STUDENT **PAPER** 3

The Impact of Climate Shocks and Women's Empowerment on Child Undernutrition in Mozambique

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ABSTRACT

Changing environmental conditions constitutes one of the greatest threats to human health by reducing agricultural yields and exacerbating the burden of undernutrition. Mozambique is a region characterized by a high dependence on agricultural productivity and an increasing prevalence of climate shocks in the form of droughts and floods. Low food availability as a result of changing environmental conditions can impair child development and long-term agricultural productivity, thus necessitating efforts to understand and protect children's health. Women's empowerment is strongly associated with children's nutritional status, such that disparities in maternal autonomy and educational attainment may explain variations in climate-related vulnerabilities in this regional context. The purpose of this research is to determine the extent climate shocks are associated with child undernutrition among different populations in Mozambique by focusing on droughts and floods during the main crop growing season. In addition, this research investigates the potential of women's empowerment for mitigating climate-related vulnerabilities of children. Demographic health data is linked with regional gridded climate data using a stratified regression analysis to provide information on the impact of climate shocks on child undernutrition among livelihood subgroups of croppers and fishers. This cross-sectional study found that exposure to climate shocks during the main rainy season, from November to May, increases the risk of stunting in children under age five and that women's empowerment may not be a mitigating factor in the protection of children's health from climate shocks. Identifying population groups most adversely affected by climate change will be important for reducing social inequities and achieving the Sustainable Development Goals within Mozambique.

INTRODUCTION

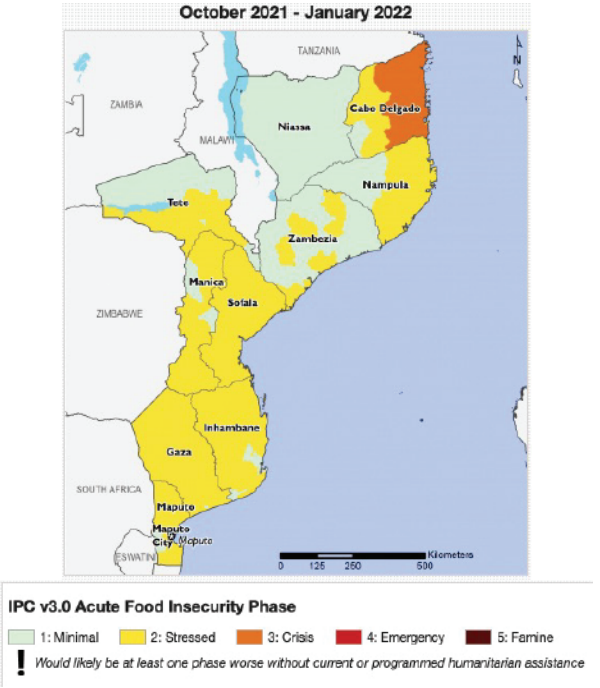
Mozambique is one of the poorest countries in the world and one of most affected countries by climate change in Africa (Global Climate Index, 2021). Malnutrition, one of the five largest threats to adverse health impacts of climate change, is prevalent in Mozambique as nearly half (42.3%) of children under age 5 are stunted (WFP, 2021). This country experiences exceptionally high climate variability and extreme climate events including droughts, floods, and cyclones due to its tropical to subtropical climate. The population primarily subsists on agriculture for food and income, although productivity is low (USAID, 2018). These climate trends in combination with high food insecurity and low agricultural adaptive capacity is of great concern for the country's economic and social stability.

Unlike Mozambique, other regions in Sub-Saharan Africa have been extensively studied for the health risks of climate change. Food insecurity following climate shocks in Kenya increase the rates of stunting and droughts in Ethiopia increase the risk of stunting and wasting in children (Grace et al., 2012; Dimitrova, 2021). While studies have evaluated the biophysical and economic ramifications of climate change and variability in Mozambique (Arthur, 2012; Ardnt, 2014; Osbahr, 2008), few recent studies have explicitly evaluated the implications of climate change on human health at the household level (Jorge, 2009).

Studies of Mozambique regarding the correlation of climate variability, crop yields, and undernutrition are rather limited. Therefore, this study seeks to contribute to the discussion of environmental vulnerabilities in this country by examining the impact of different climate shocks and effect modifiers on health in Mozambique specifically. The purpose of this research is to investigate if extreme precipitation events and droughts are related to child undernutrition, specifically stunting in children under age 5. By linking climate data with demographic health data, this study analyzes if 1) droughts and extreme precipitation events are associated with higher risk of undernutrition among children and if 2) children of women who are well educated or have decision-making autonomy have better nutritional status and are less likely to be affected by extreme climate events. It is of crucial importance to study the relationship of climate shocks to child undernutrition rates as children's health and wellbeing directly affects national development (UNICEF, 2015). This publication contributes to research involved in building resilience through an evidence base to inform research-based policy and to develop targeted adaptation strategies at the regional and household level in areas in which climate changes are likely to negatively impact agricultural productivity.

FIGURE 2:

Regional food insecurity phases in Mozambique 2021. Source: Famine Early Warning Systems Network



Linking climate shocks and child undernutrition in Mozambique

Nutrition insecurity and undernutrition are major consequences of climate change (Tirado, 2013). The three fundamental aspects of food security include: availability, access, and utilization (FAO, 2006). The principal mechanisms whereby climate shocks affect children's nutrition is the impact on household food security in regards to food availability and access (Grace et al., 2012). Given that most of the population subsists on agriculture for nutrition and employment, the health and wellbeing of households is climate-dependent.

Changes in climate variability, weather averages, and extreme weather events (droughts and floods) negatively impact food productivity as these factors hinder the stability, quantity, and quality of crop yields (Porter, 2005). Climate shocks such as excessive rainfall, extreme temperatures, and droughts are among the environmental risk factors for malnutrition in the form of wasting, stunting, and underweight children (Brown, 2020). Since Mozambique is

projected to experience more frequent and intense droughts and floods, concern about losses in food production is high (Mavume, 2021).

Linking women's empowerment and education to child nutritional status

The nutritional and educational status of parents, specifically mothers who are typically the primary caregiver, is a key factor in children's nutritional status. Among other complexities, the degree to which women and their children are susceptible to climate-related undernutrition is influenced by the level of maternal education, decision-making autonomy of women, and place of residence (Dimitrova & Muttarak, 2015). The vicious cycle of undernutrition can be perpetuated through generations in a cycle driven by poverty, natural disasters, and lack of resources (Fanzo, 2012). During periods of regional conflict and climate impacts, mothers' education and wealth status is considered mitigating factors to child malnutrition through improved feeding practices, income, and healthcare seeking behaviors (Brown 2020). Therefore, maternal characteristics such as education attainment may have a protective effect on child nutrition against climate shocks.

Women's empowerment indicators are associated with child development along three domains: control of resources and autonomy, workload and time, and social support (Cunningham et al., 2015). A study using Ethiopian household survey data concluded that women's empowerment indicators are positively associated with improved nutrition for both children and women (Yimer and Tadesse 2015). Women's empowerment characteristics are important to this study to emphasize the importance of reducing gender inequities and improving educational infrastructure in the effort to improve child nutritional outcomes. Centering women's empowerment in Sustainable Development policies has the potential to help build adaptive capacity and inter-generational equity in the face of future climate threats.

Livelihood strategies

Regional differences dependent on household place of residence or methods of subsistence result in differential vulnerabilities in child nutrition. Livelihood strategies are ways in which households survive directly off the land or through commercial markets, which have varying implications on child nutrition. Given the socioeconomic variability across different livelihood strategies, identifying subgroups among these zones can be important factors involved in understanding the nutritional status of children. Maps of livelihood zones (Figure 2), created by the Famine Early Warning Systems Network (FEWS NET), display households who utilize similar methods of obtaining food, income and other essential resources. Distinguishing these zones helps to delineate vulnerabilities to food insecurity in the event of natural disasters. The livelihood zones can be distinguished in Mozambique as: Cropping, Fishing, and Agro-pastoral, and Tourism.

The majority of the demographic household clusters retrieved from the Demographic Health Survey were located within the Cropping (green) and Fishing (blue) zones. Because of this, these two regions were compared in order to assess the differentials among livelihood strategies.

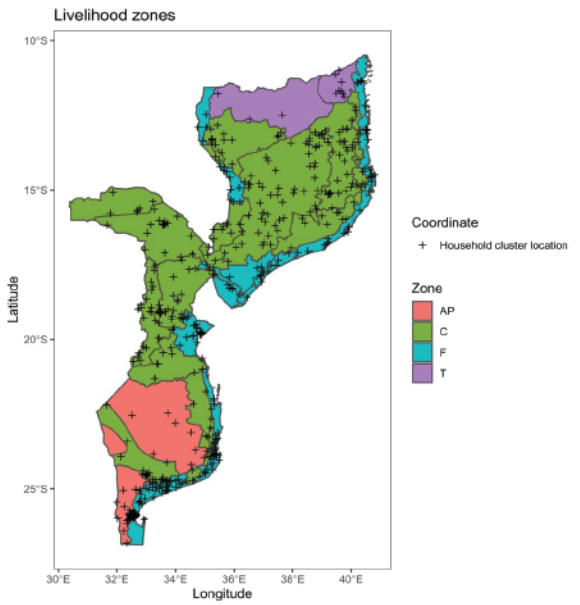
DATA & METHODS

Two datasets were linked to investigate the impact of climate shocks on children's nutritional status: the 2011 Demographic Health Survey (DHS) for Mozambique and the Standardized Precipitation Evapotranspiration Index (SPEI). Livelihood information was derived from the Famine Early Warning Systems Network (FEWS NET) to differentiate the climate vulnerabilities of subgroups by livelihood strategies.

DHS surveys provide detailed information at the individual and household level on a wide range of health-related indicators including the

FIGURE 1:

Main livelihood zones in Mozambique based on the livelihood data from the Famine Early Warning Systems Network. Household clusters from the Demographic Health Survey are denoted by the crosses.



nutritional status of children, women's empowerment and education, and household assets. The global positioning system (GPS) coordinates of household clusters are used to link the DHS surveys with the climate data.

Child undernutrition is measured by constructing indicators of stunting and wasting as dependent variables using anthropometric data of children under the age of five, as defined by the WHO Multicentre Growth Reference Study (MGRS) (WHO, 2004). Children who are more than two standard deviations (HAZ <-2) from the height-for-age ratio for their age group are considered stunted, while children who are more than two standard deviations (WHZ <-2) from the weight-for-height for their height range are considered wasted (WHO, 2004). Stunting is a result of chronic undernutrition and is typically associated with poverty, poor maternal health and nutrition, frequent illness, and/or improper feeding practices. Therefore, stunted children are less likely to reach their physical and cognitive developmental potential. (WHO, 2004). Wasting is indicative of recent and acute weight loss that may persist for long periods of time, as a result of poor food quality and quantity and/or prolonged illnesses (WHO, 2004). Children who are underweight can be stunted, wasted, or both. External climate data is used to construct measures of climate anomalies and is linked with the DHS data using information about the geographical location of household clusters. A Standardized Precipitation Evapotranspiration Index (SPEI) is constructed, which can be used to measure both droughts and extreme precipitation events. SPEI is considered superior to other drought indices since it captures the effects of evaporation and transpiration due to temperature, in addition to precipitation. This data is often used to understand the intensity and distribution of droughts in a region. In this study, an incidence of drought was defined as SPEI ≤ -1 standard deviation from the average set at 0.

Information about livelihood strategies was derived from the FEWS NET for Mozambique. Founded by the United States Agency for International Development, The FEWS NET is a leading provider of early warning and analysis of acute food security around the world. The DHS household clusters are concentrated primarily within the Cropper and Fisher livelihood zones; therefore, these two subgroups were compared for the purposes of this analysis. The full sample size totalled 6,450 children under the age of five, with 3,384 children in the Cropping region and 2,375 children in the Fishing region.

To understand the interaction of the climate data, these data sets were cross-examined on R programming software using information about the geographical coordinates of household clusters in DHS. The DHS household clusters were linked with the FEWS NET livelihood information to characterize the demographic information with the livelihood zones. The demographic statistics of the main livelihood groups, Croppers and Fishers, were compared to summarize the primary dependent and control variables to be used in the regression model.

TABLE 1:

Survey questions from the DHS Survey are categorized into dummy variables for the Principal Component Analysis to create a Women's Empowerment Variable for analysis.

Variable	Categorization
1. Who usually decides on respondent's health care 2. Who usually decides on large household purchases 3. Who usually decides on visits to family or relatives	1 = Respondent alone 0 = Joint decision 0 = Husband/other alone
1. Getting permission to go to healthcare 2. Not wanting to go alone	1 = No problem/Not a big problem 0 = Big problem
Beating is justified if: 1. She goes out 2. She neglects the children 3. She argues with partner 4. She refuses to have sex with partner	1 = No 0= Yes/Don't know
Woman education - level of schooling	1 = Primary, Secondary, Higher 0 = No education

The Women's Empowerment Variable is based on a composite of questions regarding the woman's decision-making ability, mobility, views on violence, and level of education from the DHS survey. The survey questions are categorized into dummy variables in which respondents' answers that suggest maternal empowerment are characterized by 1 and answers that suggest maternal disempowerment are characterized by 0 (Table 1). For example, women who could make decisions on health care alone were scored 1 and were scored 0 otherwise. Principal Component Analysis is used to summarize various qualitative variables on a data table into one summary variable that is easier to visualize and analyze.

REGRESSION ANALYSIS

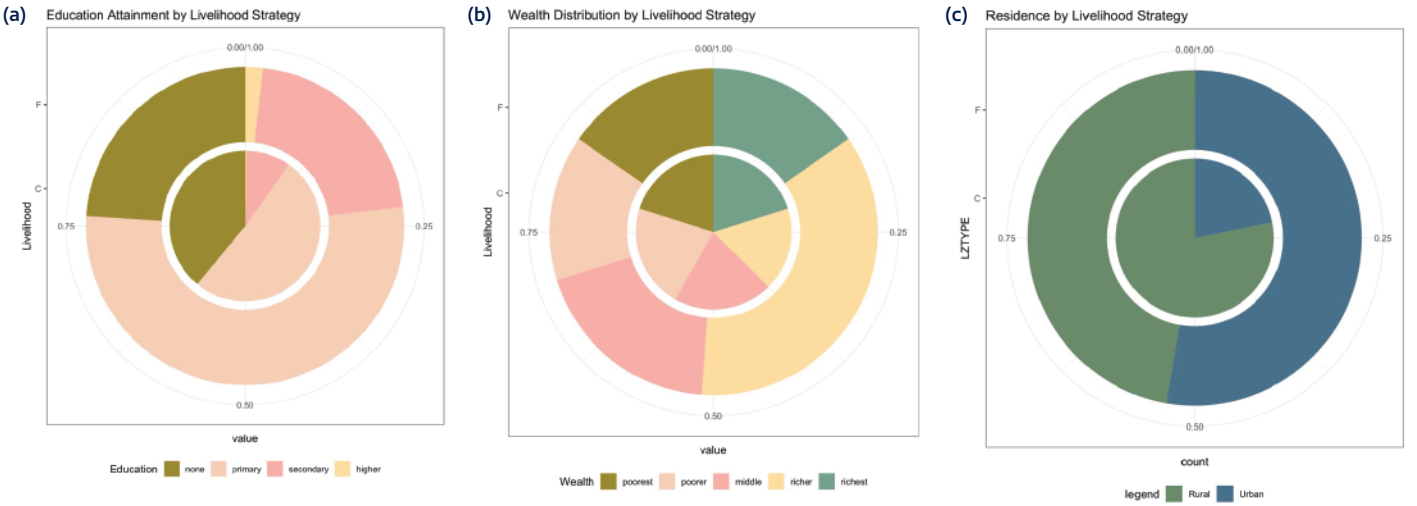
The analysis uses a regression model based on stratified subgroups by livelihood strategies along individual, maternal, and household characteristics. The regression model will investigate the impact of climate shocks (SPEI) on child nutritional outcomes by differentiating between livelihood strategies and controlling for individual and household characteristics. By isolating individual and household characteristics, the impact of climate conditions on child nutrition can be assessed.

The two livelihood groups have significantly different individual, household, and occupational differences. Within these zones, a larger proportion of the population of Croppers reside in rural areas while a larger proportion of Fishers reside in urban residences. Approximately half of both populations have at least a primary level of education, while a larger proportion of Croppers have no education. In addition, the majority of the population of Croppers live in the lower wealth percentiles (poorer and poorest), while half of the Fishing population live in the higher wealth percentiles (richer and richest).

Overall, there is greater prevalence of stunting (39.9%) than wasting (4.5%) in the entire population. There is a significant difference in the proportions of children stunted in children between Croppers and Fishers, whereby Croppers have a higher burden of undernourished children. Given the low prevalence of wasting, I focus on stunting in children in the following regression results.

FIGURE 3:

A comparison of the proportion of the education attainment, wealth distribution, and household residences. The inner circle represents households in the Fisher zone and the outer circle represents the households in the Cropper zone.



RESULTS

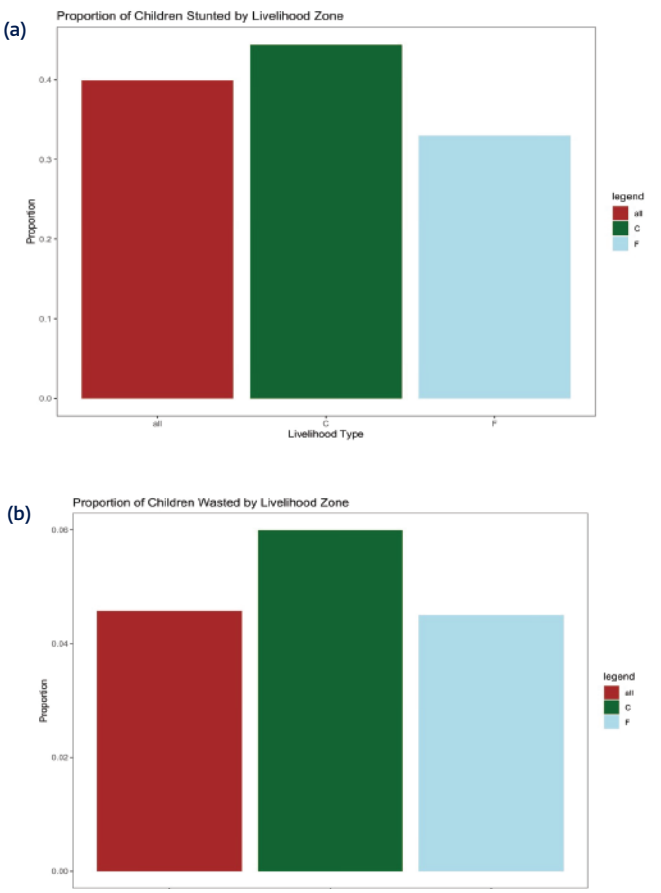
Demographic Statistics

The two livelihood groups have significantly different individual, household, and occupational differences. Within these zones, a larger proportion of the population of Croppers reside in rural areas while a larger proportion of Fishers reside in urban residences (Figure 3c). Approximately half of both populations have at least a primary level of education, while a larger proportion of Croppers have no education (Figure 3a). In addition, most of the population of Croppers live in the lower wealth percentiles (poorer and poorest), while half of the Fishing population live in the higher wealth percentiles (richer and richest) (Figure 3b).

Overall, there is greater prevalence of stunting (39.9%) (Figure 4a) than wasting (4.5%) (Figure 4b) in the entire population. There is a significant difference in the proportions of children stunted in children between Croppers and Fishers, whereby Croppers have a higher burden of undernourished children (Figure 4a). Given the low prevalence of wasting, I focus on stunting in children in the following regression results.

FIGURE 3:

Proportion of stunted and wasted children in Croppers (green), Fishers (blue), and the total sample of DHS households (red).



Regression Analysis Results

Tables 2 and 3 present the regression estimates of the odds of stunting for children aged under five. The analysis is performed on the full sample of children as well as on the sample of Croppers and Fishers separately, in order to distinguish the differences in undernutrition among these groups as a result of drought. SPEI is measured on a 6-month and 12-month scale. Rainy season SPEI calculated at the 6-month scale captures the cumulative precipitation and evaporation during the main rainy season, which is the primary crop growing season from November to May (FEWS NET). Year-long SPEI calculated at the 12-month scale captures the cumulative effect of dry weather over a year-long period of time in which crop productivity can be negatively affected. Similarly, rainy season drought is represented by the incidence of drought at the 6-month scale, while year long drought is represented by the 12-month scale.* For both SPEI and drought regressions, I focus on exposure during pregnancy as it is the period which presents the strongest associations as it is a period of critical exposure for fetal development.

Based on the regression results, rainy season SPEI from the 6-month time scale is strongly associated with child stunting for the Croppers, while SPEI from the 6-month time scale does not seem to affect the risk of stunting for Fishers. Similarly, drought during the 6-month rainy season is associated with child stunting for the Cropping group, while drought during the 6-month rainy season does not seem to affect the risk of stunting for Fishers. This suggests that droughts during the rainy season are particularly harmful to children among Cropping regions. In contrast, I do not find any evidence that long-term SPEI or drought from the 12-month time scale is associated with the risk of child stunting within the entire sample.

Investigating the interaction with the Women's Empowerment Index

Figure 6 presents the regression estimates of the height-for-age of children under 5-years old. The

TABLE 2:

Impact of the average seasonal SPEI during pregnancy on the risk of stunting by livelihood zone. The asterisks indicate a statistically significant p-value between SPEI and risk of stunted children.

Impact of SPEI during pregnancy on risk of stunting by livelihood zone

	Utero All		Utero Croppers		Utero Fishers	
Predictors	*Odds Ratios*	*Conf. Int (95%)*	*Odds Ratios*	*Conf. Int (95%)*	*Odds Ratios*	*Conf. Int (95%)*
Rainy Season SPEI	0.92 *	0.84 – 1.00	0.84 ***	0.75 – 0.95	0.99	0.85 – 1.15
Year Long SPEI	1.10	0.93 – 1.31	1.00	0.79 – 1.28	1.08	0.82 – 1.42

** p<0.1 ** p<0.05 *** p<0.01*

TABLE 3:

Impact of drought incidence during pregnancy on the risk of stunting by livelihood zone.

Impact of drought during pregnancy on risk of stunting by livelihood zone

	Utero All		Utero Croppers		Utero Fishers	
Predictors	*Odds Ratios*	*Conf. Int (95%)*	*Odds Ratios*	*Conf. Int (95%)*	*Odds Ratios*	*Conf. Int (95%)*
Rainy Season Drought	1.18 *	0.99 – 1.42	1.32 *	1.00 – 1.75	1.23	0.93 – 1.63
Year Long Drought	1.10	0.93 – 1.31	1.00	0.79 – 1.28	1.08	0.82 – 1.42

** p<0.1 ** p<0.05 *** p<0.01*

Women's Empowerment Index (WEI) is included in the regression analysis as an interaction term to test whether height-for-age (HAZ) outcomes in children are differential between mothers who are empowered or unempowered and were exposed to drought in pregnancy. HAZ was used as the dependent variable, a continuous variable which preserves the total sample size in consideration for the WEI. Based on the initial regression model, the 6-month rainy season was used to capture the effects of drought during pregnancy since this time frame shows stronger associations with child stunting. Similarly, the exposure period was set to drought during pregnancy as this period is a critical period of exposure.

The Rainy Season Drought regression results represent the HAZ estimates of the total sample and the Rainy Season Drought * WEI includes the same regression interacted with the WEI variable. The results show that there is no statistical difference in the HAZ of children when

TABLE 4:

Impact of drought incidence during pregnancy on the risk of stunting with an interaction term using the Women's Empowerment Index.

HAZ from droughts during the rainy season interacted with Women's Empowerment Index

	Drought During Utero Rainy Season	
Predictors	*Estimates*	*Conf. Int (95%)*
drought06_rainy_utero	-0.06	-0.23 – 0.11
empower.cat.3 [Not Empowered]	-0.00	-0.08 – 0.08
drought06_rainy_utero * empower.cat.3 [Not Empowered]	-0.09	-0.33 – 0.15

** p<0.1 ** p<0.05 *** p<0.01*

interacted with the WEI variable (-0.09) as opposed to the total sample (-0.06). This suggests that maternal empowerment may not be enough to significantly mitigate the negative effects of drought, although other individual or household characteristics may play a larger role in child nutritional outcomes.

Investigating non-linear effects

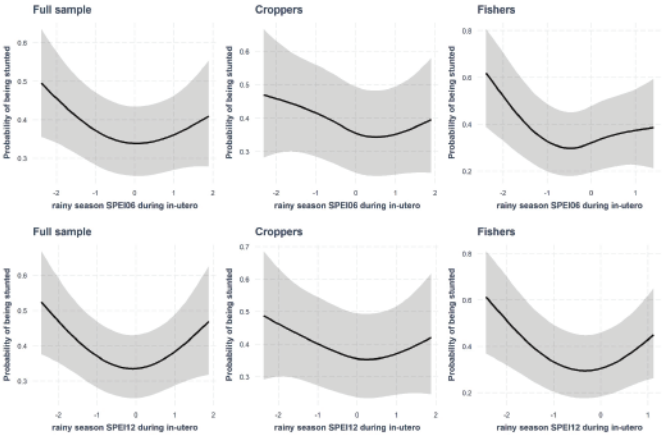
The potential of non-linear associations of SPEI on child undernutrition are investigated using a non-linear regression model. Figure 6 shows the predicted probabilities of stunting at different scales of SPEI of 6-months (top panels) and 12-months (bottom panels) derived from this non-linear model.

The results show that children who have been exposed to extreme droughts (SPEI <= -1.5) are more likely to be stunted, where the probability of stunted children increases from 34% at SPEI 0 to 50% at SPEI -2. This trend is observed similarly among the samples of croppers and fishers. The probability of stunted children also increases at extreme wet conditions of SPEI (>= 1.5). Extreme positive SPEI are possibly indicative of exposure to flood, which can negatively impact child health due to increased prevalence of water-borne diseases. The results from Figure 5 validate the findings from Tables 2 and 3 that exposure to drought during the main rainy season perpetuates the risk of chronic undernutrition to children.

The nonlinear effects are observed similarly in both the SPEI 6-month and 12-month time scales across the full sample as well as among the croppers and fishers. This suggests that exposure to extreme levels of SPEI during the year of pregnancy exacerbates child undernutrition.

FIGURE 5

Impacts of SPEI on the risk of stunting. The figure shows the probabilities of stunting based on a non-linear regression model of the SPEI index.



DISCUSSION

In this study, demographic information for Mozambique was combined with regional gridded climate data SPEI to determine the association of climate shocks and child undernutrition. DHS data for Mozambique was combined with livelihood information to summarize the individual, maternal, and household statistics of livelihood subgroups. The high prevalence of stunting in Mozambique indicates that children are affected by chronic climate shock events throughout development, or otherwise long-term vulnerabilities in food availability or disease. The results of this study show that exposure to climate shocks, in the

form of droughts or floods, during pregnancy increases the risk of chronic undernutrition (stunting). In addition, the results show that there is no strong association between maternal empowerment and protection of child nutrition against climate shocks.

The demographic statistics show significant differences among Croppers and Fishers along measures of residence, education level, wealth, and child nutritional outcomes. Croppers primarily live in rural settings and are likely to be more reliant on agricultural production as a form of subsistence and have less access to additional resources. Fishers are more likely to earn wages in urban settings and have access to basic needs, although living in densely populated regions can have complex confounding challenges. There is a higher prevalence of stunting in areas of Mozambique where livelihood strategies rely on crop production. Regions of Mozambique where households primarily subsist through crop production are particularly susceptible to child undernutrition when shocks occur during the main rainy season. Cropping regions largely subsist on agricultural production for food and income. Therefore, disturbances on traditionally rain fed crops may exacerbate difficulties for smallholder farmers and limit the nutritional intake of children. Existing inequities, poor governance, and regional conflict coupled with frequent exposure to climate shocks reduce the capacity to cope with environmental impacts (Brown et al., 2020). Planned agricultural initiatives involving the collective action of government, NGOs and local communities can build resilience to shocks in a region characterized by low adaptive capacities (Osbahr et al., 2008).

The regression results present evidence that droughts during pregnancy are detrimental to children's development. Previous studies have shown that pregnancy is a critical period of exposure and environmental stressors during this period can be detrimental to child health in the future (Olson 2020). This suggests that climate shocks events even before a child is born presents long term complications during child development. Additionally, this means that precipitation during the primary crop growing season is key to nutritional outcomes, given that agricultural production is primarily based on precipitation (FAO and WFP 2000).

This analysis aligns with previous literature, which has found a negative association between climate-related stressors and children's nutritional outcomes in Sub-Saharan Africa (Brown & Funk 2008, Dimitrova & Muttarak 2020, Grace 2012). Droughts and floods are projected to increase in magnitude and frequency in Mozambique, which will exacerbate the burden of undernutrition and make protecting children's health more difficult (USAID, 2018). Therefore, it is important to understand which groups of children are most vulnerable to climate shocks in order to more effectively coordinate and allocate humanitarian aid. Future studies should consider creating a map of stunting and SPEI to spatially identify regions of vulnerability.

Furthermore, I did not find evidence for women's empowerment as a mitigating factor against the negative effects of climate shocks on children. It may be possible that other individual or household factors including wealth status, place of residence, or regional conflict play a larger role in the nutritional outcomes of children in the event of climate shocks (Deutsch & Silber 2019). Alleviating social inequities overall and establishing adequate infrastructure for emergency food systems may aid in building resilience in this region.

Certain limitations affect the results of this study. Given the cross-sectional nature of the design of the regression models, causal inference cannot be determined. Therefore, this study cannot determine the direct mechanisms by which climate shocks are linked with undernutrition in children. The overall sample size of the nationally representative data is small in respect to other studies, such that the effect of climate shocks on child undernutrition may be over or

underestimated. It is possible that the sample was too small to perform an accurate principle component analysis, therefore future studies should explore the relationship of women's empowerment using larger data sets. Additionally, there is currently no standardized method to best measure women's empowerment in certain communities. Studies in the future should seek to establish an accurate index of women's empowerment, especially as it pertains to measuring progress towards the Sustainable Development Goals including Zero Hunger, Gender Equality, and No Poverty.

In conclusion, this study finds a strong association between child undernutrition and exposure to droughts and extreme precipitation events during pregnancy in Mozambique, particularly for communities in Cropping regions. This information is crucial as it contributes to the limited, but growing body of literature which improves our understanding that climate change poses a significant concern to human survival through impacts on natural resources, environment, and economic productivity. Additionally, the work indicates that maternal empowerment may not have the potential to mitigate vulnerability to climate shocks, while other factors at the individual, household and community level may have a larger influence. In the hopes of addressing child undernutrition in Mozambique, there is an urgent need to develop refined early warning systems that can anticipate the communities most susceptible to future climate-related threats to prompt timely interventions and develop targeted adaptation strategies.

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McNair Cohort: 2020

Biography:

I am Marinelle Villanueva and graduated in Spring 2021 with a double major in Environmental Systems: Ecology, Behavior, and Evolution & Global Health. I was heavily involved in the Kaibig@ng Filipinx community at UCSD as the Director of Peer Counseling and UCSD OASIS as an OASIS Learning Community mentor, where these experiences allowed me to be a leader and support system for underrepresented students on campus. In addition, I served as a UCSD Sustainability Ambassador to spread awareness for the Carbon Neutrality Initiative and ways in which students and faculty can be a part of achieving this goal. Research has played a large role in my career development, including my experience in the Doris Duke Conservation Scholars Program @ NAU where I conducted conservation and environmental justice-focused research. In the future, I aim to continue a career centered on research and policy development for climate change resilience and mitigation, particularly for marginalized communities. My research interests include climate change, food security, environmental health disparities, and sustainable development. I hope to use my passion for the environment to uplift and protect disadvantaged communities in our changing climate.

> *I hope my voice will amplify climate and environmental issues that are oftentimes ignored.*
>
> *This publication can be my first step towards using my research capacity and platform to ... shed light on the environmental conditions that affect communities often overlooked and inspire personal, institutional, and/or governmental action...and [ultimately] inspire climate action that will preserve our natural world while protecting the most vulnerable communities.*

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