Stress under shocks: Food insecurity, weather shocks, and mental health in Malawi

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Abstract

It is believed that poor populations are disproportionately affected by mental illness due to the lack of employment, low income, food insecurity, and financial insecurity. We study the causal relationship between food insecurity and mental health in the presence of weather shocks. We use high-frequency phone survey data from the Living Standard Measurement Study (LSMS) high-frequency phone survey in Malawi and combine it with weather data from the Global Drought Observatory (GBO). We estimate the causal effects of food insecurity on mental illness by employing two-way fixed effects estimator and instrumental variable method. We instrument household food insecurity with weather shocks in a nearby community. We find that household food insecurity increases mental illness, and the effect is more pronounced when there is a drought shock within the community. Also, the adverse effects of food insecurity on mental illness are more pronounced for female respondents and female-headed households than for male respondents and male-headed households, respectively.

Keywords: Mental illness, food insecurity, weather shocks, longitudinal data, Malawi

JEL Codes: I15, I14, O13

1. Introduction

Mental health is one of the most important but least researched aspects of human health in developing countries (Deaton and Tortora 2015; Das et al. 2007). Even though mental illness has become a global public health concern, it still has not been adequately addressed in many developing countries (Sharan et al. 2009). Many factors contribute to mental illness, but food insecurity, poverty, and poor living conditions are a few leading determinants (Weigel et al. 2016; Ridley et al. 2020; Elgar et al. 2021; Nagata et al. 2021; Das et al. 2007). Extreme weather events such as floods and droughts can affect mental health directly as well as by disrupting agricultural operations and damaging properties. The weather-induced reduction in agricultural productivity can increase food insecurity, which in turn induces stress and anxiety (McLaughlin, Bozzola and Nugent 2023; Mulungu and Manning 2023). The potential three-way relationship among weather shocks, food insecurity, and mental health has not been well studied. Thus, we estimate the impacts of food insecurity on mental health in the presence of weather shocks in Malawi.

Malawi presents a unique case to study the relationship between food insecurity, mental health, and weather shocks. As of May 2022, approximately 5.4 million people were experiencing moderate to severe chronic food insecurity (IPC 2022) due to high poverty rates, limited agricultural productivity, and climatic shocks, the situation is exacerbated by extreme weather events like droughts, floods, and cyclones that disrupt agricultural systems (World Bank Group 2019). These shocks not only worsen food insecurity but also contribute to psychological stress, anxiety, and depression as individuals struggle to access sufficient and nutritious food. The compounded effects of poverty and climatic instability highlight the vulnerability of Malawi's population to mental health challenges and the need for integrated approaches to enhance resilience and address the root causes of these crises.

The study of mental health and food insecurity is not a new topic, but the existing studies have significant limitations. First, most existing studies have been focused on the relationship between food insecurity and mental health at aggregated regional or country levels (Sharpe and Davison 2022; Elgar et al. 2021; Maynard et al. 2018). Some experimental studies have been conducted on relatively small populations within a community (Cole and Tembo 2011; Hadley and Patil 2008), but they are in short supply. Second, the majority of empirical studies examine the relationship using cross-sectional data (Trudell et al. 2021; Kamelkova, Strømme and Diaz 2023), which cannot remove the time effects and overlooks the potential dynamic effects. Third, most studies on food insecurity and mental health are correlational studies (Maynard et al. 2018). Only a handful of papers document the causal effects of food insecurity on mental health (Cole and Tembo 2011; Thomas, Miller and Morrissey 2019; Gundersen and Kreider 2009), but these studies focus on specific regions of a country raising questions about external validity. Finally, the literature on food insecurity and mental health has mostly overlooked other covariate shocks such as weather shocks raising questions on where the estimated relationship suffers omitted variable bias.

This study bridges these gaps by investigating how weather shocks affect the relationship between food insecurity and mental health issues. Understanding how food insecurity affects mental health in the presence of weather shocks has important implications for public health and agricultural policies in rural areas where the incidence of food insecurity is high, agriculture is the mainstay of life, and access to healthcare services is poor. We leverage the availability of high-frequency geo-coded microdata from Malawi and match them with weather (rainfall and temperature) data at a spatial resolution of 0.25 degree obtained from the Global Drought Observatory (GBO). Rainfall data are converted into Standardized Precipitation Indexes (SPI), which we use to construct two weather shock measures: drought and flood in the agricultural

seasons. Food insecurity is measured with the Food Insecurity Experience Scale (FIES) and mental health is measured with the Patient Health Questionnaire-8 (PHQ-8). We combine the high-frequency phone surveys (HFPS) data with weather data to tease out the effects of weather shocks on the relationship between food insecurity and mental health outcomes. The HFPS data are monthly phone surveys that cover all regions of Malawi and span between May 2020 and May 2023. The HFPS sample is drawn from the 4th round of the Living Standards Measurement Study - Integrated Surveys on Agriculture (LSMS-ISA) in Malawi.

We estimate the impacts of food insecurity on mental health in the context of weather shock exposure using a two-way fixed effect estimator, accounting for both individual and time-fixed effects. We interact variables measuring weather shocks with household food insecurity measures to explore the effects of food insecurity on mental health in the presence of weather shocks. Further, we use instrument food insecurity with weather shocks in a neighboring community to address the potential endogeneity of food insecurity. Results show that a 1% increase in household food insecurity increases the prevalence of mental illness by 7.4% percentage points. The impact of food insecurity on mental health becomes stronger when households experience drought shocks. Flood shocks, on the other hand, do not appear to significantly modify the relationship between food insecurity and mental health.

This paper makes significant contributions to the existing literature in several ways. First, it addresses the limited number of rigorous empirical studies on the relationship between weather-induced food insecurity and mental health by focusing on this critical but under-researched linkage. Second, unlike most studies that rely on cross-sectional data or data from small geographic areas, this study utilizes a high-frequency nationally representative panel dataset, allowing for broader geographic coverage and temporal analysis. Lastly, this paper employs several econometric

techniques to establish a causal relationship between mental health and food insecurity, which could address potential endogeneity issues and offer robust insights into this complex dynamic.

The rest of the paper is structured as follows. Section 2 gives a literature review on this topic. Section 3 describes the data used in this study. Section 4 outlines the empirical strategy while Section 5 presents our results and discussion. Section 6 concludes.

2. Literature Review

The interplay between food insecurity and mental health has emerged as a critical concern in low- and middle-income countries, where agricultural livelihoods remain vulnerable to climatic variability. While research consistently demonstrates an association between food insecurity and adverse mental health outcomes, establishing causality has proven challenging due to methodological limitations and the complex, bidirectional nature of this relationship. Rainfall shocks - an exogenous source of variation in food security - offer a promising pathway to better understand these causal mechanisms, particularly in regions heavily dependent on rain-fed agriculture.

Recent research has begun to explore how environmental factors, particularly climate change, affect mental health through various pathways. Atwoli et al. (2022) document how climate change exacerbates mental health issues in Africa through both direct and indirect pathways, including economic instability and displacement. Garrett-Wright, Malin and Jones (2023) specifically highlight how farmers' lack of control over weather conditions serves as a significant stressor affecting mental health. Rainfall is one of the primary drivers of agricultural productivity, particularly in sub-Saharan Africa, where rain-fed agriculture remains the dominant livelihood strategy. Cole and Tembo (2011) found that food insecurity during dry seasons had a more pronounced impact on mental health, suggesting that seasonal rainfall variability plays a critical

role in shaping psychological outcomes. Studies like those by Garrett-Wright et al. (2023) and Nuvey et al. (2020) have shown how climatic shocks, such as droughts and floods, lead to agricultural losses, contributing to food insecurity and subsequent mental health challenges. Garrett-Wright et al. (2023) identified weather variability as a significant stressor for farmers, while Nuvey et al. (2020) highlighted the psychological toll of livestock losses due to environmental shocks in Ghana.

Multiple studies have documented robust associations between food insecurity and adverse mental health outcomes across Africa. In rural Zambia, Cole and Tembo (2011) found that food insecurity significantly exacerbated mental health problems, with effects particularly pronounced during the dry season when food scarcity peaked. Their multilevel regression analysis revealed higher psychiatric symptom scores among food-insecure households, suggesting seasonal variations in this relationship. This association appears consistent across different contexts. Jones (2017), analyzing data from 149 countries, identified a clear dose-response relationship where increasing levels of food insecurity progressively worsened mental health outcomes. In sub-Saharan Africa specifically, Sweetland et al. (2019) found substantial rates of moderate to severe mental distress among food-insecure populations: 35.5% in Nigeria, 30.8% in Uganda, and 30.4% in Ghana. A nationally representative study in South Africa by Sorsdahl and Stein (2010) further confirmed these patterns, showing that 38% of households experienced food insufficiency, significantly correlating with the increased prevalence of DSM-IV disorders.

Trudell et al. (2021) noted in their systematic review of 64 studies, a critical limitation persists: most research relies on cross-sectional data, making it difficult to establish causality. Cole and Tembo (2011) made progress toward addressing these limitations through their longitudinal study in rural Zambia, which found that food insecurity's impact on mental health varied seasonally.

However, even this improved design cannot fully address endogeneity concerns, as sometimes variant unobserved factors might influence both food security and mental health outcomes. This methodological constraint underscores the need for research designs that can better identify causal pathways between food insecurity and mental health outcomes.

Understanding the causal relationship between food insecurity and mental health through rainfall shocks has critical implications for policy and intervention design. As documented by Nuvey et al. (2020), agricultural shocks profoundly affect farmers' mental well-being, suggesting that weather variability could serve as an exogenous source of variation to establish causality. This approach is particularly relevant as Rose et al. (2023) demonstrate how external shocks can exacerbate mental health challenges in farming communities.

While the association between food insecurity and mental health is well-documented, establishing causality remains a critical research frontier. Using rainfall shocks as an identification strategy offers a rigorous approach to understanding this relationship, potentially informing interventions that address both immediate food security needs and mental health support in contexts where climate variability increasingly threatens agricultural livelihoods.

3. Data

To analyze the three-way relationship between food insecurity, mental health, and weather shocks in Malawi, our data are gathered from multiple sources. The food insecurity and mental health data are from the World Bank's Living Standards Measurement Study - Longitudinal High-Frequency Phone Surveys (HFPS) and combined with Living Standards Measurement Study - Integrated Surveys on Agriculture (LSMS-ISA) household survey data. The weather data are gathered from the Global Drought Observatory (GBO).

3.1 High-Frequency Phone Surveys

The World Bank's Living Standards Measurement Study - Longitudinal High-Frequency Phone Surveys (HFPS) for Malawi were conducted between May 2020 and May 2023 (World Bank 2020). The HFPS is implemented by the National Statistical Office (NSO), which includes 21 rounds of phone interview surveys. The first 12 rounds were conducted monthly during May 2020 and June 2021 and the rest of the rounds were collected bi-monthly. The sampling design for the high-frequency phone surveys (HFPS) is based on the face-to-face LSMS-ISA survey - Malawi Integrated Household Panel Survey (IHPS) 2019. The 2019 LSMS-ISA Malawi data are a nationally representative sample of 3,181 households, which is representative at the national, urban/rural, and regional levels. Among the 3,181 households interviewed during the IHPS in 2019, 73 percent of households provided at least one phone number. Of those contacted, 1,729 households were fully interviewed through phone surveys.

Our empirical approach relies on longitudinal analysis of household-level measures of food insecurity and respondent-level measures of mental health. Since mental health data was only collected in rounds 6, 9, and 18, we focus exclusively on the sample that appears in all three of these rounds of high-frequency phone surveys (HFPS). This provides us with a sample size of 1,263 unique households in Malawi. Our total balanced panel is 3,789 households across three rounds of survey. Using high-frequency phone surveys (HFPS) is likely to have some selection biases. We follow Abay et al. (2023) and Rudin-Rush et al. (2022) to use mean sampling weights to mitigate the phone survey selection bias. The presence of selection bias and non-response bias means that results based on the raw data likely underestimate the real impact of food insecurity on mental health because poorer households are both less likely than wealthier households to have phones and more likely to be vulnerable and experience food insecurity. The phone survey sampling weights build on the sampling weights for the pre-pandemic survey to ensure weights

are representative of the population and account for demographic variables like age, income, and location. We use survey mean sampling weights to adjust for differences in phone ownership and non-response bias. Additionally, our study examines how food insecurity impacts mental health under weather shocks, using data collected entirely during the COVID-19 period. We recognize that the unique context of the pandemic likely influenced mental health outcomes due to factors such as COVID-19 infection rates and shutdown policies. To account for these confounding factors, we include controls for COVID-19 infection rates and time-fixed effects, capturing temporal trends and mitigating the impact of pandemic-related variability on our analysis. While we acknowledge the limitation of not having pre-COVID-19 mental health data, this does not undermine the validity of our study. Since all mental health data were collected within the COVID-19 period, the focus of our analysis is on relative variations in mental health outcomes driven by food insecurity and weather shocks, rather than on absolute mental health levels. By controlling for pandemic-related influences, we aim to isolate the relationship between food insecurity, weather shocks, and mental health as much as possible. We recognize that future studies incorporating pre- and post-COVID-19 data could provide deeper insights into the broader impacts of the pandemic on mental health. However, our study remains a valuable contribution to understanding how intersecting crises, such as food insecurity and weather shocks, affect mental health during periods of global pandemic.

3.2 Mental health indicator

Mental health indicators are our key outcome variables, which are drawn from rounds 6, 9, and 18 of the HFPS survey in Malawi. In the HFPS survey, individual mental health was assessed using the Patient Health Questionnaire-8 (PHQ-8). The Patient Health Questionnaire-8 (PHQ-8) is a standardized tool used to assess depressive symptoms in individuals (Kroenke et al. 2009). It

is a shortened version of the PHQ-9, excluding the ninth question about suicidal ideation. The omission of the suicide-related question (item 9) makes the PHQ-8 less sensitive to ethical concerns in non-clinical or remote settings. It is commonly chosen for population-level research where immediate intervention is not feasible. The PHQ-8 consists of eight items, each reflecting one of the core symptoms of major depressive disorder (MDD) as defined in the DSM (Diagnostic and Statistical Manual of Mental Disorders). These symptoms include loss of interest or pleasure in activities, feelings of hopelessness, fatigue, sleep disturbances, changes in appetite, low self-worth, difficulties with concentration, and psychomotor changes such as restlessness or slowed movement. Participants are asked to indicate how often they experienced these symptoms over the past two weeks. It elicits psychiatric symptomatology by asking the number of days the person experienced mental health issues in the past two weeks. The respondents were provided with four options to choose from: "Not at all-0", "Several days-1", "More than half the days-2", and "Nearly every day-3". We calculated each respondent's total score by summing the scores of all eight questions, with the total score ranging between 0 and 24. Standard cut-off points are often used to classify the severity of depression: 0–4 represents no or minimal depression, 5–9 mild depression, 10–14 moderate depression, 15–19 moderately severe depression, and 20–24 severe depression. These classifications are useful for identifying individuals who may benefit from further assessment or intervention. A score of ≥ 10 is considered a depressive symptom in both clinical and research settings (Kroenke et al. 2009).

Table 1 Summary of mental health measures

Variable	Obs	Mean	SD	Min	Max
Mentally ill (rawscore>=10)	3789	0.0449	0.207	0.00	1.00
Mental health (rawscore)	3789	2.9335	3.283	0.00	24.00
Low energy	3789	0.4885	0.716	0.00	3.00

Restlessness/slowness	3789	0.2024	0.500	0.00	3.00
Sleeping problems	3789	0.3874	0.696	0.00	3.00
Little interest	3788	0.4131	0.692	0.00	3.00
Trouble concentrating	3789	0.2378	0.547	0.00	3.00
Self-worth	3789	0.4217	0.704	0.00	3.00
Feeling down	3789	0.5131	0.738	0.00	3.00
Appetite issues	3789	0.2695	0.587	0.00	3.00

3.3 Food insecurity experience scale

The Food Insecurity Experience Scale (FIES) is a globally recognized tool developed by the Food and Agriculture Organization (FAO) of the United Nations to measure individual and household food insecurity (Ballard, Kepple and Cafiero 2013). The FIES assesses food insecurity across multiple severity levels, ranging from mild (uncertainty about food availability) to severe (skipping meals or going entire days without eating). The FIES consists of eight dichotomous questions (Yes/No) that inquire about a respondent's experiences with food insecurity. These questions address the psychological and behavioral responses to food insecurity, such as worrying about the ability to obtain food, compromising on the quality or quantity of food, reducing portion sizes, skipping meals, or going hungry. The responses to these questions are analyzed using a statistical approach based on the Rasch model, which estimates the severity of food insecurity on a continuous scale. This model enables comparison across different populations and geographic regions, making the FIES a robust tool for cross-country studies and monitoring global food insecurity trends. The scale categorizes food insecurity into three levels: 1. Mild: Worrying about food or reducing dietary quality. 2. Moderate: Reducing food quantity or skipping meals. 3. Severe: Experiencing hunger and going without food for a day or more. In our study on the relationship

between food insecurity, mental health, and weather shocks during the COVID-19 period, the FIES is an ideal indicator for measuring food insecurity. Its standardized design ensures consistency, while its ability to capture different severity levels provides nuanced insights into how varying degrees of food insecurity impact mental health outcomes.

Table 2 Summary of food insecurity variables

Variable	Obs	Mean	SD	Min	Max
Food insecurity (Yes=1, No=0)	3789	0.7707	0.420	0.00	1.00
FIES Raw score	3789	4.1040	2.940	0.00	8.00
Mild food insecurity	3789	0.7707	0.420	0.00	1.00
Moderate food insecurity	3789	0.5946	0.491	0.00	1.00
Severe food insecurity	3789	0.3075	0.462	0.00	1.00
Worried about food	3789	0.5756	0.494	0.00	1.00
Went w/out eating for a whole day	3789	0.1668	0.373	0.00	1.00
Skipped meals	3789	0.5574	0.497	0.00	1.00
Food shortage	3789	0.4297	0.495	0.00	1.00
Went hungry	3789	0.4772	0.500	0.00	1.00
Poor nutrition	3789	0.6540	0.476	0.00	1.00
Ate limited variety	3789	0.6653	0.472	0.00	1.00
Ate less	3789	0.5780	0.494	0.00	1.00

3.4 Weather shocks indicators

The rainfall measure data is sourced from the Global Drought Observatory (GBO), a component of the Copernicus Earth Observation program under the European Union's Space Programme. Specifically, SPI-3 products for Malawi. The Standardized Precipitation Index (SPI)

is calculated using precipitation data from the Global Precipitation Climatology Centre (GPCC)[1]. SPI-3, the 3-month accumulation period index, is utilized to monitor meteorological droughts and assess their intensity. The index is computed at a spatial resolution of 0.25 degree, using monthly precipitation data for the reference period 1981-2010. We use information on the geographic locations—the modified geocodes available for each household—to combine the survey data with spatially explicit information on precipitation.

The SPI measures rainfall conditions in a location for a specified accumulation period, relative to the previous 30-year average for that location (McKee, Doesken and Kleist n.d.). The index is based on the cumulative probability of a given rainfall event occurring. The rainfall distribution is smoothed using a moving bandwidth for the period of precipitation specified (typically 1-month, 3-month, 6-month, or 12-month) and fitted to a gamma distribution. Representing the rainfall distribution with a cumulative probability function allows the identification of spatial weather shocks of varying degrees of severity within a given period. Shocks are constructed by using different standard deviation thresholds, where positive deviations indicate higher than normal rainfall and negative deviations indicate lower than normal rainfall.

We use a 3-month SPI (SPI3) to construct two weather shock variables adopting the following methodology (Staffieri, Sitko and Maluccio 2023). Rainfall is important to agricultural production and crops are sensitive to weather shocks. Based on the major crop calendar in Malawi, the growing season for the major crops (maize, rice and sorghum) is between October and April. Hence, we use weather indicators for these 7 months which are considered as agricultural season rainfall. For each round, we use the agricultural season rainfall before the interview month. For

[1] A new version of the SPI-3 using data from Climate Hazards Group InfraRed Precipitation (CHIRPS) has been released on the GBO's website which we intend to use for subsequently. CHIRPS has a finer spatial resolution of 0.05 degrees as compared to the GPCC's 0.25 degrees.

example, for interview round 6 we use weather data between October 2019 to April 2020; for interview round 9 we use October 2020 to April 2021; for round 18 we use October 2022 to April 2023. We identify localized drought shocks by constructing a binary variable that takes a value of one when SPI3 <= -2.0 and zero otherwise. We identify localized flood shocks by constructing a binary variable that takes a value of one when SPI3 >= 2.0 and zero otherwise. By focusing on extreme values of SPI3, we capture events in both the left and right tail of the rainfall distribution.

Table 3 SPI values and indicators

SPI	Conditions	Weather shock indicator
SPI<-2.0	Extremely dry	Drought (Yes=1, No=0)
SPI >2.0	Extremely wet	Flood Drought (Yes=1, No=0)

4. Empirical Model

4.1 Two-Way Fixed Effects Estimator

We employ a two-way fixed effects estimator to control for unobserved heterogeneity. Equation (1) provides an estimating equation for the relationship between mental health and food insecurity under weather shocks.

$$Mental\ Health_{ijt} = \alpha_0 + \alpha_1\ Food\_insecurity_{it} + \alpha_2\ Weather\_shocks_{ijt-1} + \alpha_3(Weather\_shocks_{ijt-1} * Food\_insecurity_{it}) + \Theta X_{it} + \mu_i + c_t + \varepsilon_{ijt} \quad (1)$$

Where $Mental\ Health_{it}$ denotes the mental health status of individual j in household i at time t, $Food\ Insecurity_{it}$ denotes the food security status in household i at time t, $Weather\ Shocks_{it-1}$ is a binary variable equal to one if community j experienced a negative deviation (SPI3 < -2.0) from normal rainfall in year t-1 and zero otherwise; if community j experienced a positive

deviation (SPI3 > 2.0) from normal rainfall in year t-1 and zero otherwise. We regress drought and flood shocks separately. X_{it} denotes the vector of control variables, such as household size, consumption expenditure, employment status, etc. We also control the exposure to COVID-19 because the pandemic posed direct health threats and disrupted social and economic activities (Sharpe et al. 2021).

4.2 Endogeneity issues

In examining the causal relationship between food insecurity and mental health, addressing potential endogeneity is crucial to ensure unbiased and reliable estimates. Endogeneity may arise due to reverse causality, where mental health issues could affect a household's ability to secure food, or due to omitted variable bias from unobserved factors such as community-level shocks or socio-economic conditions that simultaneously impact both food insecurity and mental health.

To mitigate these concerns, we employ an instrumental variable (IV) approach and include weather shocks in nearby regions as instruments. Weather shocks in nearby communities serve as an exogenous source of variation, as they are likely to affect food availability and prices but are unlikely to directly influence the mental health of households in the primary study area. These instruments are chosen to satisfy the relevance and exclusion restrictions. Weather shocks are closely linked to agricultural production and food supply, ensuring relevance, while their spatial and temporal separation reduces the likelihood of a direct impact on mental health

Despite these measures, we acknowledge potential limitations. For instance, the exclusion restriction for weather shocks may not fully hold if indirect pathways, such as shared market dynamics, affect both communities. To address this, we include community-level fixed effects and control for regional weather patterns, ensuring that our instruments capture idiosyncratic shocks rather than broader trends. Additionally, a robustness check is performed to compare the results

from IV estimates with those obtained using a two-way fixed effects estimator. By carefully addressing these endogeneity concerns, we aim to isolate the causal impact of food insecurity on mental health, providing insights that are policy-relevant and grounded in rigorous methodological frameworks.

5. Results

5.1 Main results

The relationship between food insecurity and mental health is further complicated by weather shocks such as drought and flood shocks. Table 4 examines the effects of food insecurity and weather shocks on mental health, using the mental health rawscore as the dependent variable. In Model (1), we only include food insecurity indicators as independent variables. A one-unit increase in food insecurity is associated with an increase in mental health problems by approximately 0.074 units, which reflects the direct and substantial psychological burden of food insecurity on individuals.

Table 4 Effects of food insecurity under weather shocks on mental health.

	DV: Mental Health Rawscore				
	(1)	(2)	(3)	(4)	(5)
FIES Rawscore	0.074***	0.074***	0.065***	0.074	0.074
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Drought shock (t-1)		0.045	0.044		
		(0.030)	(0.047)		
FIES X Drought shock			0.022**		
			(0.010)		
Flood shock				-0.091	

				(0.063)	
FIES X Flood shock					-0.006
					(0.022)
Controls	Yes	Yes	Yes	Yes	Yes
Household Fixed Effects	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Obs	3405	3405	3405	3405	3405

Notes: Standard errors are in parentheses. Level of significance *p < .10, **p < .05, ***p < .01.

In Models (2) and (3), we found that drought shocks alone do not have a statistically significant direct effect on mental health. However, the interaction term between food insecurity and drought in Model (3) is positive and statistically significant. This finding suggests that while drought itself may not directly worsen mental health, it amplifies the negative mental health impacts of food insecurity. Households facing both food insecurity and drought are likely to experience compounded stress, highlighting the need for targeted interventions in drought-prone areas.

Flood shocks, on the other hand, appear to have a weaker and more context-specific impact on mental health. The coefficient for flood shocks in Model (4) is negative but not statistically significant, and the interaction term between food insecurity and flood in Model (5) is also insignificant. This suggests that, unlike drought, floods may not universally exacerbate the mental health effects of food insecurity. Adaptive strategies or resilience mechanisms in flood-prone areas could play a role in mitigating these impacts, though further research is needed to confirm this hypothesis.

The graphs below examine the relationships between food insecurity, drought, flood, and various mental health outcomes. Each graph highlights specific dimensions of these relationships, focusing on how food insecurity interacts with weather shocks to affect mental health components like low energy, sleep problems, self-worth, and others.

Food insecurity, measured by the FIES Rawscore and binary variable food insecurity, emerges as a significant driver of mental health issues. Across all domains, higher food insecurity is associated with worsening outcomes such as increased feelings of low energy, self-worth issues, and difficulty concentrating. These effects are consistent across most mental health components, which highlights the pervasive psychological burden of food insecurity on individuals and households.

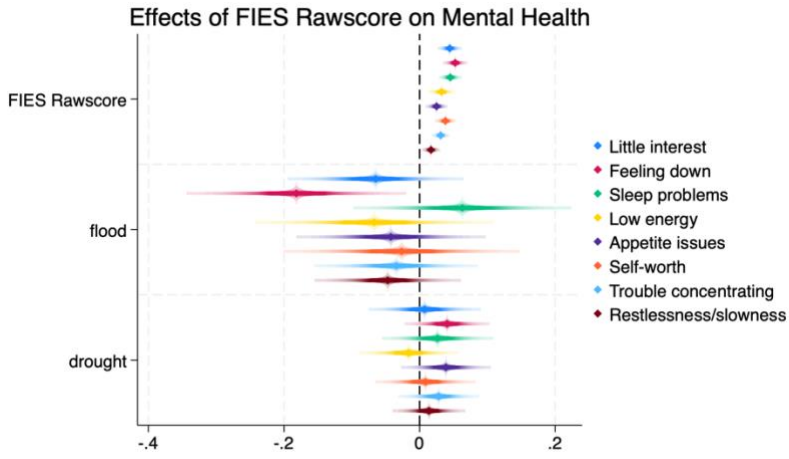

Figure 1 Effects of FIES Rawscore on Mental Health

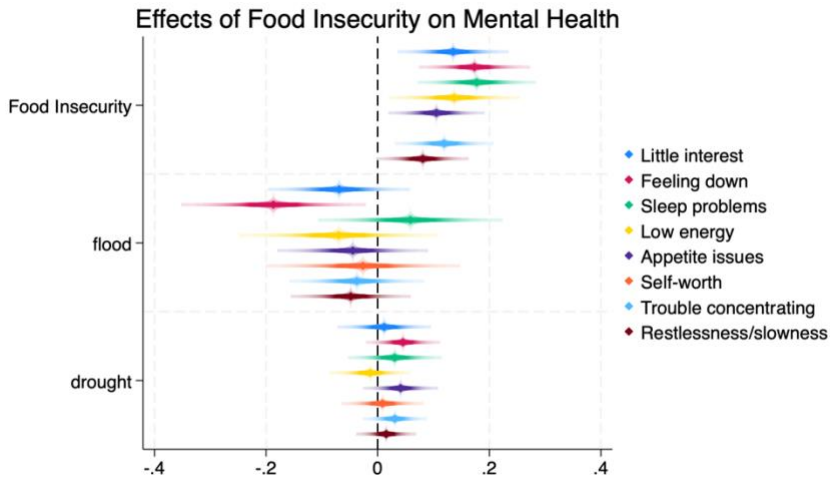

Figure 2 Effects of Food Insecurity on Mental Health

Droughts amplify the negative effects of food insecurity on mental health more consistently than floods. The combination of food insecurity and drought results in pronounced effects on key mental health outcomes such as sleep problems, low energy, and trouble concentrating. This suggests that the compounding stress of drought-related food shortages and insecurity intensifies the psychological strain on affected populations. In contrast, the interaction between food insecurity and floods produces more variable outcomes. While floods exacerbate specific mental health issues, such as feelings of sadness and difficulty concentrating, their overall impact is less consistent compared to droughts. This may reflect adaptive strategies or regional differences in coping mechanisms for flood-related disruptions.

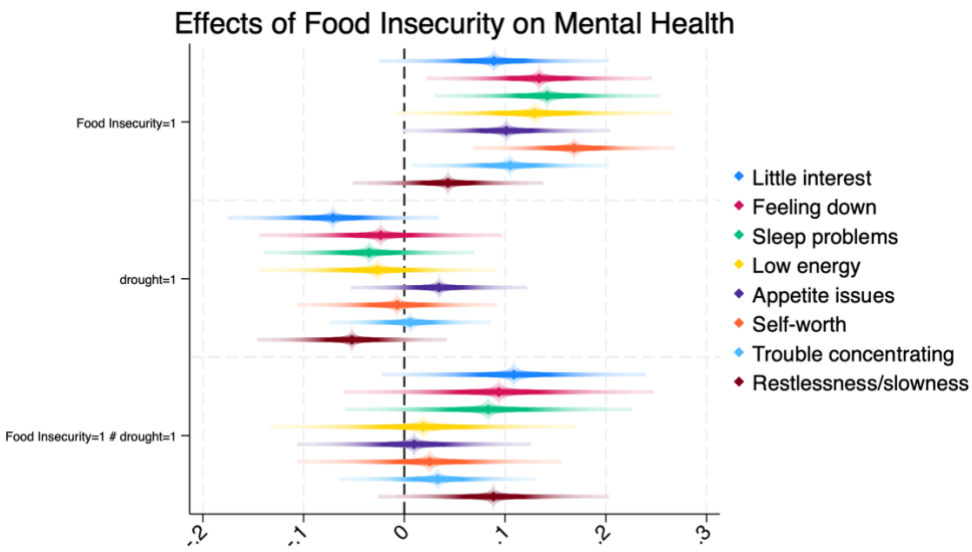

Figure 3 Effects of Food Insecurity on Mental Health under Drought Shock

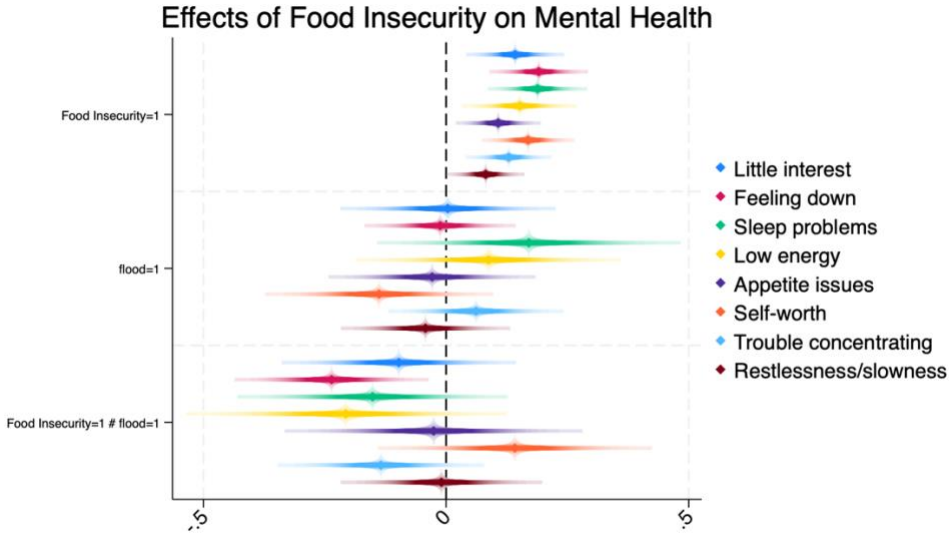

Figure 4 Effects of Food Insecurity on Mental Health under Flood Shock

5.2 Heterogeneity

The impacts of food insecurity on mental health are not uniform across populations, which are more pronounced for certain vulnerable groups (Ivers and Cullen 2011; Maynard et al. 2018). This

section explores how these effects vary by gender and wealth quintiles, with a highlighting of the moderating role of drought as an environmental stressor.

Table 5 presents the regression results analyzing the interaction between food insecurity (FIES) and drought shocks on mental health by respondent's gender and household head's gender. The impact of food insecurity on mental health is more pronounced for female-headed households and female respondents. Drought shock amplifies the negative mental health effects of food insecurity for female respondents. For female-headed households, there is a 17.9% increase in mental health impacts under drought shocks. Given these findings, we can expect that weather shocks will likely lead to increased mental health issues. Consequently, as food insecurity worsens due to these environmental stressors, the mental health impacts are expected to intensify, particularly for vulnerable groups like females.

Table 5 Effects of food insecurity under drought on mental health by gender

	DV: Mental Health Rawscore							
	Respondent's gender				Household head's gender			
	female		male		female		male	
FIES x Drought	0.125**	0.122*	-0.022	0.056	0.179**	0.100**	-0.005	0.031
	(0.060)	(0.065)	(0.049)	(0.045)	(0.021)	(0.043)	(0.045)	(0.103)
Constant	7.448***	7.106	3.404**	60.345*	9.441***	-0.464	3.696**	186.342*
	(1.816)	(83.679)	(1.490)	(35.401)	(2.284)	(35.228)	(1.337)	(94.418)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	No	Yes	No	Yes	No	Yes	No	Yes
Round FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Observations	1324	1189	2081	1986	680	649	2725	2717

Notes: Standard errors are in parentheses. Level of significance *p < .10, **p < .05, ***p < .01.

Table 6 examines how the interaction between food insecurity and drought affects mental health across wealth quintiles. The analysis reveals significant heterogeneity in these effects, highlighting the disproportionate burden borne by poorer households. For the wealthiest households (Quintile 1, representing 5.86% of the sample), the interaction term is negative and statistically significant (-0.389). This indicates that drought mitigates the mental health impacts of food insecurity for these households, likely due to their access to coping mechanisms such as savings, insurance, or diversified livelihoods. In contrast, the poorest households (Quintile 5, representing 33.49% of the population) experience a positive and significant interaction effect (0.135). This finding highlights the heightened vulnerability of poorer households, who often lack the financial and social resources needed to buffer against the compounded effects of food insecurity and drought.

Table 6 Effects of food insecurity under drought on mental health by wealth quantile

	DV: Mental Health Rawscore				
	(1)	(2)	(3)	(4)	(5)
FIES x Drought	-0.389**	0.134	0.046	0.166**	0.135**
	(0.185)	(0.134)	(0.097)	(0.067)	(0.062)
Constant	-155.013	49.053	-2.029	49.863	39.607
	(221.368)	(109.069)	(86.393)	(67.285)	(59.019)
Controls	Yes	Yes	Yes	Yes	Yes

Household FE	Yes	Yes	Yes	Yes	Yes
Round FE	Yes	Yes	Yes	Yes	Yes
Observations	198	384	654	993	1263

Notes: Standard errors are in parentheses. Level of significance *p < .10, **p < .05, ***p < .01.

To address the impacts of food insecurity on mental health under weather shocks, it is essential to implement targeted food security programs in different areas and among diverse groups. Local governments need to invest in climate resilience and adaptation strategies and strengthen social safety nets to build more resilient and informed communities.

6. Conclusion and Discussion

This study explores the complex interplay between food insecurity, mental health, and weather shocks in Malawi, providing critical insights into an under-researched but increasingly important area of public health and environmental policy. By leveraging high-frequency, geocoded panel data and integrating it with rainfall-based weather indicators, we examine how food insecurity influences mental health outcomes in the presence of environmental stressors like droughts and floods. The findings highlight the pervasive psychological burden of food insecurity on individuals and households. Food insecurity is consistently associated with worsening mental health outcomes, including increased feelings of low energy, self-worth issues, and trouble concentrating. These impacts are further amplified in the context of drought shocks, underscoring the compounded stress that environmental and economic challenges place on vulnerable populations. In contrast, the effects of floods on mental health are less consistent and may depend on adaptive strategies or regional resilience.

The heterogeneity analysis reveals that the mental health impacts of food insecurity and weather shocks are disproportionately borne by certain groups. Female respondents and female-headed households are particularly vulnerable, with droughts exacerbating the psychological toll of food insecurity more significantly for these groups. Similarly, poorer households, lacking access to financial and social safety nets, face greater mental health challenges under food insecurity and drought conditions. In contrast, wealthier households appear more resilient, likely due to better access to coping mechanisms such as savings and diversified livelihoods.

This research contributes to the literature by using robust econometric techniques to establish causal relationships and by employing longitudinal data that captures temporal and geographic variations. The findings have important policy implications. Targeted interventions are needed to address the dual challenges of food insecurity and environmental shocks. For drought-prone areas, climate-resilient agricultural practices and mental health support programs should be integrated into food security initiatives. For flood-prone regions, strategies should focus on strengthening community resilience and addressing specific mental health challenges.

This study provides valuable insights into the relationship between food insecurity and mental health in the context of weather shocks. However, several limitations must be acknowledged to contextualize the findings and inform future research directions. First, we have food insecurity measures at the household level, but we lack individual-level data on mental health. This aggregation may mask important intra-household differences, as individuals within the same household may experience and respond to food insecurity differently based on age, gender, or role in the household. Consequently, the estimated effects may not fully capture the heterogeneity in mental health outcomes. Second, the mental health measures used in this study rely on self-reported data, which may be subject to reporting biases. For example, cultural stigma associated

with mental illness could lead to underreporting of symptoms, particularly in rural and conservative communities. Last, we rely on high-frequency phone survey data, which provides a snapshot of conditions at specific intervals. However, mental health and food insecurity are dynamic phenomena that can fluctuate significantly over short periods. Future research could benefit from more frequent or continuous data collection to better capture their relationship.

In conclusion, food insecurity and weather shocks interact to create a significant and complex burden on mental health, particularly for vulnerable groups such as women and poorer households. Addressing this multifaceted issue requires coordinated efforts to enhance food security, build climate resilience, and improve access to mental health resources. As climate change continues to intensify the frequency and severity of environmental shocks, understanding and addressing the interconnections between food insecurity, mental health, and weather shocks will be critical to fostering more resilient and equitable communities.

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