

FAO-DIEM OPEN SCIENCE RESEARCH GRANT INCEPTION REPORT

Climate-Induced Shocks, Food Insecurity and Strategies for Tackling
Evolving Impacts within the Alliance of Sahel States

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EXECUTIVE SUMMARY

This study sought to analyse and quantify the impacts of floods (proxy through positive rainfall anomalies) and droughts (negative rainfall anomalies) on household food security in the Alliance of Sahel States (AES), namely Burkina Faso, Mali and Niger. These countries are also designated crisis countries by the FAO. The goal of the study was to determine and recommend to the countries' governments, the FAO and other development partners, pathways to buffering vulnerable households' food security against climate –induced shocks. The specific objectives of the study were to:

- 1) Assess how positive and negative rainfall shocks affect food security in the AES, and
- 2) Explore and recommend available strategies needed to enhance resilience, support adaptation and reduce food insecurity in these states.

Two datasets, household survey and satellite precipitation data, were used for the analysis. The household survey data was obtained from the FAO DIEM household survey database, while the precipitation data was extracted from the ECMWF Climate Reanalysis v5 (ERA5) high, spatiotemporal resolution monthly precipitation data provided by the European Centre for Medium-Range Weather Forecasts (ECMWF), Copernicus Climate Change Services. The FAO-DIEM data contains information on various food security indicators. The study however, focused on three of these food security indicators, namely the Food Consumption Score (FCS), the Reduced Coping Strategy Index (rCSI) and Food Insecurity Experience Scale (FIES).

The multiple linear regression model was used to estimate the effects of positive and negative rainfall anomalies on household food security.

From the analysis, the following conclusions can be drawn:

- 1) Both positive rainfall anomalies and droughts threaten food security within the AES. While the incidence of floods is disruptive in the short term with implications for food production, droughts cause long term food production risks and livelihood stress. Unlike droughts the incidence and effects of which unfold gradually, the incidence of floods is sudden. Thus, adjusting to the sudden shocks of flood effects is more difficult than adjusting to the gradual effects of droughts. The fast-track nature of flood incidence may imply difficulties for households to adequately ex-ante coping measures. This way, ex-post flood damages may be more deleterious than those of droughts.
- 2) Crop-livestock diversification is associated with reduced vulnerability and improved household resilience and food security. Thus, the adoption of livestock-crop diversification strategies could be used to spread and reduce the risks associated with floods and droughts. Moreover, crop -livestock

diversification appears to be useful for sustaining and smoothing household consumption and income patterns to provide a stronger buffer against food insecurity and improve the quality of diets and nutrition among households.

Generally, food insecurity interventions, namely cash, food, and asset support, are expected to serve as swift and targeted responses to crises, while linking social protection to nutrition and overall household welfare. Addressing the bottlenecks to food security and consolidating the gains from the social protection divide could be the beginning of safeguarding food supplies, protecting rural economies and ensuring the sustainability of food systems in crisis communities.

Based on the above conclusions, the following recommendations are provided to guide the actions of governments of the AES countries, FAO and other development interest groups:

- 1) In the short term, there is the need for integrated support systems such as cash and asset support as well as targeted food reliefs under more severe situations. This is critical as it addresses the very immediate hunger and potential food insecurity problems while protecting livelihoods. It also, supports and builds seasonal and shock responsive programming whilst strengthening local markets, targeting and protecting the very vulnerable in the society as well as building the adaptive capacities of communities to climate shocks.
- 2) In the medium term, we recommend the promotion of crop-livestock diversification across the AES. The promotion of crop-livestock diversification is a sure bet to stabilising and smoothing households' income and food supply. This intervention will help bridge seasonal food shortage gaps within households and prevent them from impulse sales of assets. Additionally, the economic viability of households would be enhanced with more market participation due to the benefits and cross-effects of integrating crops and livestock.
- 3) In the long, there is the need to strengthen flood preparedness and rapid response mechanisms. The importance of this cannot be overstated as this could build the long-term resilience of households and communities to reduce repeated displacements caused by floods and droughts. Also, strengthening flood preparedness and rapid response mechanisms would preserve development gains and thus ensure that resources are channelled to other equally pressing developmental needs. These would save lives in the now and protect livelihoods and developmental gains for the future.

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1 INTRODUCTION

Climate change and climate extremes cause food insecurity. The Food and Agriculture Organization (FAO) and the Intergovernmental Panel on Climate Change (IPCC) report that climate-induced shocks such as droughts and floods present immediate threats to food production and supply, causing food insecurity, hunger, health, and socioeconomic consequences for poor households (Hadley et al., 2023).

Climate shocks and severe food insecurity are rampant and widespread in the Alliance of Sahel States (AES), i.e., Burkina Faso, Mali, and Niger. These states are expected to experience the severest humanitarian impacts from future climate shocks (Akouwerabou et al., 2024). This is due to the region's already fragile and harsh natural environment, heavy reliance on rain-fed agriculture, poor resource allocation, and its military rule, compounded by the insecurity posed by non-state armed groups.

In the 2024 cropping season, Burkina Faso, Mali and Niger experienced a severe, two-month-long dry spell and are currently facing food supply deficits, price hikes, and worsening hunger. This year's weather forecasts by the Ghana Meteorological Agency already warn of another prolonged dry spell for the Sahel in the 2025 cropping season. This turned out not to be the case as the region experienced normal to above-normal precipitation this year (2025).

The FAO established the Data in Emergencies (DIEM) Information System in June 2020 to regularly collect survey data on the impact of shocks on poor urban, peri-urban, and rural farm households in food-crisis countries, including those affected by AES. The purpose is to inform decision-making to support agricultural livelihoods in crisis countries. Within this context, we propose to examine, analyse, and quantify the impact of climate-induced shocks on food security in the AES. The findings will inform decision-making to support household food security in these food-crisis states and offer resilience-enhancing, strategic, and actionable food security interventions to their governments and the FAO.

The key question we ask is, how do drought and flood shocks affect food security in the AES? and 2) what urgent strategies are needed to enhance resilience, support adaptation, and reduce food insecurity in the AES? The findings will contribute fundamentally to Sustainable Development Goal (SDG) 2: end hunger, achieve food security, improve nutrition, and promote sustainable agriculture; and to those SDGs focused on the environment, health, and democratic governance.

We obtained and used mainly two datasets for this analysis. The first dataset is from the FAO-DIEM household survey database, which covers 30,005 observations and includes household and food security variables. The second set is from the ECMWF Climate Reanalysis v5 (ERA5) and comprises monthly precipitation data

provided by the European Centre for Medium-Range Weather Forecasts (ECMWF), Copernicus Climate Change Service. The ECMWF dataset is used to estimate the drought and flood variables of the three countries.

Having obtained and processed the datasets, we applied a range of analytical methods, namely descriptive statistics and regression analysis to estimate the relationship between climate-induced shocks and three selected food security indicators – the Food Consumption Score (FCS), the Food Insecurity Experience Scale (FIES), and the reduced Coping Strategy Index (rCSI).

The following section discusses the research objectives and methods, including the data and variables, and the analytical models applied to the data. Section 3 presents the timelines for the study, and Section 4 presents and discusses the descriptive statistics and results from the models. The policy implications and conclusions in Section 5.

2 MEASURABLE OBJECTIVES AND METHODS

We seek to understand, analyse, and quantify the impacts of drought and flood shocks on household food security in the AES, namely Burkina Faso, Mali, and Niger. Our goal is to identify and recommend to governments, the FAO, and other development partners pathways to buffer vulnerable households against climate-induced shocks.

The specific objectives seek to:

- 1) Assess how positive and negative rainfall shocks affect food security in the AES, and
- 2) Explore available strategies needed to enhance resilience, support adaptation, and reduce food insecurity in these states.

2.1 Datasets and Variables

The household survey data used for the analysis was obtained from the FAO DIEM database. The climate data extracted from the ECMWF Climate Reanalysis v5 (ERA5) monthly precipitation data provided by the European Centre for Medium-Range Weather Forecasts (ECMWF), Copernicus Climate Change Service.

The first dataset, the FAO DIEM survey data, is a multi-locational dataset obtained across the three AES and utilised a total of 30,005 observations. The surveys comprised two (2) rounds of surveys for Burkina Faso, conducted in September 2023 and January 2025. There are five (5) survey rounds each for Mali and Niger. The surveys for Mali were conducted in May/June 2023, September/October 2023, December 2023 /January 2024, June/July 2024 and October 2024, while those February/March 2023. May/June 2024, May/June 2024 and October/November 2024. Since the periods during which the survey was conducted reflect different stages

of the rainy and production seasons, the indicators of food security under study are likely to reveal seasonal disparities.

The sample sizes are 7,656, 11,296, and 11,053, respectively, for Burkina Faso, Mali, and Niger. These samples, however, were trimmed down to 3,718 (25.86%), 5,356 (37.25%), and 5,306 (36.50%) for Burkina Faso, Mali, and Niger, respectively, after thorough data cleaning to ensure consistency of data across the three countries over the data collection period. The data collection period for this study spanned from 2022 to 2024 (FAO, 2025). The FAO-DIEM data contains variables on food security indicators like the FIES, HDDS, and FCS, as well as climate-related variables such as flood and drought indicators. Additional details on data collection methods can be found in the DIEM Monitoring Briefs for the three AES and across the reported rounds.

The ERA5 climate data spanned the period from 1981 to 2024. Shape files from the FAO GAUL (Global Administrative Units Layers) were used to extract monthly precipitation and disaggregate by country, region and districts. The data was extracted at the spatial resolution of approximately 9km. A 43-year-long average was computed and used to compute the Standardized Precipitation Index (SPI) using the R SPEI package. Following the World Metrological Organisation (WMO, 2012) and studies by Liebenehm et al. (2024), SPI values below -1 and above +1 constitute negative and positive rainfall shocks, respectively (i.e., synonymous to droughts and floods). The resulting data was then merged with the FAO DIEM data for the analysis.

The West African Sahel (WAS) is known for high climate variability and vulnerability to hydro-meteorological extremes, especially rainfall, which is a critical driver of the livelihoods of populations whose primary source of food and income is rain-fed agriculture (Yolanda et al., 2024).

The study focuses on three food security measures: the FCS, FIES and rCSI. There is a significant utility in estimating these indicators. First, they are comparable across contexts. Second, concordance based on the convergence of available data and information from the AES. In both directions, classifying the severity of chronic and acute food insecurity across geography and time is possible (Vaitla et al., 2015).

2.2 Analytical Methods

The empirical approach employs two distinct impact models from the existing climate econometrics literature to model the impact of climate-induced shocks (positive and negative rainfall shocks) on four food security indicators for the three AES under study.

The multiple linear regression model was applied in estimating the relationship between drought and rainfall anomalies on three food security outcomes (FCS, FIES and rCSI).

The multiple linear regression model is expressed as:

$$FS_i = b_0 + b_k X + b_1 Drought1 + b_2 Drought2 + b_3 Abundant_rain1 + b_4 Abundant_rain2 + \delta_c + \gamma_t + \varepsilon$$

(1)

Where FS denotes the variables FCS, FIES or rCSI; b_1 and b_2 respectively measure the effect of moderate and severe drought; and b_3 and b_4 alternatively, measure the effects of moderate and severe excess rainfall anomalies. The X is a vector of controlled variables, δ_c and γ_t measures the country and year effects and ε is the error term.

We also controlled for household exposure to interventions (i.e., whether the household receives cash support, asset support or food support).

Since flash floods and rainfall that leads to flooding tend to occur in short periods, resulting in immediate, abnormal precipitation excesses, a 3-month SPI is used to compute rainfall anomalies. And since droughts become more severe over extended periods, causing a gradual depletion of soil moisture, a 6-month SPI was used to compute for drought shocks. Fundamentally, a moderate drought is when the SPI is 6 or its lags are less than -1, while a severe drought is when the SPI lags are less than -2. Conversely, a moderate rainfall anomaly is when the SPI value is 6 or its lag is greater than 1, while a severe rainfall anomaly is when the SPI lag is greater than 2.

The results demonstrate the extent to which existing climate shocks affect smallholder farmers and how interventions may potentially reduce food insecurity, support adaptation efforts and ensure long-term resilience. Interventions and methodologies for mitigating climate-induced shocks within AES are to eradicate food insecurity amid increasing climatic shocks.

The focus on food security is crucial. Food security has significant benefits for achieving SDG 2 (zero hunger), SDG 3 (good health and well-being), and SDG 13 (climate action). Additionally, benchmarking empirical evidence on the mechanisms linking climate-induced shocks to food insecurity is essential for creating a holistic understanding of the food security situation in AES, for regional comparisons and ultimately for the sharing of best practices among crisis countries.

Fundamentally, we estimate separate regression models for each food security indicator. We evaluate how the four food security indicators vary across countries in response to flood and drought shocks. We recognise that the distribution of climate-induced impacts of shocks for each AES is not uniform across the AES but depends on the specific contexts, the environment, and local economies, including the income and assets status of households. For instance, households within the lowest income quartile will be worse off following climate-induced shocks than those within the upper income quartile. This distribution of climate impacts across and within the AES is expected to hold for the two empirical models applied for the analysis.

3 PROJECT TIMELINES

The revised timelines for the project following the signing of the contract are presented in Table 3.1.

Table 3.1: Timelines for the project execution

Deliverables	Time frame (Months)		
	August 2025	September 2025	January 2026
Milestone 1: Inception report with revised methodology and descriptive statistics			
Milestone 2: draft narrative including research methodology and results			
Milestone 3: final report including ppt presentation, DIEM Research grey literature report draft and draft manuscript for submission to a peer-reviewed journal			

4 RESULTS AND DISCUSSIONS

4.1 Food Security in the Alliance of Sahel States (AES)

This section presents the findings of the study in the form of tables and charts, with accompanying relevant discussions. The section starts with the presentation of summary statistics providing a simple quantification of the frequency distribution and distributional implications of the three food security measures forming the focus of this study – the reduced Coping Strategy Index (rLCSI), the Food Consumption Score (FCS), and the Food Insecurity Experience Scale (FIES). The summary statistics of these measures are respectively presented and discussed in the following sections.

4.1.1 Descriptive statistics of food security measures across AES

With arid and semi-arid agroecology, the countries of the AES face a harsh natural environment that has been worsened by climate change. Climate change is quickly increasing the frequency of extreme weather events and worsening the impacts of climate-related shocks, especially on agriculture and the food security of farm households. The descriptive statistics (frequency distributions and related percentages) shown in Table 4.1 illustrate the distribution of food security indicators across the AES. These are provided at the country level for the entire study period, with the round-by-round distributions detailed in the appendix.

The summarized statistics show that about 20% of the households across observed countries are in a poor food insecurity situation. Food insecurity, as measured by FCS, shows that food insecurity was worst for Niger, with nearly 60% of households in a poor food insecurity situation. This means most agricultural households

in Niger are facing the biggest food crisis situation within the AES and may require emergency food aid and related interventions to smooth their consumption. On the other hand, Burkina Faso has about one in two households (50%) being food secure, with a significant minority (16%) of the households in a poor food insecurity situation.

The Niger case is not particularly unexpected, given evidence from the dataset showing that Nigerien households experienced drier conditions due to lower rainfall levels across much of the survey period. Conversely, nearly a quarter of the population across countries (crises and emergencies) was food insecure. Again, this was cumulative higher for Niger with nearly half of the respondents finding themselves in dire food insecurity situations. The FIES, which is a subjective experience over a longer period, complements the findings from the FCS, with Niger reporting an average of nearly 4, implying at least one person responded in the affirmative to about four experience-based questions. These have been highlighted by the probability of moderate food insecurity (p_{mod}) and probability of severe food insecurity (p_{sev}) statistics, where the probabilities of moderate and severe food insecurity were reported to be about 45% and 9%, respectively.

Table 4.1: Descriptive statistics of food security indicators at the country level

Indicator	Burkina Faso		Mali		Niger		Cross Country	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
FCS								
Poor (0)	596	16.03	520	9.71	1,097	59.43	2,213	20.27
Borderline (1)	1,214	32.65	1,106	20.65	249	13.49	2,569	23.53
Acceptable (2)	1,908	51.32	3,730	69.64	500	27.09	6,138	56.21
Total	3,718	100.00	5,356	100.00	1,846	100.00	10,920	100.00
Indicator	Mean	SD	Mean	SD	Mean	SD	Mean	SD
FCS	38.25	17.18	50.58	23.52	22.62	26.57	41.67	24.40
FIES	2.64	2.52	3.06	2.69	3.53	2.75	3.13	2.69
P _{mod}	0.38	0.42	0.43	0.42	0.45	0.44	0.42	0.43
P _{sev}	0.05	0.16	0.08	0.18	0.09	0.22	0.07	0.19

Source: Estimates from FAO-DIEM Data

4.1.2 Seasonal precipitation among AES

The boxplots in Figure 4.1 by country show that the overall spread of SPI lagged at 3 months, ranging from -2.31 to 0.61, with some outliers for Burkina Faso, whereas the spread in the extreme values reported by Mali

and Niger ranges from -3.74 to 2.93 and -2.55 to 3.83, respectively. This means that Mali and Niger showed wider variation in terms of rainfall shocks as compared to Burkina Faso.

The observed SPI values for Mali and Niger for some households were ≥ 3 and ≥ 4 respectively. This suggests incidences of severe drought, given also the lower total rainfall levels in these countries relative to Burkina Faso, which experienced moderate incidences of drought. Because of the high dependency of the AES on rain-fed agriculture, this implies that the food security situation in Malian and Nigerien agricultural households is expected to be more severe due to the negative climate related shocks (i.e., drought) than in Burkina Faso.

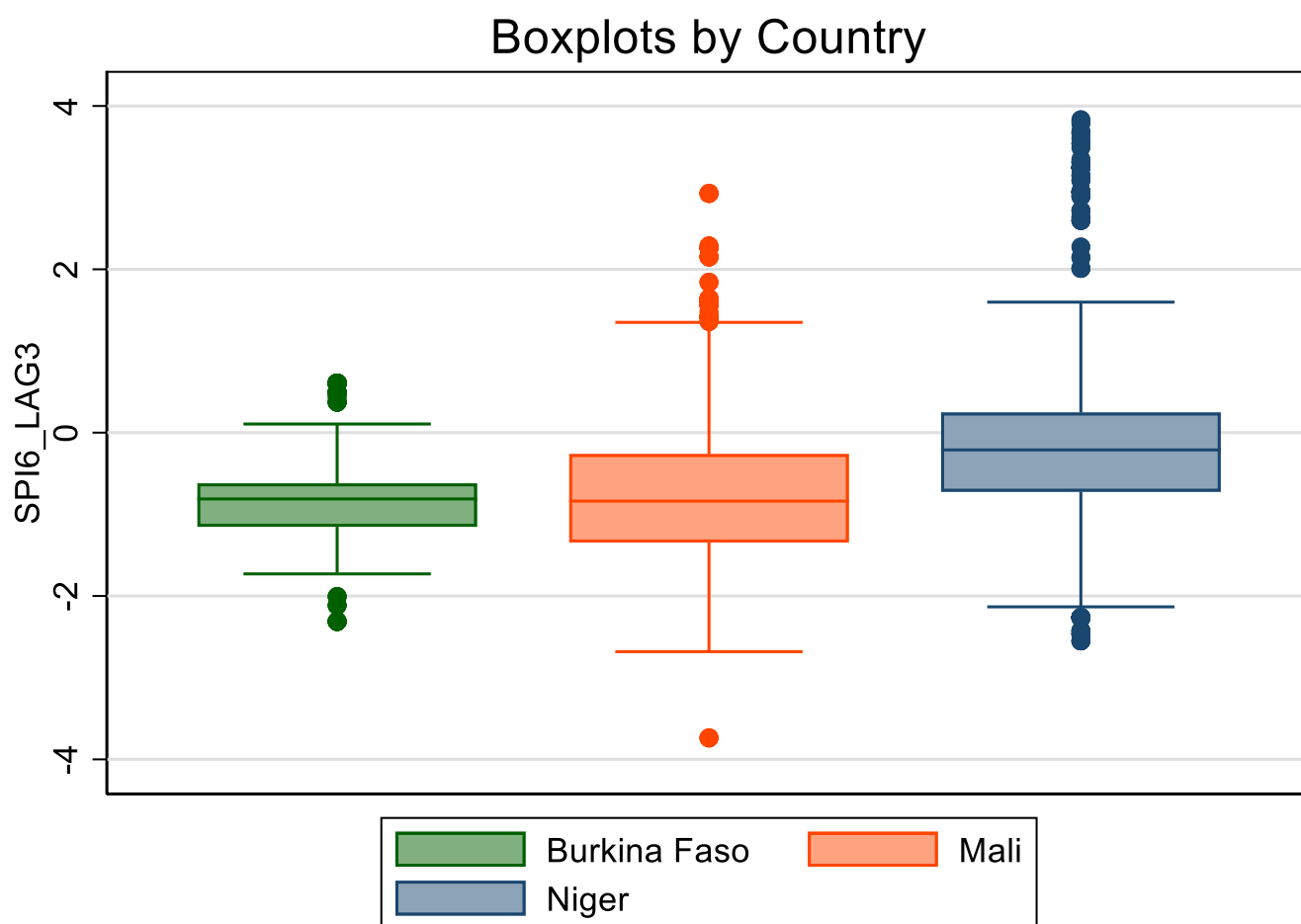


Figure 4.1: Box plot of lagged standardized precipitation indices (SPI_lag3) by country in the AES

The boxplot in Figures 4.2 depicts the spread of SPI lagged at 6 months, with Burkina Faso and Niger reporting no outliers. However, the distribution shown in the Figure indicates that Burkina Faso experiences consistent dry conditions. In Mali, there appears to be greater fluctuations between dry and wet period; however, SPI

values greater than +1 suggests occasional wet anomalies which could be linked to rainfall events of climate shifts.

Given that the median hovers around 0.5 in Niger, this implies less severe overall dryness. The spread from a minimum of -2.5 to +1.5 reveals high variability with occasional extreme rainfall anomalies. The outcomes point to the need to design long-term drought mitigation strategies and adaptive cropping systems among others.

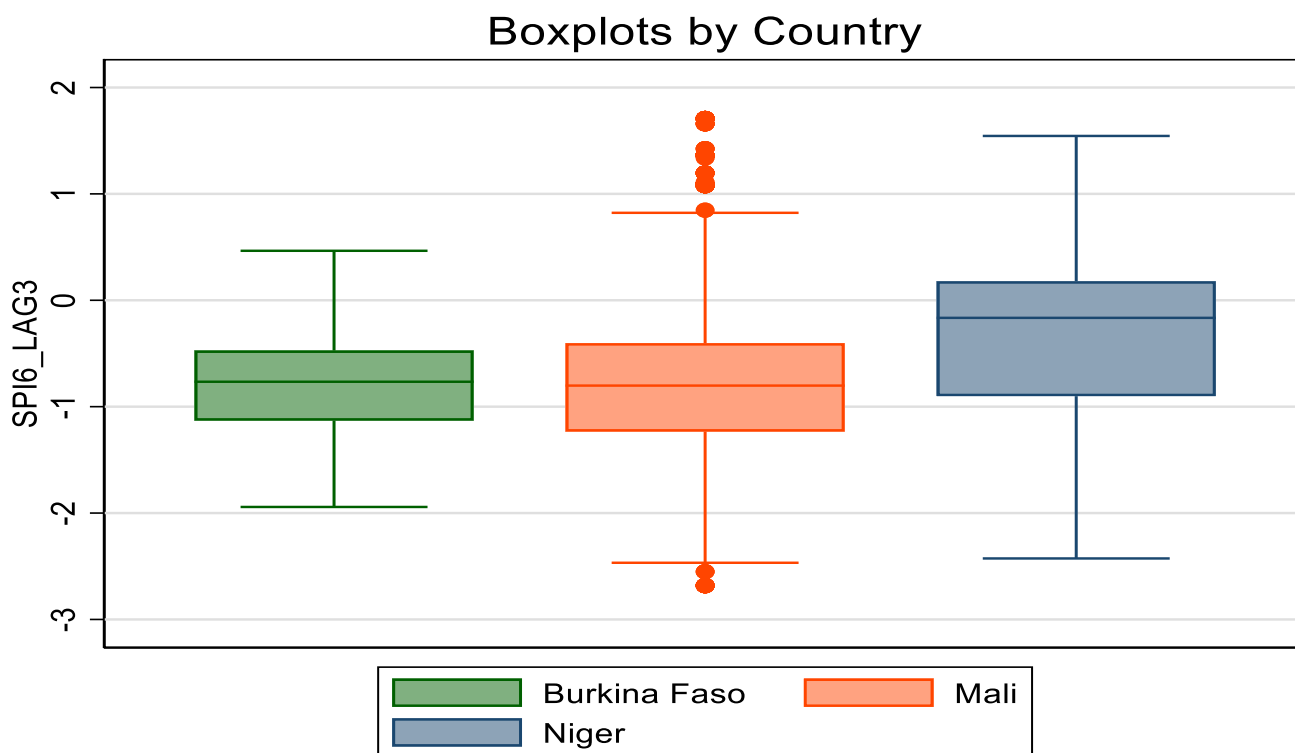


Figure 4.2: Box plot of standardized precipitation indices (SPI_{lag6}) for AES

4.1.3 Summary statistics of household, farm, and socioeconomic variables

Table 4.2 presents summary statistics for relevant predictors of household food security, including their measurement scales and mean values. These statistics are based on the sample sizes of 7,656, 11,296 and 11,053 households, respectively for Burkina Faso, Mali and Niger, and on the pooled dataset. The results showed that over 90% of households across AES were headed by men. Men are usually the heads of households in the Sahel Region and traditionally being the custodians of the household’s productive resources, were the main respondents in the DIEM surveys. About one in four (24.9%) of the households in the AES interviewed had educated heads, with percentages for Niger (26.4%) and Mali (26.3%) higher than for Burkina Faso (21.2%). Similarly, about 23% were engaged in sole crop farming, with Niger reporting slightly higher farmers, while about 10% owned livestock. Generally, most households across Burkina Faso, Mali and Niger

engaged in both crop and livestock production. Specifically, about 81.2% of households engaged in both crop and livestock production in Burkina Faso followed by 53% in Niger and 44% in Mali.

Across the AES, the average household income was about 160,000 CFA across the three countries. However, Mali reported the highest household income of over 200,000 CFA. A significant majority of households stated that they did not receive any support in the form of cash, food or productive assets. Among the 15% that received some support, the highest form of support was food received by about (10% of the households, often required to smooth consumption under emergency food insecurity situations, followed by productive assets support (3%) and cash support (2.4%) This is followed by asset support and cash support in that order.

While the average SPIs point to near normal rainfall distributions, the minimum and maximum values, as stated earlier by the box plots in Figures 1 and 2, show instances of anomalies in rainfall resulting in abundant rains and seasonal dryness to droughts.

Table 4.2: Summary statistics of explanatory variables at country level

Variable	Description	Burkina Faso	Mali	Niger	Cross Country
female_head	Dummy (1=female)	0.056 (0.231)	0.075 (0.264)	0.075 (0.263)	0.070 (0.256)
Education of household head	Dummy (1=formal education)	0.212 (0.409)	0.263 (0.440)	0.264 (0.441)	0.249 (0.433)
Crop farming	Dummy (1=Yes)	0.121 (0.327)	0.264 (0.441)	0.268 (0.443)	0.229 (0.420)
Livestock producer	Dummy (1=Yes)	0.024 (0.154)	0.103 (0.303)	0.110 (0.313)	0.085 (0.279)
Both crop and Livestock producer	Dummy (1=Yes)	0.812 (0.390)	0.442 (0.496)	0.530 (0.499)	0.570 (0.495)
Household income	Continuous (CFA)	114715.20 (131966.40)	207958.00 (203481.50)	151225.40 (154602.20)	155815.60 (167506.50)
Lean season	Dummy (1=Yes)	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)
No support	Dummy (1=Yes)	0.840 (0.367)	0.840 (0.366)	0.882 (0.323)	0.856 (0.352)
Cash support	Dummy (1=Yes)	0.025 (0.156)	0.021 (0.142)	0.026 (0.159)	0.024 (0.152)
Food support	Dummy (1=Yes)	0.091 (0.287)	0.106 (0.307)	0.077 (0.267)	0.091 (0.287)
Asset support	Dummy (1=Yes)	0.045 (0.207)	0.034 (0.180)	0.015 (0.122)	0.030 (0.170)
Non-farm household	Dummy (1=Yes)	0.042 (0.201)	0.190 (0.394)	0.092 (0.288)	0.116 (0.320)
Drought	Continuous (from SPI)	0.629 (0.483)	0.691 (0.462)	0.448 (0.497)	0.585 (0.493)
Drought1 (moderate)	Continuous (from SPI)	0.629 (0.483)	0.673 (0.469)	0.399 (0.490)	0.561 (0.496)
Drought2 (severe)	Continuous (from SPI)	0.000 (0.000)	0.047 (0.211)	0.048 (0.215)	0.035 (0.185)
Abundant_rain	Continuous (from SPI)	0.000	0.139	0.243	0.141

		(0.000)	(0.346)	(0.429)	(0.348)
Abundant_rain (moderate)	Continuous (from SPI)	0.000 (0.000)	0.109 (0.312)	0.071 (0.257)	0.067 (0.250)
Abundant_rain (severe)	Continuous (from SPI)	0.000 (0.000)	0.030 (0.170)	0.183 (0.387)	0.079 (0.269)
spi6_lag3	Continuous (index)	-0.812 (0.422)	-0.764 (0.864)	-0.226 (0.786)	-0.578 (0.790)
spi6_lag6	Continuous (index)	-0.761 (0.557)	-0.757 (0.695)	-0.287 (0.765)	-0.585 (0.727)
No. of obs.		3718	5356	5306	14380

Source: Estimates from FAO-DIEM Data

4.2 Climate-induced shocks and food security nexus in the Alliance of Sahel States

One of the sectors projected to be directly affected by climate-related shocks is agriculture. These effects are and food security of farm households. The effects are especially expected to be more pronounced in developing countries with fragile, rainfed agroecologies such as Burkina Faso, Mali, and Niger. The direct effects of climate change on agriculture will then pose threats to household food security

To measure the effects of rainfall deficits (droughts) and rainfall surplus (floods) on food security in the AES, we fitted ordinary least squares (OLS) regression with year and country controls to estimate the climate shock-food security nexus based on three food security outcomes (i.e., food consumption score, food insecurity experience scale, and reduced coping strategy index).

4.2.1 Climate-induced shocks and household food consumption

The results in Table 4.6 indicate that climate-induced shocks, such as moderate drought conditions, significantly reduce household food consumption in Burkina Faso, whereas the effect is statistically insignificant in Mali and Niger. At the cross-country level, however, moderate drought exerts a significant negative effect on food consumption, suggesting that even relatively mild rainfall deficits pose food security risks across the region.

Severe droughts are shown to have a more pronounced negative effect, significantly reducing household food consumption in both Mali and Niger, as well as across the AES. The reason for the positive effect of moderate drought on food consumption in Niger may reflect long-term adaptation to arid conditions, given the country's chronically dry climate. Households in Niger may have developed coping strategies such as livelihood diversification, reliance on pastoral systems or social safety networks that partially buffer the effects of moderate drought shocks. However, the significant negative impact of severe drought highlights the limits of

such adaptive strategies, indicating that prolonged or extreme drought remains detrimental to household food security. Hence, both moderate and severe droughts pose major threats to food security in the AES, with increasing severity amplifying adverse outcomes.

Moderate rainfall anomalies were not significant across countries, but severe rainfall anomalies adversely affected household food consumption in Mali and Niger. At the cross-country domain, both severe and moderate rainfall anomalies were not significant, suggesting regional differences and adaptive capabilities, where some households, by means of locations, may not experience rainfall surpluses that may cause increasing vulnerability and decline in caloric intake by affected households. Burkina Faso did not experience statistically significant excess rainfall anomalies during the study/referenced period.

Income plays a crucial role in reducing vulnerability due to climate-induced shocks. Thus, the drought-food consumption relationship observed in Burkina Faso is consistent with Nacanabo (2025), who found that drought significantly increases the probability of income poverty among agricultural households by nearly threefold relative to positive rainfall anomalies. Given the strong link between poverty and food access, climate-induced income effects directly reduce food access and consumption. Also, Gansonré (2024) showed that both positive and negative rainfall anomalies reduce household food expenditures across major food types. Specifically, a one standard deviation increase in rainfall variability was found to reduce expenditures for cereal-based products, animal-based products, and processed foods by 11.96%, 21.31%, and 16.23%, respectively (Gansonré, 2024). These will in turn affect the overall caloric intake by such households as found in this study.

Among household characteristics, the education of the household head consistently improves food consumption outcomes, indicating that improved human capital enhances income-generating opportunities, access to information, and the ability to manage climate risks. Higher household income is also associated with improved food consumption in Burkina Faso and Mali, reinforcing the central role of economic access in determining dietary adequacy.

Livelihood strategies exhibit heterogeneous effects across countries. In Niger, households engaged in both crop and livestock production achieve better food consumption outcomes than those relying solely on crop production, highlighting the buffering role of mixed farming systems in highly climate-variable environments. In Mali, households that engage exclusively in livestock production have higher caloric intake than mixed producers, whereas engagement in non-farm activities is particularly beneficial in Niger.

These findings suggest that livelihood diversification across agricultural and non-agricultural activities plays a critical role in enhancing food security, although the effectiveness of specific strategies remains context specific. Finally, the negative association between food and cash assistance and household food consumption,

reflects targeting effects, whereby social support programs are directed toward already food-insecure households.

Table 4.3: Relationship between climate-induced shocks and household food consumption

VARIABLES	Burkina Faso	Mali	Niger	cross country
Female head of household	-1.057 (2.085)	-0.0661 (2.421)	-3.261*** (1.235)	-1.301 (1.079)
Formal education of household head	2.073** (1.005)	2.397** (1.156)	3.633*** (0.636)	5.070*** (0.563)
Crop producer	-1.852 (3.559)	-1.448 (1.099)	-3.109*** (0.656)	-4.743*** (0.613)
Livestock producer	-2.941 (3.363)	4.554*** (1.447)	1.652 (1.110)	1.044 (0.948)
Non-farm households		2.327 (6.492)	15.18*** (1.805)	4.835*** (1.791)
Household income	4.488*** (0.784)	3.613*** (0.473)		
Lean season	2.220 (1.652)	0.134 (1.036)	0.615 (0.518)	0.0716 (0.594)
Cash support	-0.234 (2.544)	-2.423 (2.683)	-5.185*** (1.656)	-4.860*** (1.427)
Food support	-6.864** (3.050)	1.220 (1.407)	0.761 (0.855)	-1.787** (0.748)
Asset support	-1.084 (2.283)	3.299 (2.121)	3.025** (1.311)	1.115 (1.180)
Drought1(moderate)	-6.909*** (2.326)	-1.263 (1.033)	3.824*** (0.543)	-1.327*** (0.498)
Drought2(severe)		-13.97*** (1.886)	-3.665** (1.685)	-10.52*** (1.661)
Abundant_rain1(moderate)		-1.623 (3.157)	1.115 (2.105)	-3.488* (1.867)
Abundant_rain2(severe)		-11.45*** (4.027)	-5.140** (2.129)	0.0391 (2.637)
2024.year		-11.33*** (1.203)	-0.982 (0.675)	7.647*** (0.834)
Mali				11.95*** (0.631)
Niger				-20.53*** (0.920)
Constant	-7.716 (8.951)	11.58** (5.745)	38.08*** (0.578)	39.00*** (0.604)
Observations	2,929	2,247	8,769	8,769
R-squared	0.134	0.119	0.029	0.218

Robust standard errors in parentheses

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

4.5.2 Climate-induced shocks and household food insecurity experience scale (FIES)

The results in Table 4.7 also show that both moderate and severe drought positively contribute to household food insecurity for Mali, Niger, and the cross-country domain. While the moderate rainfall anomaly was insignificant in explaining household food insecurity across all countries under study, the severe rainfall anomaly significantly contributed to food insecurity in Mali and Niger. The results suggest that extremely abundant rains beyond 2 standard deviations significantly influence household food insecurity as compared to a 1-point standard deviation.

Again, the education of the household head significantly reduces food insecurity in Mali, Niger, and the pooled sample. Meanwhile engaging in both crops and livestock integration (the baseline) is proven to be more effective in reducing household food insecurity than solely engaging in crops, livestock or non-farm activities. Food insecurity appears more pronounced in the lean season for Mali and Niger but not Burkina Faso. The result on the lean season was expected and is consistent with Lain and Brunelin (2025) who found that real monetary consumption of households in the Sahel such as Mali and Niger is about 10.5% lower in the lean season, affecting the economic access to food and food security for that matter. Around this time, which is usually before the harvest season, most households exhaust their food stock and tend to manage their food consumption patterns until the next harvest. In terms of the support systems, asset support shows an inverse relationship with food insecurity relative to those who received no support.

Table 4.4: Relationship between climate-induced shocks and household food insecurity experience scale

VARIABLES	(1) Burkina Faso	(2) Mali	(3) Niger	(5) cross country
Gender of household head	0.830*** (0.309)	0.467* (0.268)	0.865*** (0.210)	0.630*** (0.108)
Education of household head	0.139 (0.228)	-0.314*** (0.115)	-0.394*** (0.0948)	-0.349*** (0.0566)
Crop producer	0.182 (0.581)	0.448*** (0.116)	0.624*** (0.0973)	0.716*** (0.0597)
Livestock producer	1.028*** (0.334)	0.227 (0.168)	0.229* (0.135)	0.339*** (0.0866)
Off-farm households		1.324*** (0.470)	0.684*** (0.195)	0.544*** (0.192)
Household income	-0.475*** (0.146)	-0.577*** (0.0495)		
Lean season	-0.364* (0.206)	0.626*** (0.105)	0.240** (0.0947)	0.189*** (0.0550)

Cash support	-0.194 (0.417)	0.0908 (0.305)	-0.0819 (0.261)	0.338** (0.145)
Food support	0.0979 (0.700)	0.149 (0.160)	0.244* (0.134)	0.0987 (0.0822)
Asset support	-1.076*** (0.293)	-0.561** (0.224)	-0.582*** (0.201)	-0.657*** (0.114)
Drought1	0.531 (0.435)	0.547*** (0.104)	0.451*** (0.0861)	0.298*** (0.0514)
Drought2		1.859*** (0.228)	1.413*** (0.200)	0.339** (0.143)
Abundant_rain1		0.469 (0.333)	0.245 (0.216)	-0.388*** (0.120)
Abundant_rain2		1.327** (0.660)	1.334** (0.523)	0.0365 (0.112)
2024.year		0.530*** (0.126)	0.379*** (0.111)	-0.185** (0.0722)
Mali				0.157** (0.0666)
Niger				1.064*** (0.0753)
Constant	7.595*** (1.573)	8.307*** (0.605)	2.040*** (0.0809)	2.182*** (0.0650)
Observations	2,912	2,240	3,700	11,856
R-squared	0.086	0.166	0.065	0.057

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2.3 Climate-induced shocks and food insecurity measured by rCSI

The reduced coping strategy index (rCSI) measures short-term household food access constraints by assessing the frequency and severity of food-based coping behaviours.

The rCSI reflects how households manage short-term disruptions to food access (Maxwell and Caldwell, 2008). This makes the rCSI particularly suitable for analysing the immediate impacts of climate-induced shocks (Maxwell et al., 2003). The results in table 4.8 indicate that drought shock significantly increases households' reliance on food-based coping strategies across the AES, with effects intensifying as drought severity increases. Both moderate and severe droughts are associated with higher rCSI in Mali, Niger, and the pooled sample. Rainfall anomaly only showed a significantly positive effect at the cross-country level. The findings are consistent with Gautier et al (2016) who argue that severe droughts and rainfall anomalies rapidly translate into heightened food stress and coping intensity in West Africa.

Among the control variables, higher household income and asset support consistently reduced coping intensity, highlighting their adaptive role in buffering climatic shocks. Education lowers rCSI in Niger and in

the pooled sample, reflecting enhanced adaptive capacity. Moreover, households engaged in both crop and livestock integration show a relatively lower probability of engaging in stressful coping strategies while the positive association between food assistance and rCSI likely reflects program targeting toward already food-stressed households rather than demonstrating the efficacy of the intervention itself.

Table 4.5: Relationship between climate-induced shocks and food insecurity measured by the rCSI

VARIABLES	(1) Burkina Faso	(2) Mali	(3) Niger	(4) cross country
Gender of household head	4.248 (3.106)	2.618** (1.323)	3.800*** (1.079)	3.203*** (0.733)
Education of household head	2.220 (1.345)	-0.876 (0.623)	-1.621*** (0.527)	-0.661* (0.357)
Crop producer	3.077 (4.729)	2.435*** (0.628)	3.361*** (0.544)	2.472*** (0.396)
Livestock producer	5.236 (3.266)	1.070 (0.834)	1.012 (0.711)	-0.421 (0.532)
Off-farm households		3.065 (3.306)	2.702*** (1.019)	2.819*** (0.994)
Household income	-1.931** (0.859)	-2.261*** (0.284)		
Lean season	-1.080 (1.471)	3.555*** (0.578)	1.938*** (0.538)	-0.300 (0.387)
Cash support	1.116 (2.337)	0.888 (1.856)	0.607 (1.697)	0.819 (1.009)
Food support	0.108 (4.842)	2.312** (0.910)	2.257*** (0.779)	2.163*** (0.559)
Asset support	-6.878*** (1.857)	-1.173 (0.990)	-1.861* (0.952)	-4.626*** (0.563)
Drought1	2.679 (3.042)	1.015* (0.580)	0.844* (0.478)	2.112*** (0.325)
Drought2		5.162*** (0.996)	4.086*** (0.941)	3.253*** (0.900)
Abundant_rain1		2.445 (2.143)	1.990 (1.429)	-0.129 (1.133)
Abundant_rain2		2.119 (4.122)	3.764 (3.791)	7.545*** (1.906)
2024.year		4.034*** (0.694)	2.717*** (0.641)	9.152*** (0.478)
Mali				-2.301*** (0.420)
Niger				-4.771*** (0.551)
Constant	30.06*** (8.119)	31.78*** (3.490)	7.859*** (0.452)	9.091*** (0.451)
Observations	2,929	2,247	3,708	8,769
R-squared	0.062	0.121	0.049	0.081

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5. STUDY LIMITATIONS

Before presenting the conclusions of this study, some limitations are worth noting. Firstly, the reliance on only secondary data curtailed the ability of the study to draw qualitative insights into the findings. While the secondary data from FAO-DIEM household surveys and ERA5 reanalysis datasets are robust and widely used, the authors were unable to interrogate respondents to attain qualitative insights into the non-empirical dimensions of food insecurity.

Secondly, there were temporal and seasonal differences across survey rounds. The DIEM surveys were conducted at various times of year and in different years and seasons across the AES. Burkina Faso had only two rounds of surveys, while Mali and Niger each had five. These differences in survey timing reflect different stages of farm and off-farm calendars and may introduce seasonality bias, making cross-country and intertemporal comparisons more challenging. As a result, some variations in food security indicators might partly be due to seasonal effects rather than solely from climate events like droughts or floods. Although controlling for the lean season helps capture most food insecurity peaks, it does not eliminate all remaining bias.

Finally, climate-induced shocks were specified as proxies through rainfall-based SPI indicators, focusing on droughts and excess rainfall. This approach does not capture other relevant climate stressors such as temperature extremes, heat stress, windstorms, or localized flooding dynamics. Moreover, self-reported incidence of drought and flood in the FAO-DIEM dataset were skewed and not used for further analysis.

These limitations do not undermine the study's contributions but should be acknowledged when interpreting the findings and generalizing policy recommendations beyond the study context.

6. CONCLUSIONS AND RECOMMENDATIONS

Sub-Saharan Africa, especially the Sahelian countries with their arid and semi-arid agroecology and heavy reliance on rainfall-driven agriculture, is facing immense challenges from climatic shocks, unstable food production, food insecurity, and other forms of vulnerabilities. Under the rain-fed systems of the AES, trends in precipitation indices show high variability, as do food security statuses of agricultural households.

This study examined the effect of climate-induced shocks on food security in the AES. The purpose is to produce the empirical evidence needed to inform decision-making to support household food security in these food-crisis states, and to recommend resilience-enhancing, strategic, and actionable food security interventions to their governments and the FAO. Based on the findings, we have drawn some important policy conclusions and made recommendations for further research.

The study is relevant because it analyses, in a novel way, the impact of climate change on food security using a combination of household survey data and a matched satellite precipitation dataset. To the best of our knowledge, this study, unlike previous studies such as Diffenbaugh and Burke (2019), is the first to examine food insecurity across the AES.

Generally, the findings show that climate-induced precipitation shocks, namely negative rainfall anomalies (drought) and positive rainfall anomalies (floods), can threaten food production and food security across the three AES. Severe drought, for instance, consistently reduced food production and consumption, leading to increasing food insecurity and forcing households into more intensive food-based and livelihood coping strategies. Excess rainfall shocks also worsened outcomes, particularly in Mali and Niger, highlighting a dual vulnerability to rainfall deficits and surpluses. Ultimately, the implications of a continuous and increased incidence of climate-related shocks for food security may be consequential.

The multidimensional indicators of food security estimated by the study reveal complex implications of climate-induced shocks for food security in each of the three AES and for the pooled dataset. This may be attributed to the interactions among socioeconomic variables such as household income, education, enterprise combinations, and a portfolio of external interventions, viz., food, cash, and asset support. Thus, any given indicator may be limited in its ability to predict the actual level of food insecurity, and the explicit outcomes of the selected climatic shocks may be hard to gauge.

The following recommendations are made:

1. Climate risk management should prioritize both drought and flood resilience through climate-smart agriculture, improved water management, early warning systems, and scalable shock-responsive social protection tailored to shock severity.
2. Supporting crop-livestock diversification serves as a major entry point for reducing food insecurity in the AES. Crop and livestock integration builds household adaptive capacity and improves food security.
3. Socioeconomic factors like income, education, and assets are essential in improving household food security. Higher education and income improve food consumption, reduce food insecurity, and lower

reliance on erosive coping strategies, while asset support consistently reduces rCSI and FIES. This confirms that economic and productive buffers are critical in translating shocks into manageable stress rather than crisis.

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5 Appendix

Table 5.1: Descriptive statistics of FCS by rounds across AES

Indicator	Burkina Faso		Niger		Mali	
	Freq.	%	Freq.	%	Freq.	%
FCS			Round 6		Round 5	
Poor (0)	596	16.03	754	100.00	82	7.61
Borderline (1)	1,214	32.65	0	0.00	200	18.57
Acceptable (2)	1,908	51.32	0	0.00	795	73.82
Total	3,718	100.00	754	100.00	1,077	100
			Round 9		Round 6	
Poor (0)			343	31.41	92	8.97
Borderline (1)			249	22.8	175	17.06
Acceptable (2)			500	45.79	759	73.98
Total			1,092	100	1,026	100
					Round 7	
Poor (0)					59	4.44
Borderline (1)					227	17.07
Acceptable (2)					1,044	78.5
Total					1,330	100
					Round 8	
Poor (0)					202	21.02
Borderline (1)					305	31.74
Acceptable (2)					454	47.24
Total					961	100
					Round 9	
Poor (0)					85	8.84
Borderline (1)					199	20.69
Acceptable (2)					678	70.48
Total					962	100

Table 5.2: Descriptive statistics of LCS I by rounds across AES

LCSI	Burkina Faso		Mali		Niger	
	Freq.	%	Freq.	%	Freq.	%
			Round 5		Round 6	
No coping (0)	1,078	28.99	337	31.29	179	23.74
Stress (1)	1,222	32.87	223	20.71	201	26.66
Crises (2)	887	23.86	187	17.36	224	29.71
Emergency (3)	531	14.28	330	30.64	150	19.89
Total	3,718	100	1,077	100	754	100
			Round 6		Round 7	
No coping (0)			334	32.55	131	17.08
Stress (1)			213	20.76	217	28.29
Crises (2)			213	20.76	271	35.33

Emergency (3)	266	25.93	148	19.3
Total	1,026	100	767	100

	Round 7		Round 8	
No coping (0)	581	43.68	240	23.46
Stress (1)	394	29.62	319	31.18
Crises (2)	185	13.91	224	21.9
Emergency (3)	170	12.78	240	23.46
Total	1,330	100	1,023	100

	Round 9		Round 9	
No coping (0)	196	20.4	171	15.66
Stress (1)	529	55.05	314	28.75
Crises (2)	112	11.65	208	19.05
Emergency (3)	124	12.9	399	36.54
Total	961	100	1,092	100

	Round 9		Round 10	
No coping (0)	250	25.99	331	19.82
Stress (1)	564	58.63	652	39.04
Crises (2)	53	5.51	325	19.46
Emergency (3)	95	9.88	362	21.68
Total	962	100	1,670	100

Source: Estimates from FAO-DIEM Data

Table 5.3: Summaries of explanatory variables by rounds per country

Variable	Burkina Faso	Mali					Niger					Cross Country
		Round 5	Round 6	Round 7	Round 8	Round 9	Round 6	Round 7	Round 8	Round 9	Round 10	
female_head	0.056 (0.231)	0.055 (0.228)	0.051 (0.219)	0.102 (0.302)	0.075 (0.263)	0.090 (0.286)	0.090 (0.286)	0.091 (0.288)	0.087 (0.282)	0.085 (0.279)	0.051 (0.221)	0.070 (0.256)
educ_hhead	0.212 (0.409)	0.328 (0.470)	0.349 (0.477)	0.211 (0.408)	0.170 (0.375)			0.365 (0.482)	0.342 (0.475)	0.317 (0.465)	0.114 (0.318)	0.249 (0.433)
crop_produ~r	0.121 (0.327)	0.199 (0.399)	0.263 (0.441)	0.219 (0.414)	0.318 (0.466)	0.345 (0.476)	0.345 (0.476)	0.245 (0.430)	0.172 (0.378)	0.302 (0.459)	0.361 (0.480)	0.229 (0.420)
livestock_~r	0.024 (0.154)	0.114 (0.318)	0.104 (0.306)	0.104 (0.305)	0.097 (0.296)	0.091 (0.288)	0.091 (0.288)	0.160 (0.367)	0.171 (0.377)	0.097 (0.296)	0.029 (0.169)	0.085 (0.279)
tot_income	114715.20 (131966.40)		208276.00 (215501.30)	208860.80 (197863.70)	206085.10 (196877.20)			192329.30 (150739.30)	194428.70 (187308.50)	182730.70 (194073.10)	100732.10 (93625.70)	155815.60 (167506.50)
lean_season	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)		1.000 (0.000)	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)	1.000 (0.000)
drought	0.629 (0.483)	0.521 (0.500)	0.735 (0.442)	0.732 (0.443)	0.768 (0.422)	0.702 (0.458)	0.702 (0.458)	0.849 (0.359)	0.360 (0.480)	0.531 (0.499)	0.408 (0.492)	0.585 (0.493)
drought1	0.629 (0.483)	0.521 (0.500)	0.684 (0.465)	0.732 (0.443)	0.751 (0.432)	0.674 (0.469)	0.674 (0.469)	0.677 (0.468)	0.358 (0.480)	0.508 (0.500)	0.359 (0.480)	0.561 (0.496)
drought2	0.000 (0.000)	0.011 (0.105)	0.052 (0.221)	0.063 (0.243)	0.069 (0.253)	0.037 (0.190)	0.037 (0.190)	0.172 (0.378)	0.002 (0.044)	0.023 (0.150)	0.049 (0.216)	0.035 (0.185)
off_farm_hh	0.042 (0.201)	0.168 (0.374)	0.208 (0.406)	0.207 (0.405)	0.163 (0.370)	0.209 (0.407)	0.209 (0.407)	0.150 (0.357)	0.103 (0.304)	0.143 (0.350)	0.005 (0.073)	0.116 (0.320)
abundant_r~n	0.000 (0.000)	0.118 (0.323)	0.010 (0.098)	0.000 (0.000)	0.102 (0.303)	0.529 (0.499)	0.529 (0.499)	0.095 (0.294)	0.050 (0.218)	0.098 (0.297)	0.586 (0.493)	0.141 (0.348)
abundant_r~1	0.000 (0.000)	0.118 (0.323)	0.010 (0.098)	0.000 (0.000)	0.081 (0.273)	0.384 (0.487)	0.384 (0.487)	0.095 (0.294)	0.050 (0.218)	0.020 (0.141)	0.090 (0.287)	0.067 (0.250)
abundant_r~2	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.021 (0.143)	0.146 (0.353)	0.146 (0.353)	0.000 (0.000)	0.000 (0.000)	0.080 (0.271)	0.531 (0.499)	0.079 (0.269)
spi6_lag3	-0.812 (0.422)	-0.230 (0.695)	-0.782 (0.622)	-1.227 (0.669)	-0.995 (0.734)	-0.472 (1.136)	-0.472 (1.136)	0.041 (0.368)	-0.470 (0.964)	0.191 (0.902)	-0.647 (0.507)	-0.578 (0.790)
spi6_lag6	-0.761 (0.557)	-0.190 (0.739)	-0.445 (0.601)	-0.918 (0.438)	-1.111 (0.648)	-1.148 (0.478)	-1.148 (0.478)	0.301 (0.554)	0.045 (0.512)	-0.849 (0.457)	-0.560 (0.845)	-0.585 (0.727)
precip_mm	60.987 (42.145)	11.791 (17.939)	66.700 (71.408)	0.031 (0.033)	44.572 (70.505)	65.551 (86.744)	65.551 (86.744)	32.867 (24.346)	11.325 (23.280)	7.258 (14.535)	15.814 (54.871)	33.729 (52.811)
precip_m	0.061 (0.042)	0.012 (0.018)	0.067 (0.071)	0.00003 (0.00003)	0.045 (0.071)	0.066 (0.087)	0.066 (0.087)	0.033 (0.024)	0.011 (0.023)	0.007 (0.015)	0.016 (0.055)	0.034 (0.053)
No. of obs.	3718	1077	1026	1330	961	962	754	767	1023	1092	1670	14380

*Table of means with standard deviations in parentheses