [1]	Pulses [2]	Edible oils [3]	Fruits & vegetables [4]	Animal-source foods [5]	Processed Foods [6]	Total [7]
Panel A: Calorie intake (kcal/person/day)							
2011-12	1615.51	152.31	82.87	88.76	26.75	117.17	2083.36
	(679.69)	(148.70)	(92.08)	(133.50)	(74.05)	(75.72)	(841.56)
2015-16	1420.31	195.40	91.65	93.01	43.75	112.41	1956.54
	(650.61)	(153.34)	(95.54)	(124.08)	(90.29)	(75.43)	(809.13)
2018-19	1369.57	210.94	87.96	114.74	45.36	115.80	1944.37
	(609.87)	(149.62)	(88.17)	(135.02)	(84.57)	(72.72)	(757.26)
Panel B: Protein intake (grams/person/day)							
2011-12	31.56	0.09	11.48	1.96	2.11	4.72	51.92
	(13.61)	(0.43)	(13.31)	(3.12)	(5.71)	(3.50)	(23.95)
2015-16	28.00	0.22	11.22	1.97	3.43	4.08	48.92
	(13.19)	(0.66)	(12.01)	(3.01)	(6.94)	(2.93)	(23.02)
2018-19	27.08	0.19	10.96	2.43	3.56	4.38	48.60
	(12.24)	(0.57)	(11.06)	(3.15)	(6.49)	(3.06)	(20.99)
Panel C: Fat intake (grams/person/day)							
2011-12	2.22	16.49	3.65	1.71	0.11	0.56	24.73
	(1.36)	(16.14)	(4.56)	(3.61)	(0.39)	(0.67)	(19.36)
2015-16	2.01	20.15	4.46	2.25	0.20	0.51	29.58
	(1.39)	(16.06)	(5.23)	(4.10)	(0.56)	(0.49)	(19.55)
2018-19	1.95	22.38	4.27	3.01	0.20	0.53	32.34
	(1.20)	(16.27)	(4.83)	(4.78)	(0.51)	(0.56)	(19.20)

Notes: Figures in parentheses are standard deviations.
Source: Bangladesh Integrated Household Surveys (BIHS), International Food Policy Research Institute (IFPRI) 2011-12, 2015-16, and 2018-19.

Table 3. Nutrient intake by age and sex of household members

	Boys [1]	Girls [2]	Adult men [3]	Adult women [4]	Elderly men [5]	Elderly women [6]
Calorie (kcal/person/day)	915.35	781.19	2574.60	1798.57	1517.40	1119.59
	(565.05)	(459.61)	(737.89)	(506.39)	(466.66)	(360.89)
Protein (g/person/day)	22.89	19.47	64.18	44.81	38.43	28.22
	(15.02)	(12.23)	(22.35)	(15.86)	(14.20)	(10.79)
Fat (g/person/day)	14.11	11.83	36.30	25.50	21.84	16.31
	(11.70)	(9.37)	(22.30)	(15.93)	(13.05)	(10.52)

Notes: Figures in parentheses are standard deviations.
Source: Bangladesh Integrated Household Surveys (BIHS), International Food Policy Research Institute (IFPRI) 2011-12, 2015-16, and 2018-19.

Table 4. Estimated effects of droughts on food consumption and nutrition

	Expenditure (BDT/person/month)			Nutrient (intake/person/month)		
	Total [1]	Food [2]	Non-food [3]	Calorie (kcal) [4]	Protein (g) [5]	Fat (g) [6]
Standardized rainfall deviation	-0.093*** (0.0124)	-0.046*** (0.0106)	-0.139*** (0.0213)	-0.0347* (0.0145)	-0.0333* (0.0162)	-0.0478* (0.0224)
Survey fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Individual fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Village X Survey fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.824	0.827	0.759	0.692	0.664	0.630
F-test	550.05	825.47	201.13	141.99	112.18	61.09
No. of observations	45,271	45,271	45,271	45,271	45,271	45,271

Notes: The dependent variable is a natural logarithm. Drought is included as a categorical variable, taking the value 1 if the standardized deviation in rainfall (12 months prior to the month of the survey) is below its long-term annual average. All regression models include household characteristics (proportion of area irrigated, household size, remittances, rainfall, and temperature) and individual characteristics (literacy, age, gender, marital status, and employment status). Figures in parentheses are standard errors clustered at the household level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 5. Estimated effects of drought on dietary diversity

	Cereals [1]	Pulses [2]	Edible oils [3]	Fruits & vegetables [4]	Animal-source Foods [5]	Processed Foods [6]
Panel A: Food expenditure (BDT/person/month)						
Standardized rainfall	-0.004	-0.123	-0.0621**	-0.0418	-0.0858**	-0.1874*
deviation	(0.010)	(0.026)	(0.021)	(0.012)	(0.028)	(0.0192)
Panel B: Calorie intake (kcal/person/month)						
Standardized rainfall	-0.031*	-0.122	-0.047***	-0.029***	-0.124***	-0.188***
deviation	(0.015)	(0.077)	(0.004)	(0.004)	(0.033)	(0.0465)
Panel C: Protein intake (g/person/month)						
Standardized rainfall	-0.031*	-0.149	0.0504***	0.0487***	-0.096**	-0.189***
deviation	(0.015)	(0.077)	(0.0030)	(0.005)	(0.033)	(0.042)
Panel D: Fat intake (g/person/month)						
Standardized rainfall	-0.044*	0.1320	-0.059***	-0.0527	-0.277***	-0.147**
deviation	(0.019)	(0.0891)	(0.005)	(0.030)	(0.044)	(0.049)

Notes: The dependent variable is the natural logarithm. Drought is included as a categorical variable, taking the value 1 if the standardized deviation in rainfall 12 months prior to the month of the survey) is below its long-term annual average. All regression models include household characteristics (proportion of area irrigated, household size, remittances, rainfall, and temperature) and individual characteristics (literacy, age, gender, marital status, and employment status). Figures in parentheses are standard errors clustered at the household level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 6. Marginal effects of droughts on food consumption and nutrition by age and gender of household members

	Expenditure (BDT/person/month)	Nutrients (intake/person/month)		
	Food	Calorie (kcal)	Protein (g)	Fat (g)
	[1]	[2]	[3]	[4]
Boys	-0.0558***	-0.0416***	-0.0431***	-0.0512***
	(0.0077)	(0.0087)	(0.0097)	(0.0134)
Girls	-0.0658***	-0.0539***	-0.0547***	-0.0609***
	(0.0077)	(0.0087)	(0.0097)	(0.0134)
Adult men	-0.0480***	-0.0312***	-0.0326***	-0.0480***
	(0.0077)	(0.0086)	(0.0097)	(0.0133)
Adult women	-0.0771***	-0.0609***	-0.0629***	-0.0775***
	(0.0077)	(0.0086)	(0.0097)	(0.0133)
Elderly men	-0.0495***	-0.0310***	-0.0342***	-0.0513***
	(0.0079)	(0.0089)	(0.0099)	(0.0137)
Elderly women	-0.0814***	-0.0716***	-0.0659***	-0.0872***
	(0.0080)	(0.0090)	(0.0101)	(0.0139)

Notes: The dependent variable is a natural logarithm. Drought is included as a categorical variable, taking the value 1 if the standardized deviation in rainfall 12 months prior to the month of the survey) is below its long-term annual average. All regression models include household characteristics (proportion of area irrigated, household size, remittances, rainfall, and temperature) and individual characteristics (literacy, age, gender, marital status, and employment status). Figures in parentheses are standard errors clustered at the household level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 7. Social safety nets and marginal effects of droughts on consumption and nutrition by age and sex

	Expenditure (BDT/person/month)	Nutrients (intake/person/month)		
	Food	Calorie (kcal)	Protein (g)	Fat (g)
	[1]	[2]	[3]	[4]
Cash transfer				
Boys	-0.0442***	-0.0419***	-0.0429***	-0.0480**
	(0.0077)	(0.0087)	(0.0097)	(0.0134)
Girls	-0.0538***	-0.0512***	-0.0515***	-0.0644***
	(0.0087)	(0.0085)	(0.0097)	(0.0134)
Men	-0.0455***	-0.0363***	-0.0369***	-0.0462***
	(0.0067)	(0.0086)	(0.0097)	(0.0134)
Women	-0.0657***	-0.0435***	-0.0443***	-0.0664***
	(0.0077)	(0.0084)	(0.0097)	(0.0133)
Elderly men	-0.0463***	-0.0383***	-0.0397***	-0.0444***
	(0.0080)	(0.0090)	(0.0100)	(0.0139)
Elderly women	-0.0744***	-0.0537***	-0.0511***	-0.0763***
	(0.0081)	(0.0091)	(0.0101)	(0.0140)
In-kind transfer				
Boys	-0.0421***	-0.0401***	-0.0454***	-0.0473***
	(0.0079)	(0.0089)	(0.0100)	(0.0138)
Girls	-0.0509***	-0.0502***	-0.0501***	-0.0556***
	(0.0080)	(0.0090)	(0.0101)	(0.0139)
Men	-0.0392***	-0.0314***	-0.0349***	-0.0435***
	(0.0079)	(0.0088)	(0.0099)	(0.0137)
Women	-0.0550***	-0.0416***	-0.0434***	-0.0543***
	(0.0078)	(0.0088)	(0.0099)	(0.0136)
Elderly men	-0.0434***	-0.0346***	-0.0381***	-0.0400***
	(0.0087)	(0.0098)	(0.0110)	(0.0152)
Elderly women	-0.0603***	-0.0506**	-0.0589*	-0.0630**
	(0.0089)	(0.0101)	(0.0113)	(0.0156)

Notes: Figures in parentheses are standard errors clustered at the household level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Appendix

Figure A1. Distribution of negative standardized deviation in annual rainfall from the long-term average (1980-2019), Bangladesh

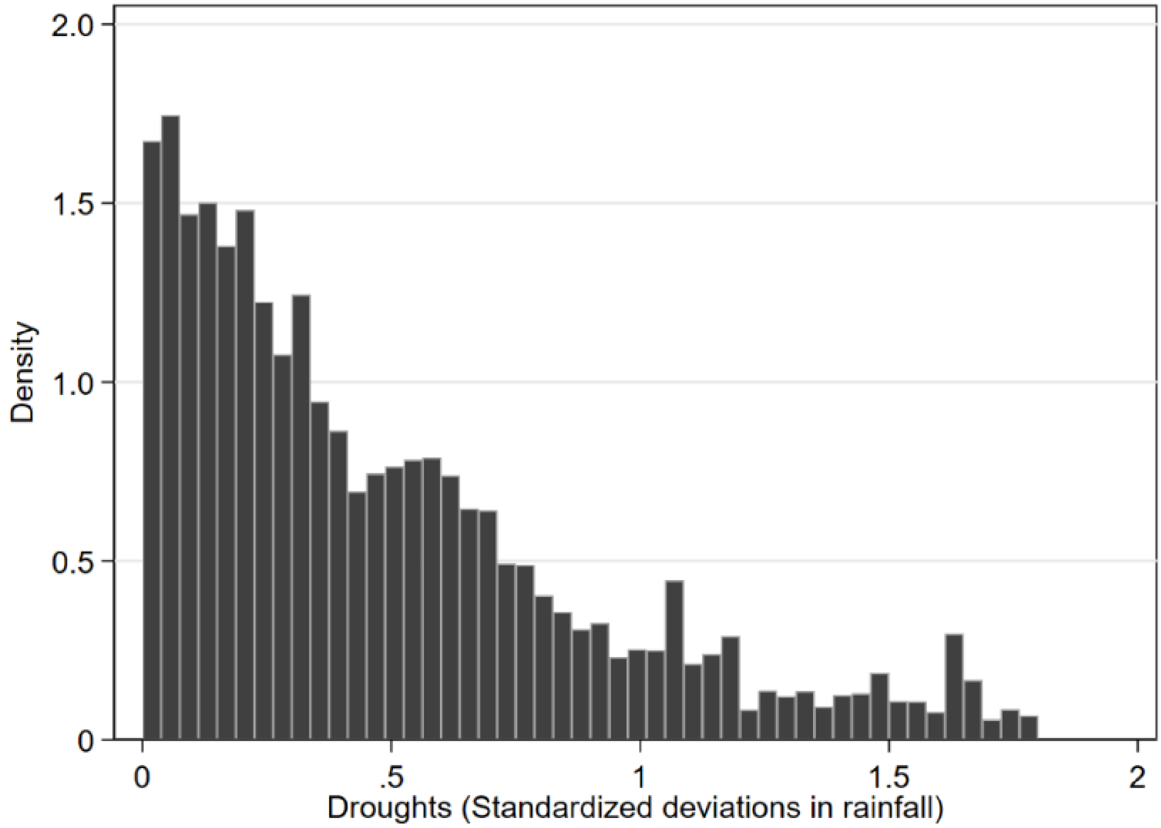


Figure. A2. Expenditure (BDT/person/month) and nutrient intake (per person/month), 2011-2019

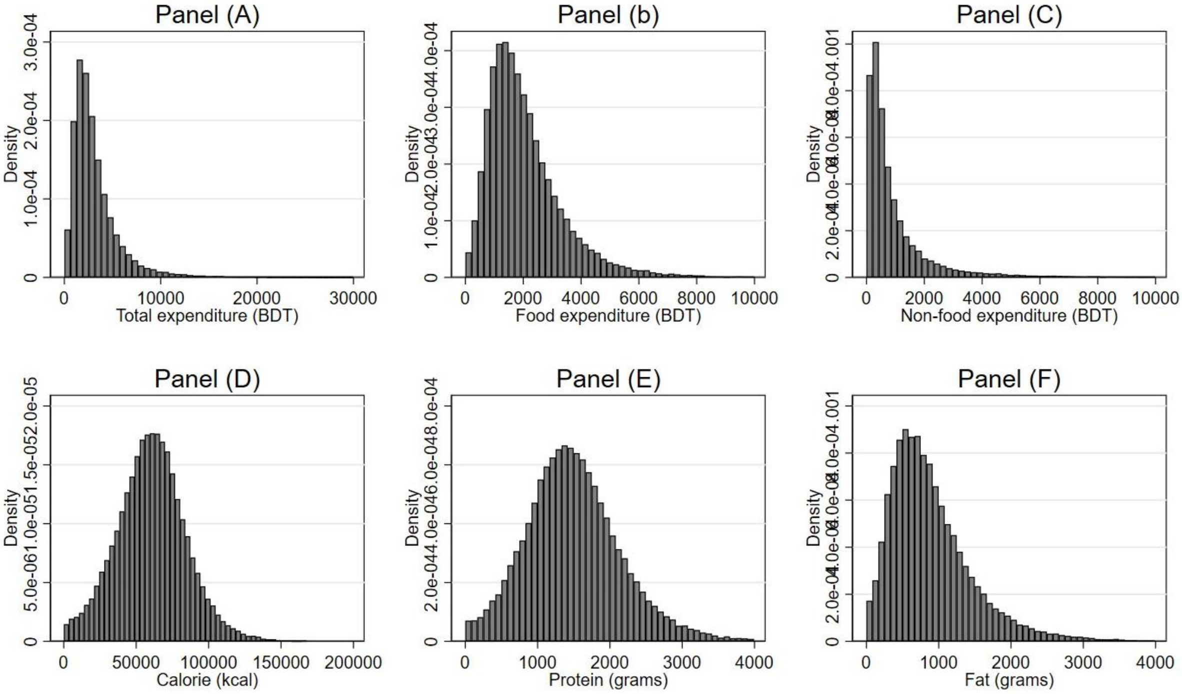


Figure A3. Percent households availing benefits of social safety nets, Bangladesh

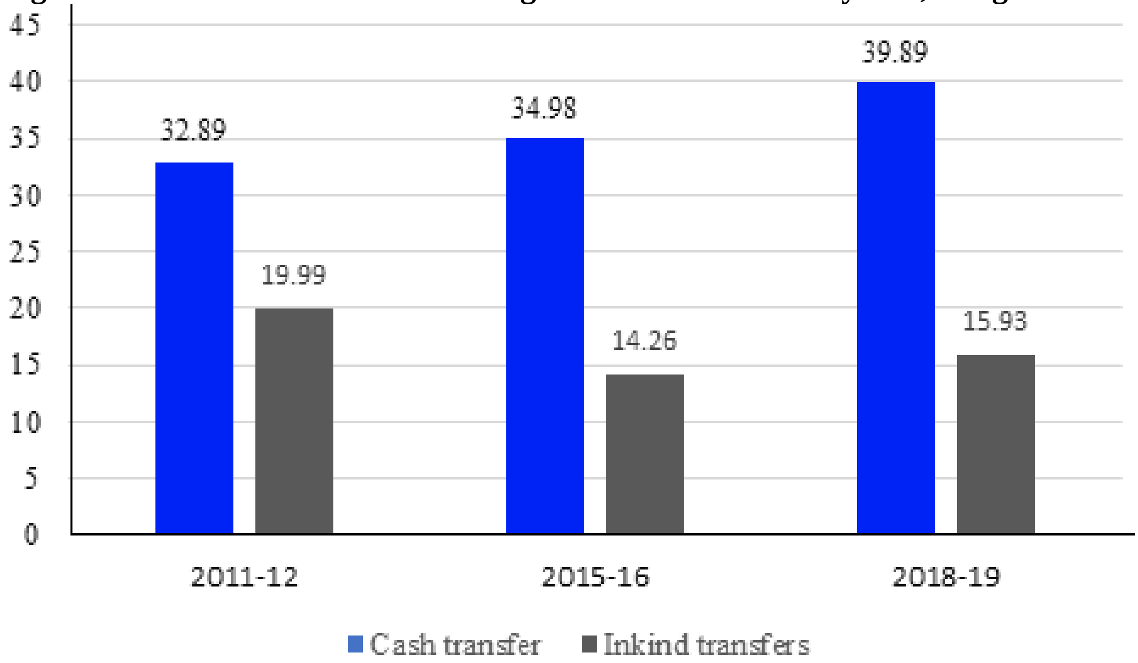


Table A1. Robustness check with winsorized outcomes

	Expenditure (BDT/person/month)			Nutrients (intake/person/month)		
	Total [1]	Non-food [2]	Food [3]	Calories (kcal) [4]	Protein (g) [5]	Fat (g) [6]
Standardized rainfall deviation	-0.065*** (0.0105)	-0.088*** (0.0184)	-0.039*** (0.0096)	-0.034** (0.0123)	-0.039** (0.0137)	-0.044* (0.0192)
Survey fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Individual fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Village X Survey fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.8211	0.7596	0.8088	0.7198	0.6906	0.648
F-stat	538.23	192.93	759.30	179.22	139.42	71.66
No. of observations	45,271	45,271	45,271	45,271	45,271	45,271

Notes: These regressions replicate Table 4 using winsorized outcomes ate 1% and 99% levels. Standard errors reported in parentheses are clustered at household level. ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.

Table A2. Robustness check with standard errors clustered at different levels

	Expenditure (BDT/person/month)			Nutrients (intake/person/month)		
	Total	Non-food	Food	Calories (kcal)	Protein (g)	Fat (g)
	[1]	[2]	[3]	[4]	[5]	[6]
	-0.093***	-0.139***	-0.046***	-0.034***	-0.033***	-0.048***
Standardized rainfall deviation	[0.0008]	[0.0016]	[0.0010]	[0.0008]	[0.0011]	[0.0014]
	(0.0010)	(0.0017)	(0.0011)	(0.0009)	(0.0012)	(0.0015)
Survey fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Individual fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Village X Survey fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.824	0.759	0.827	0.693	0.664	0.631
No. of observations	45,271	45,271	45,271	45,271	45,271	45,271

Notes: These regressions replicate Table 4 using clustered standard errors in [ ] at village level; and in ( ) district level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table A3. Robustness check with alternative model specification

	Expenditure (BDT/person/month)			Nutrients (intake/person/month)		
	Total	Non-food	Food	Calories (kcal)	Protein (g)	Fat (g)
	[1]	[2]	[3]	[4]	[5]	[6]
Standardized rainfall deviation	-0.069***	-0.116***	-0.046***	-0.010***	-0.088**	0.039***
	(0.0032)	(0.0055)	(0.0026)	(0.0025)	(0.0027)	(0.0044)
Survey fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Individual fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Village X Survey fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	45,271	45,271	45,271	45,271	45,271	45,271

Notes: These regressions replicate Table 4 using mixed-effects models. Standard errors, reported in parentheses, are clustered at the household level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table A4. Robustness check with alternative drought definitions

	Expenditure (BDT/person/month)			Nutrients (intake/person/month)		
	Total [1]	Non-food [2]	Food [3]	Calories (kcal) [4]	Protein (g) [5]	Fat (g) [6]
Standradized precipitation index	-0.059** (0.0225)	-0.125*** (0.0340)	-0.035 (0.0193)	-0.022* (0.0100)	-0.019 (0.0116)	-0.053* (0.0234)
Survey fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Individual fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Village X Survey fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.760	0.676	0.776	0.668	0.638	0.573
No. of observations	45,271	45,271	45,271	45,271	45,271	45,271

Notes: These regressions replicate Table 4, replacing standardized rainfall deviations with standardized precipitation index (<-1.5) as a measure of drought. Standard errors, reported in parentheses, are clustered at the household level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table A5. Robustness check with survey seasonal effects

	Expenditure (BDT/person/month)			Nutrients (intake/person/month)		
	Total	Non-food	Food	Calories (kcal)	Protein (g)	Fat (g)
	[1]	[2]	[3]	[4]	[5]	[6]
Standardized rainfall deviation	-0.094***	-0.139***	-0.047***	-0.035*	-0.033*	-0.048*
	(0.0124)	(0.0213)	(0.0106)	(0.0145)	(0.0162)	(0.0224)
Survey fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Individual fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Village X Survey fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.825	0.760	0.828	0.693	0.665	0.631
F-test	336.02	125.26	499.64	85.87	69.25	37.36
No. of observations	45,271	45,271	45,271	45,271	45,271	45,271

Notes: These regressions replicate Table 4 but include survey month fixed effects. Standard errors, reported in parentheses, are clustered at the household level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table A6. Descriptive statistics for the control variables, Bangladesh

Variable	2011-12	2015-16	2018-19
Household level characteristics			
Household size (No. of persons)	4.89	4.91	4.76
Percent households receiving remittances	25.12	31.19	37.09
Proportion area irrigated	63.06	64.30	65.33
Rainfall (meters)	2.3664 (0.9791)	2.2856 (0.7148)	1.6350 (0.5508)
Temperature (Degree Celsius)	24.63 (5.64)	24.08 (5.52)	24.09 (5.52)
Individual level characteristics			
Literacy (Percent)	52.82	63.67	69.94
Employment (Percent)	39.70	30.97	21.14
Marital status (Percent)			
Unmarried	46.20	40.98	36.52
Married	48.36	42.54	36.54
Widowed/divorced/separated	5.44	5.41	5.20

Notes: The table presents population-weighted statistics. The table includes only rural households, to account for attrition in the later survey periods, only the parent households were retained.