Spatial Dimensions of Food and Nutrition Security in the Northern Region of Ghana

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DOI: http://dx.doi.org/10.4314/sajg.v9i2.27

Abstract

This study focused on analyzing the trend of food insecurity in the Northern regions of Ghana. It applied the GIS-based Multi-Criteria Evaluation approach to the criteria of rainfall, land cover, population density, road networks, slope, market centres, potable water access, access to sanitation facilities, and disaster and conflict hotspots. The Weighted Linear Combination (WLC) technique, was used to standardize a set of criteria for each of the four dimensions of food security (availability, accessibility, utilization, and stability) into an ordinary numeric scale after which those factors were accumulated via weighted averaging to determine a composite index for all the districts within the study area. The research found that the food insecurity situation is relatively high, as 174,509 people (6.3 percent) are moderately food insecure while 25,246 people (0.9 percent) are severely food insecure. Overall, 199,755 people, representing 7.2 percent of the population were food insecure (both severely and moderately food insecure). The proportion of the food insecure population was highest in the Tamale metropolis (37.2 percent) and lowest in the Zabzugu and Tatale Sanguli districts (0 percent). A correlation analysis also revealed that the composite food security index was mainly influenced by food utilization (0.75) and stability (0.64). Also, there was no significant relationship between Food stability and the other three dimension of food security (food availability, accessibility, and utilization), implying that it did not influence domestic food production or market access due to the short-term nature of its effect.

Keywords: *GIS, Multi-Criteria Evaluation, Food security*

1. Introduction

Food security is considered a fundamental aspect of human need. In conjunction with essential health care, food security is a precondition for the development of human society (Feizizadeh et al., 2015). A community is considered food secured when all its people have the economic power and physical access to acquire adequate, safe, and nutritious food that provides for their dietary and nutritional preference needs and always enables them to live healthy and active lives. Four key dimensions are critical to food security: physical availability of food, economic and physical access to food, food utilization, and the stability of all other three dimensions over time (Devereux, 2006). In other words, it is considered as a household's ability to consistently access healthy foods to sustain an active and healthy lifestyle (Kane, 2014).

At local and global levels, food security is mainly influenced by the following factors; (a) access and availability of food in local environments, (b) effects of the changing climate on agriculture and natural resources, and (c) active participation in planning, developing and managing effective strategies to optimize and sustain food production with the available existing land (Kane, 2014).

Because of the strong relationship between the four (4) dimensions of food security to agriculture production, food security is very likely to be impacted by climate change. As a result, it is reasonable to expect a major impact of climate change on food security for rural households (FAO, 2018). The World Food Programme (2012), in a Comprehensive Food Security and Vulnerability Analysis (CFSVA) report, indicated that more than 20% of households in the Northern Region (Ghana), were considered either severely, moderately, or mildly food insecure. There is therefore the expectation that climate change impacts would further reduce agricultural productivity and deepen the food insecurity situation in the Northern region and the country.

According to the FAO, world hunger has continued for the third year in a row to rise, as the population of undernourished people (population facing chronic food deprivation) expanded from about 804 million (in the year 2016) to close to 821 million (in 2017). Dijk (2011) also reported that despite the reduction in the number of undernourished people by 9.6 percent between 2009 and 2010, the population of hungry people in the world remained higher than it was 40 years ago. The FAO also highlighted Africa as having the highest prevalence of undernourishment which affected more than 256 million people; 21 percent of the population of the continent (FAO, 2018). Accordingly, 72 million people, representing 30 percent of the population in Sub-Saharan Africa, suffer from undernutrition, the highest proportion of all developing regions. Although stunting (chronic malnutrition) among under 5 children has decreased from twenty-three (23) to nineteen (19) percent over the last 10 years in Ghana, the Northern region experienced an increase from 33 percent to 40 percent in some districts. During the same period, micronutrient deficiencies (hidden hunger) continue to persist. Whilst nationally, four (4) out of ten (10) women of reproductive age, and six (6) out of ten (10) children under five (5) years are anaemic, the pervasiveness is considerably higher in the north as anaemia affects between 7 and 8 out of 10 children. WFP estimates that the gross domestic product (GDP) Ghana loses annually due to child undernutrition is about 6.4 percent. This, therefore, underscores the importance of nutritional and food security to the development of humans and the socio-economic transformation of a nation (WFP, 2018).

Ghana has been commended globally for significantly reducing poverty, hunger, and malnutrition over the period 1990 and 2014 (Steiner-Asiedu et al., 2017). Additionally, Ghana has also experienced steady per-capita economic growth and improved governance in recent years. The country however still has more room to improve its nutritional situation and the health and productivity of its citizens. Rosenbloom et al. (2008), ranked Ghana as 59th from a list of 192 countries in the Global Nutritional Index (GNI). The FAO (2018) also estimates the population of severely food insecure persons living in Ghana to have increased to 2.2 million in 2017 (representing 7.9 percent of the population). Additionally, an estimated 2 million Ghanaians are considered as being at risk of becoming food insecure nation-wide; a situation that could easily be deteriorated by any

unanticipated man-made or natural shock (Darfour & Rosentrater, 2016). The world food programme estimates approximately 453,000 people in northern Ghana to be food insecure; of which thirty-nine percent (175,000) are in the Upper West Region, twenty-eight percent (126,000) in Upper East, and thirty-three percent (152,000) in the Northern Region (WFP, 2009).

Mohammadzadeh (2010), notes that many countries measure and evaluate the situation of food security with various techniques and methods. GIS and remote sensing, provide some of the most useful tools and techniques for investigating, analyzing, and understanding food and nutrition security. This can be achieved by examining the local food environments, assessing the fluctuations in land cover and land use over time, and identifying critical geographical zones in relationships to biophysical and socioeconomic attributes (Feizizadeh et al., 2015). Additionally, Composite Indicators (CIs) are emerging in numerous disciplines and fields as compelling techniques to synthesize multi-dimensional information, into a compact, single, and effective index (Alam et al., 2016; Maricic et al., 2016). Consequently, there is expanding theoretical and empirical literature about combining several indicators and the application of sophisticated statistical procedures (e.g., Lee, 2014; Moore et al., 2014; Krishnan, 2019).

In this study, peoples' ability to meet minimum food requirements in terms of availability, accessibility, utilization, and stability were analyzed using the combination of GIS and MCE methods. Results will help decision-makers determine where the vulnerable people to food insecurity are located and serve as a targeting criterion for safety net policies.

2. Methods

2.1. Study area

The study was conducted in the Northern Region of Ghana (reference to the Northern region before it was delineated into three (3) separate regions in December 2018). The area covers approximately 70,384 square kilometers and has a spatial extent of West, -2.799999; East, 0. 600000; North, 10. 749999; and South, 7. 949999. It is bordered to the south by the Volta and Brong Ahafo Regions, to the north by the Upper East and Upper West Regions, to the West by La Cote d' Ivoire, and to the east by the Republic of Togo. The terrain is typically low lying except for the north-eastern corridor and a few areas along the western portions of the region. It experiences a tropical continental climate and is characterized by relatively long periods of dry spell. The rainfall pattern is unimodal and spans the period between May - October while the dry season occurs between November to April and is characterized by temperatures between 27°C to 36°C.

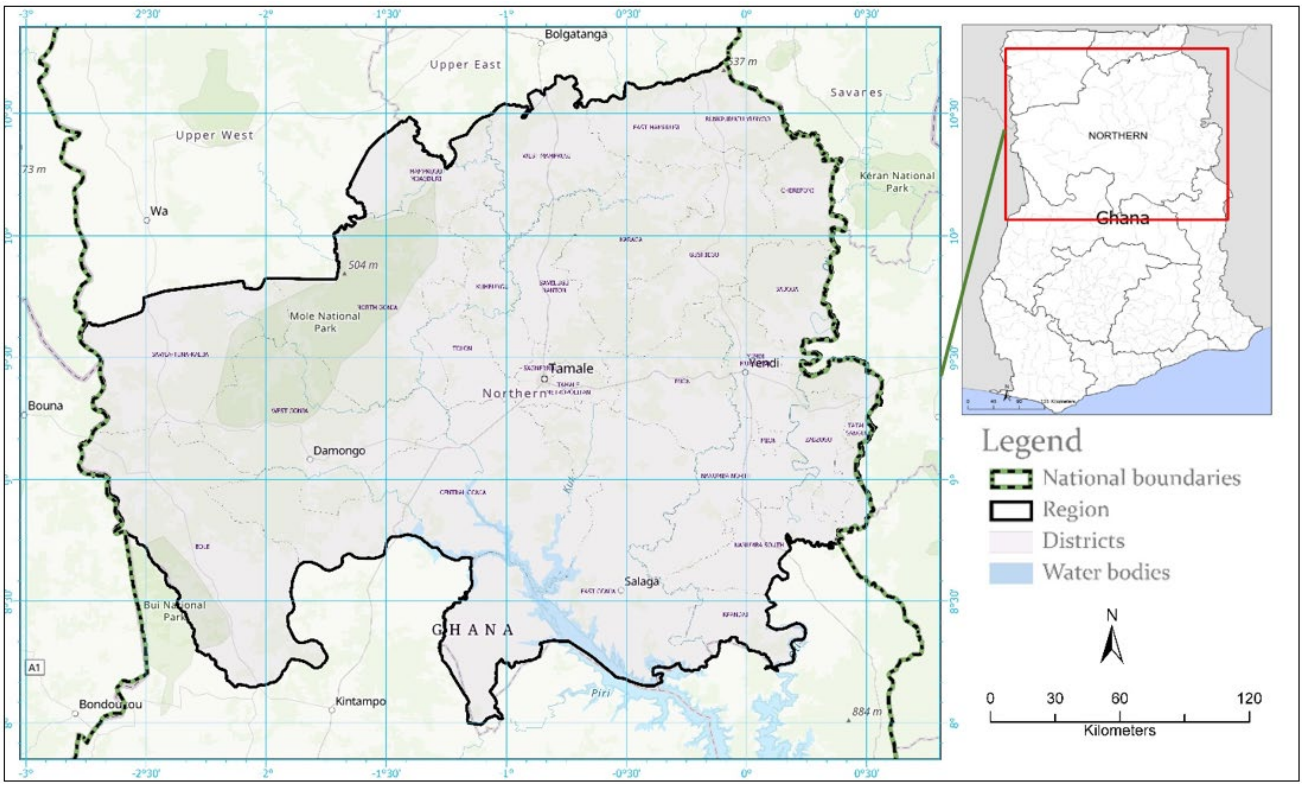

Figure 1: Map of Study Area (Northern Region - Ghana)

2.2. Dataset

As detailed in table 1, the study applied the GIS-based Multi-Criteria Evaluation approach to 9 different indicators comprising rainfall, land cover, population density, road networks, slope, market centres, potable water access, access to sanitation facilities, and disaster and conflict hotspots. All indicators used for analysis were rescaled between the ranges of 0 to 1 with 0 depicting the best value whilst 1 indicated the worst value.

Table 1: Datasets used for the study

Dimensions	Indicators	Data set	Citation
Food Availability	Rainfall variability	CHIRPS	Funk et al. (2014)
	Population density	LandScan Global Population Database	Rose et al., (2018)
	Land cover	Global land cover database	Defourny et al., (2017)
Food Access (access to markets)	Slope	NASA SRTM V3 (30-Meter SRTM;	SRTM Version 3, (2017)
	Population density	LandScan Global Population Database	Rose et al., (2018)
	Land cover	Global land cover database	Defourny et al., (2017)
	Markets coordinates	Coordinates of major markets in Ghana	WFP, (2016)
	Road network	Global Roads Open Access Data Set	CIESIN & ITOS, (2013)
Food Utilization	Access to safe drinking water	Community Water and Sanitation Agency database	CWSA, 2015
	Access to Toilet facilities	REHSU -NR, 2019 ODF league table	REHSU-2018
Food Stability	Reference of Acute Emergencies	ACLED and EM-DAT databases	Raleigh et al., (2010) EM-DAT, (2019)
Household Food Consumption Score (HFCS)		WFP Emergency Food Security Assessment	WFP, (2016)

2.3. Data Analysis

In computing the composite food insecurity score, the study adopted equal weights (0.25) for each of the four dimensions of food security based on comparable food security indicators classification by (FAO, 2013). Also, with regards to analyzing the individual indicators of the food security dimensions, equal weights were assigned due to the absence of standardized weights from prior studies but taking inspiration from the approach adopted by (FAO, 2013). All indicators used for analysis were scaled between the ranges of 0 to 1 with 0 depicting the best results whilst 1 indicated the worst result. The rescaling was done to enable comparison and combination of indicators. Spatial results presented in the form of maps together with statistical correlation evaluation can guide stakeholders to find the locations where the food insecure and vulnerable populations are located and how many they are. The detailed data flow map adopted for the analysis is presented in Figure 2.

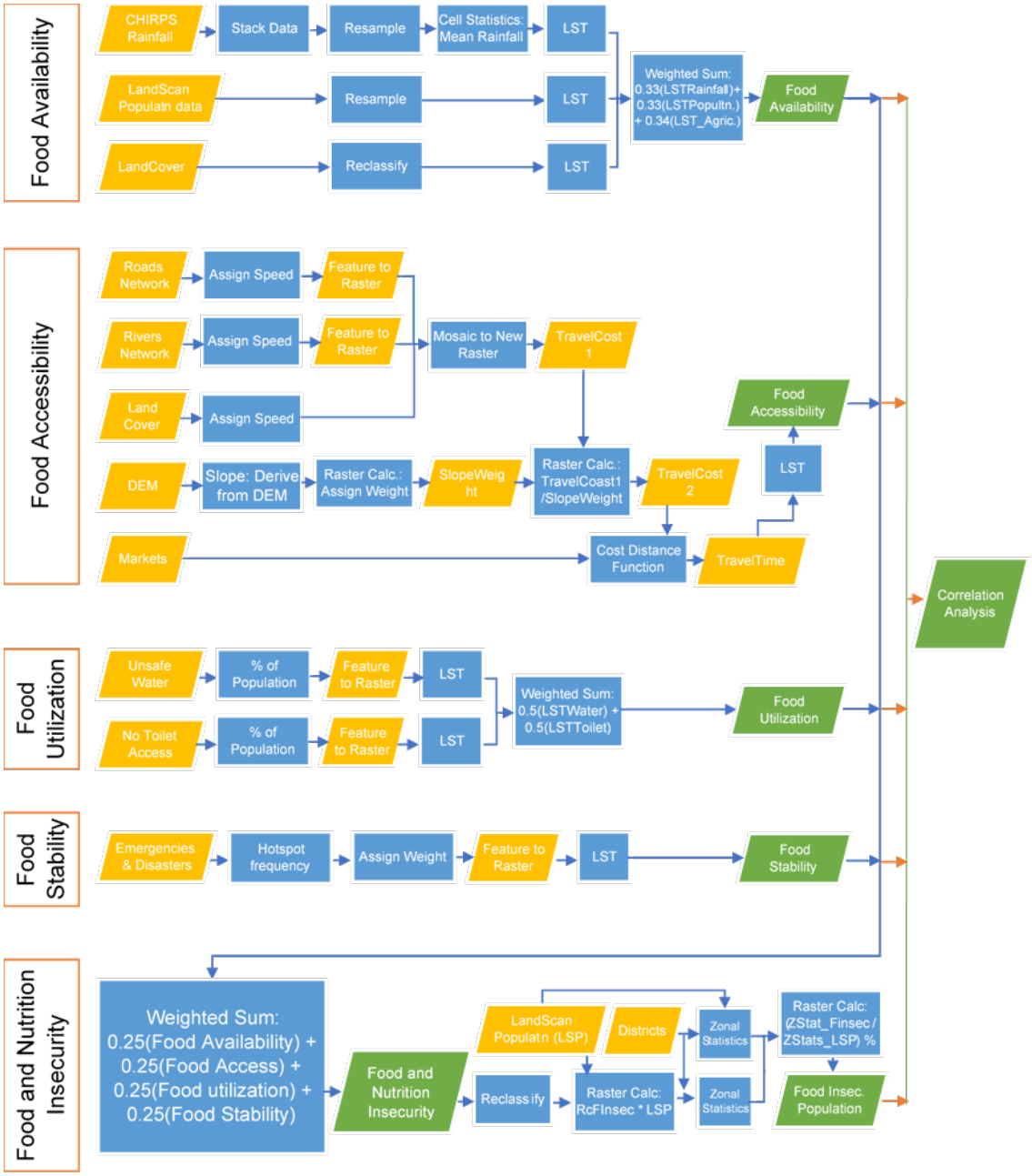

Figure 2: Flow of data analysis

3. Results and discussion

3.1. Food availability

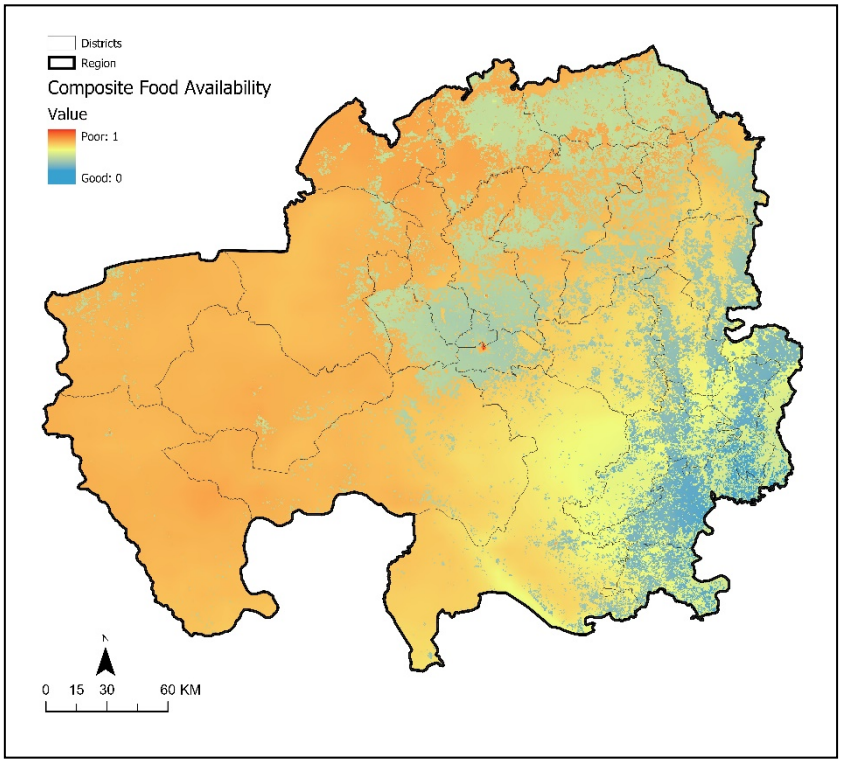

Figure 3: Food availability map of the study area

Food availability was generated by using MCE to combine population density, land cover type, and annual rainfall amount. The results as shown in figure 3 reveal that the eastern and certain areas in the central portions of the study area have better food availability levels compared to the southern and western parts. Generally, areas with high rainfall, lower population density, and arable lands were revealed to have higher food availability as opposed to the population-dense and drier sections of the study area. Accordingly, the districts with the highest indices for food availability were Nanumba South, Zabzugu, and Sagnerigu districts while the West Gonja, Mamprugu Moagduri, and Bole were the worst districts.

3.2. Food Accessibility

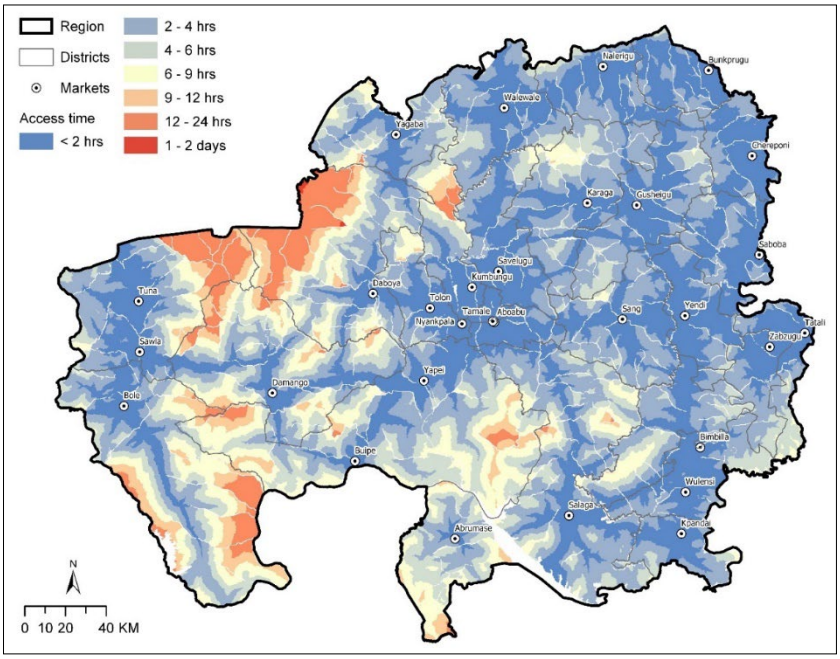

Figure 4: Food accessibility map of the study area

Travel time to markets within the district ranges from 0 hours to 28 hours. The results (Figure 4) show that the areas closest to major road networks and high population densities recorded better market accessibility. Sagnerigu, Tamale, Chereponi, Yendi, and Bunkpurugu-Yunyoo districts were the districts determined to have the best levels of food accessibility whereas, West Gonja, Sawla-Tuna-Kalba, Bole, and North Gonja districts have poor food accessibility. Access to markets, especially for rural populations, can contribute to or hinder the diversification of household economies by providing opportunities for generating income through the sale of their farm products or labour. Having limited access to markets will greatly hinder resident's food insecurity because they have reduced ability to acquire supplementary foods to complement their food production, and because of increased food costs caused by the high cost of transportation. On the other hand, areas with adequate access to markets have a better chance to cope with shocks from floods, droughts, and other disasters that affect domestic food production.

3.3. Food Utilization

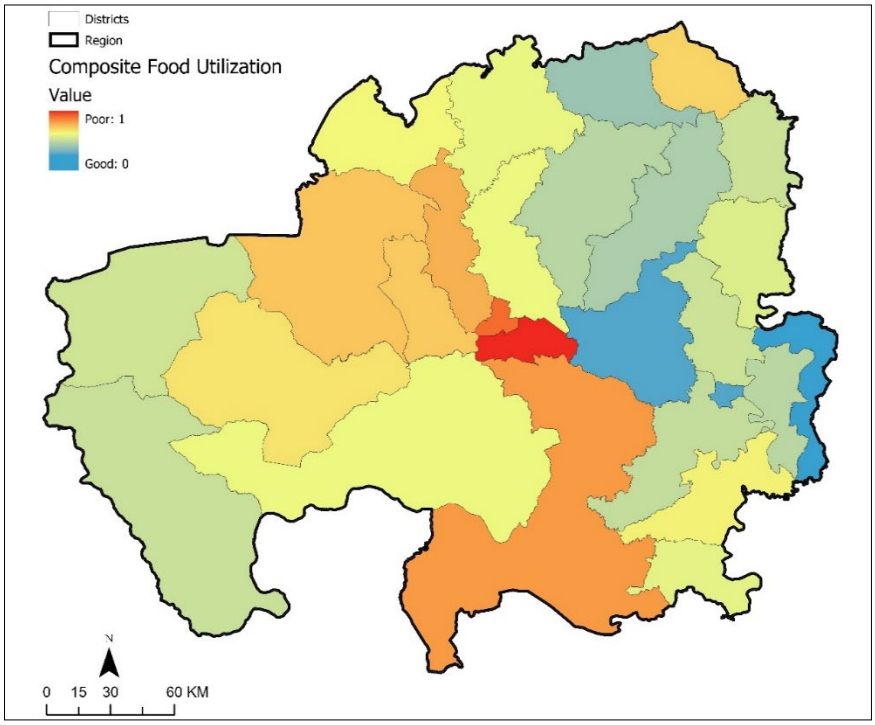

Figure 5: Food utilization map of the study area

As shown in Figure 5, Tatale Sanguli, Mion, East Mamprusi, Gushiegu, and Karaga districts were the best performing districts with regard to food utilization while the North Gonja, Kumbungu, East Gonja, Sagnerigu, and Tamale Metropolitan were the worst-performing districts. Access to safe, clean water is essential for sustaining a healthy and nutritionally quality lifestyle as illnesses such as diarrhea, cholera, typhoid, and other waterborne diseases, contracted from unsafe water sources, could lead to malnutrition, illness, and even death. Similarly, inadequate access to improved sanitation infrastructure such as household latrines and handwashing facilities results in incorrect faecal matter disposal and poor personal hygiene practices which directly influence nutritional outcomes as well. This is also confirmed by Keene et al. (2012), who noted that food can easily get polluted through exposure to unsafe drinking water, and poor sanitation and hygiene practices (such as disease pathogens on hands and from flies).

3.4. Food Stability

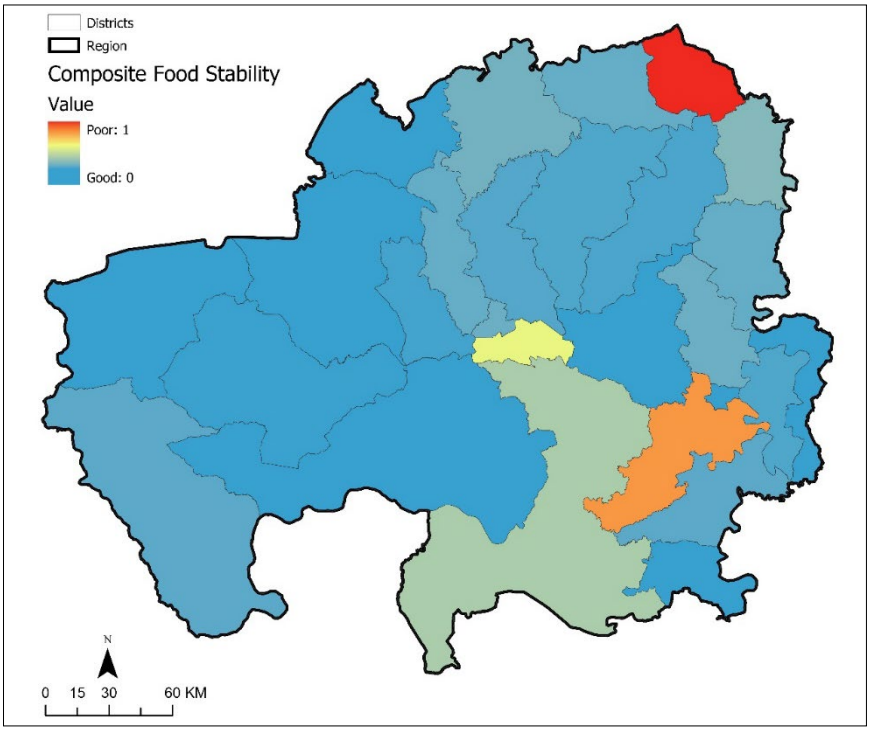

Figure 6: Food stability map of the study area

The results (as shown in Figure 6) of the final food security dimensions, stability, shows the Bunkpurugu-Yunyoo, Nanumba North, Tamale Metropolitan, East Gonja, and Chereponi districts to have severe food instability situations while the remaining districts have relatively stable environments. For the 10-year duration considered for the study, 148 incidents occurred within the region leading to the death of approximately 176 people and causing destruction and displacement of property and people. The situation of food instability is mostly as a result of armed conflicts which have led to the death of 122 people within the study area. The unstable districts identified above face major challenges with their capacity to adequately respond and effectively cope with risks when they occur over protracted periods. Their resilience may be hindered due to increases in food prices, loss of household food stocks, reduced purchasing power, and poor health and hygiene conditions of household members. Households are therefore likely to rely on livelihood coping strategies such as the sale of their productive assets, withdrawal of children from school, sale of lands, spending of savings, or engaging in social vices like prostitution and theft. These practices contribute to weakening the long term productive potential and social relationships of vulnerable households.

3.5. Composite Food Insecurity

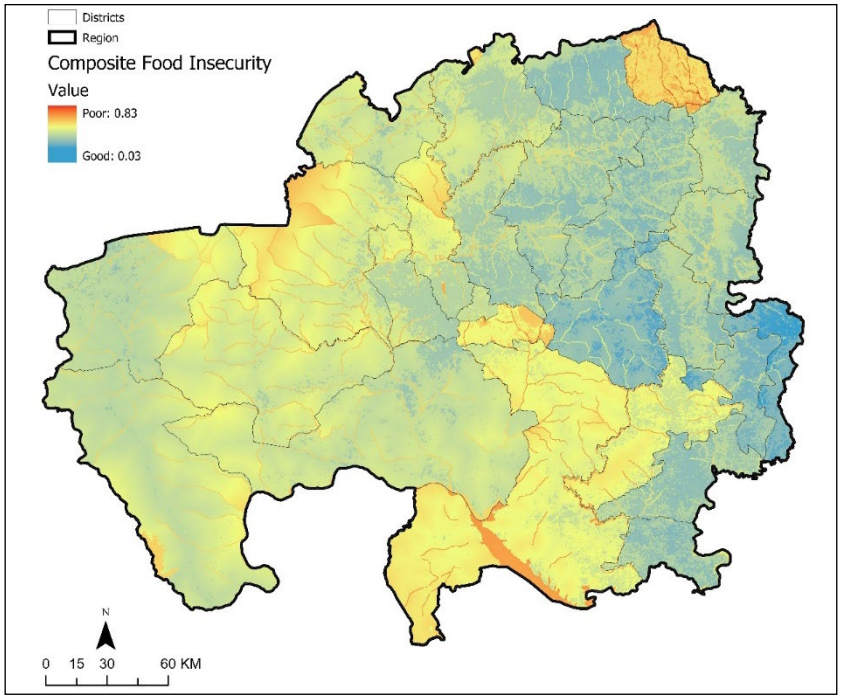

Figure 7: Map showing composite food security index of study area

Table 2: District disaggregated Food Insecurity Indices

COMPOSITE FOOD INSECURITY			1) AVAILABILITY	2) ACCESSIBILITY	3) UTILIZATION	4) STABILITY
Rank		Score/1	Score / 1	Score / 1	Score / 1	Score / 1
1	Tatale Sanguli	0.11	0.32	0.13	0.00	0.00
2	Mion	0.17	0.50	0.13	0.04	0.00
3	Zabzugu	0.18	0.26	0.12	0.30	0.03
4	East Mamprusi	0.21	0.44	0.12	0.20	0.07
5	Nanumba South	0.23	0.21	0.12	0.53	0.05
6	Kpandai	0.23	0.31	0.15	0.46	0.00
7	Gushiegu	0.23	0.51	0.13	0.26	0.03
8	Yendi Municipal	0.24	0.40	0.10	0.36	0.08
9	Karaga	0.25	0.51	0.16	0.29	0.03
10	Saboba	0.26	0.44	0.11	0.42	0.07
11	Chereponi	0.27	0.50	0.09	0.37	0.14
12	Savelugu Nanton	0.28	0.48	0.12	0.48	0.04
13	Tolon	0.32	0.47	0.14	0.64	0.02
14	West Mamprusi	0.32	0.55	0.14	0.48	0.10
15	Sawla-Tuna-Kalba	0.32	0.68	0.24	0.38	0.00
16	Sagnerigu	0.33	0.30	0.04	0.88	0.08
17	Central Gonja	0.33	0.63	0.22	0.48	0.00
18	Bole	0.34	0.69	0.28	0.35	0.05
19	Mamprugu Moagduri	0.35	0.69	0.19	0.51	0.00
20	West Gonja	0.37	0.69	0.23	0.57	0.01
21	Kumbungu	0.39	0.57	0.22	0.71	0.07
22	Nanumba North	0.41	0.37	0.16	0.34	0.78
23	North Gonja	0.41	0.67	0.34	0.66	0.00
24	East Gonja	0.45	0.54	0.22	0.77	0.25
25	Tamale Metropolitan	0.48	0.37	0.08	1.00	0.48
26	Bunkpurugu-Yunyoo	0.53	0.42	0.10	0.61	1.00

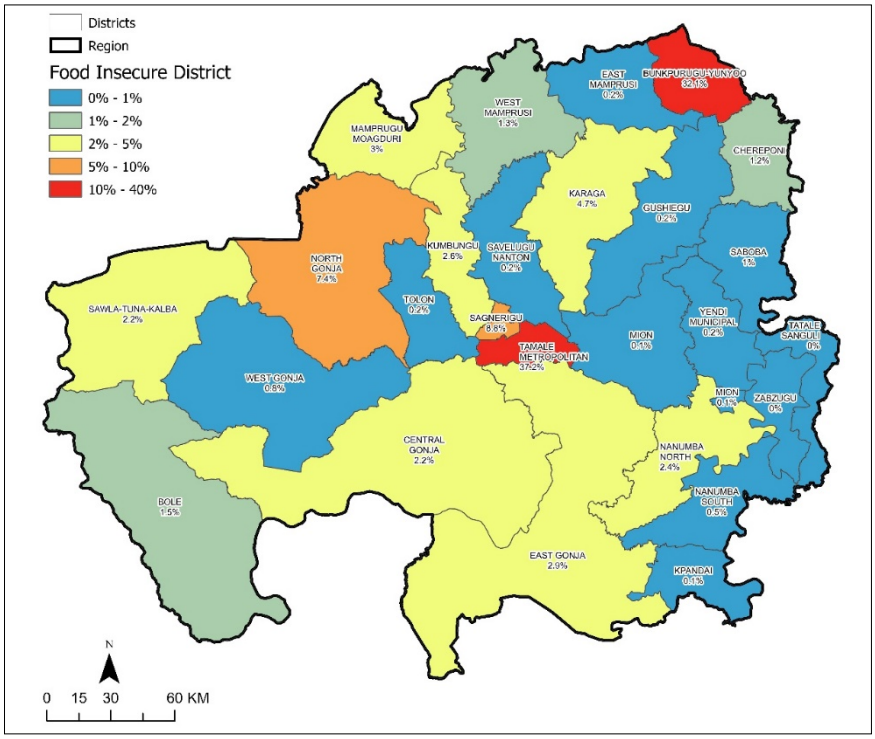

Figure 8: Map showing percentage of composite food insecure population by district.

Overall, the eastern portions have relatively lower rates of food insecurity compared to the western portions. A look at the composite district-level results, comprising data for all four-food security dimension, shows that the bottom 5 districts in terms of the average rate of food insecurity are Nanumba North, North Gonja, East Gonja, Tamale, and Bunkpurugu-Yunyoo. Inversely, Tatale Sanguli, Mion, Zabzugu, East Mamprusi, Nanumba South districts have the best rates of food insecurity (Figures 7 and Table 2).

Further analysis to compute the proportion of food insecure population were conducted using the cutoff values of <0.68 = Food Secure; 0.68 - 0.8 = Moderately Food Insecure; and 0.81 – 1 = Severely Food Insecure. The chosen cutoffs were selected to correspond to a rescaling (1-0) of the Household Food Consumption Score cutoffs used by the World Food Programme (WFP, 2016). The results indicate that 174,509 people (6.3 percent) are moderately food insecure while 25,246 people (0.9 percent) are severely food insecure. Overall, 199,755 people, representing 7.2 percent of the population were food insecure (both severely and moderately food insecure)

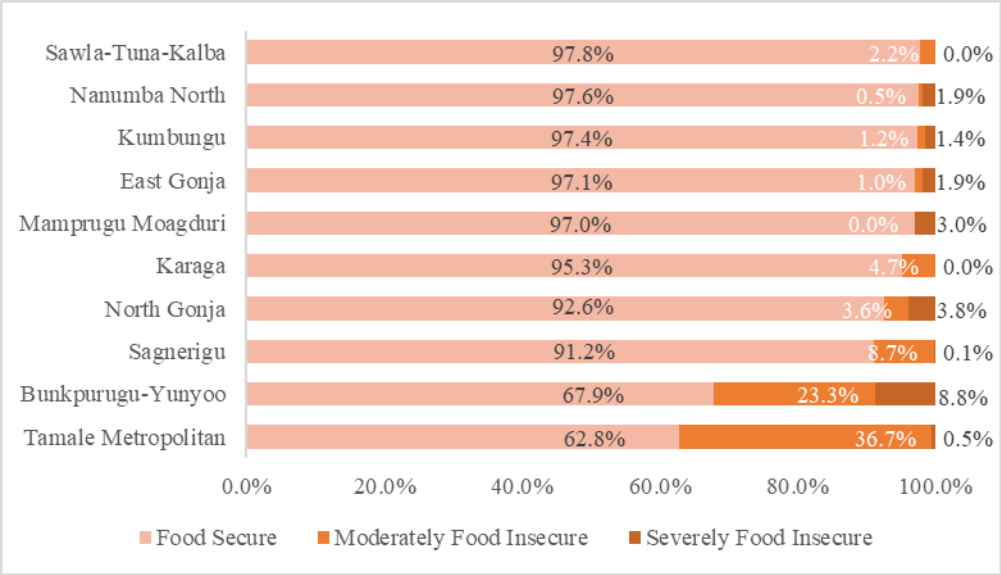

Figure 9: Top 10 food insecure districts

The proportion of the food insecure population is highest in the Tamale metropolis (37.2 percent) and lowest in the Zabzugu and Tatale Sanguli districts at 0 percent (Figure 8). Compared to the results obtained by WFP (2016), in their most recent food security report (WFP Ghana conducted the Emergency Food Security Assessment (EFSA) in early 2016 to assess the food security situation and evaluate market conditions in the northern sector of Ghana.), the level of food insecurity has reduced from 15.6 percent to 7.2 percent. Likewise, the level of moderate food insecurity has decreased from 15 percent to 6.3 percent, while the level of severe food insecurity has increased from 0.6 percent to 0.9 percent. The top 10 food-insecure districts in descending order are Tamale Metropolis, Bunkpurugu-Yunyoo, Sagnarigu, North Gonja, Karaga, Mamprugu Moaduri, East Gonja, Kumbungu, Nanumba North, and Sawla-Tuna-Kalba districts (Figure 9). Four of the top 10 food-insecure districts (the Nanumba North, Sawla-Tuna-Kalba, Bunkpurugu, and West Gonja) were similarly found by WFP, (2016) to have significantly high levels of food insecurity - a likely indication that their condition is chronic.

3.6. Correlation analysis

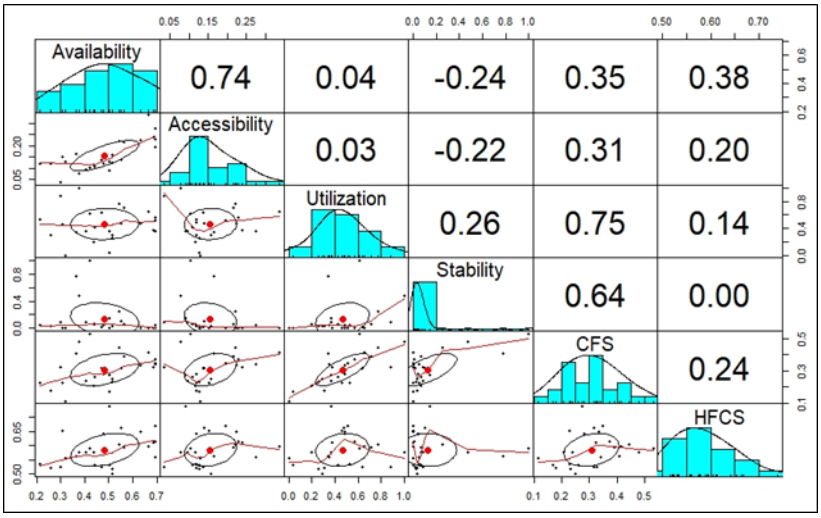

Figure 10: Correlation of food security dimensions and HFCS

A correlation matrix was adopted to check the direction and strength of association between household food consumption score, availability, accessibility, utilization, stability, and, composite food insecurity.

Test for normality with a histogram and quantile-quantile plots show 5 of the 6 variables [availability, accessibility, utilization, Composite Food Security (CFS) and Household Food Consumption Score (HFCS)] to be normally distributed while the stability variable was not Figures 10 and 11. A Shapiro-Wilk normality test (Table 2 also confirm same, as the significance value for availability (sig = 0.343), accessibility (sig = 0.093), utilization (sig = 0.916), CFS (sig = 0.984) and HFCS (sig = 0.194) exceeded 0.05 while the significance value for food stability (sign = 0.000) did not.

The results of the correlation matrix in Figure10 show varying degrees of association between the 6 variables tested. There is an observed strong positive relationship between CFS and availability (r = 0.35); CFS and accessibility (r = 0.31); CFS and utilization (r = 0.75): CFS and stability (r = 0.64); availability and accessibility (r = 0.74); and availability and HFCS (r = 0.38). Negative correlations were, on the other hand, observed between stability and two other variables, availability (r = -0.24) and accessibility (r = -0.22). The remainder of the associations, though positive, were generally quite weak.

The implication of the analysis particularly for very strongly associated variables like availability and accessibility is that communities with low domestic food production such as North Gonja, Sawla-Tuna-Kalba, Bole, and West Gonja are likely not to have adequate access to food supplies for purchase by households in their local markets. This would adversely contribute to worsening the food security situation of these areas and thus, they would require a great deal of attention from the government and the humanitarian society to boost their food security. On the other hand, given their negative association, the instability situation within the Bunkpurugu, Nanumba North, Tamale, and

East Gonja districts, do not appear to be affecting the level of food production and food access of residents within these districts. This suggests that the stability issues within these areas are short-term and only temporally disrupt household food security.

Finally, when validated against HFCS, Figure 10 generally shows a small degree of positive correlation between the results obtained by WFP and this study. This is mostly explained by the fact that the indicator of HFCS in mainly influenced by food production and market access which the correlation matrix confirms are more correlated than utilization and stability (which showed a negligible level of correlation).

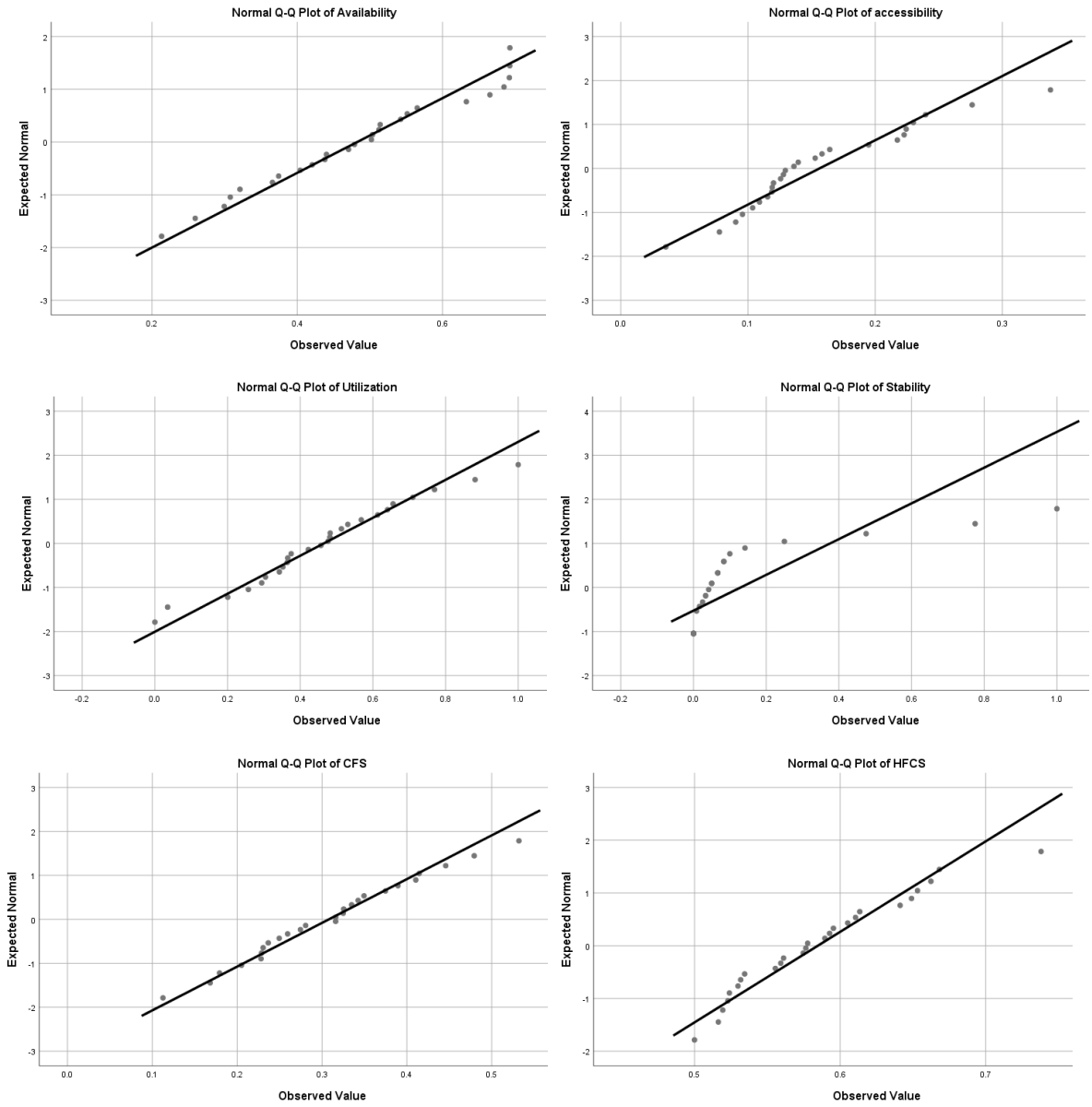

Figure 11: Q-Q plots of food insecurity dimensions and HFCS

Table 3: Shapiro-Wilk's normality test

Variables	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Availability	0.095	26	0.200*	0.957	26	0.343
Accessibility	0.174	26	0.042	0.933	26	0.093
Utilization	0.086	26	0.200*	0.982	26	0.916
Stability	0.355	26	0.000	0.557	26	0.000
CFS	0.071	26	0.200*	0.988	26	0.984
HFCS	0.114	26	0.200*	0.947	26	0.194

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

4. Conclusion

The research validates GIS-MCE as a powerful technique for conducting food security analysis as it provides the means to visualize and interpret the associations between the multiple indicators of the dimensions of food security. The results established the geographical trend in food security or deficiency within the 26 districts of the northern regions and prescribes current government SNPs that should be implemented/strengthened to mitigate the identified risks. These results are useful to decision-makers, particularly, to government departments like the Ministry of Gender, Children and Social Protection, the Ministry of Food and Agriculture, and the Ministry of Local Government and Rural Development that are geared towards poverty alleviation, gender equality, children, agriculture and governance. Generally, the study finds that the food insecurity situation in the northern region remains very high as a result of a combination of access, availability, utilization, and stability factors. Within the western and central portions of the study area, the food insecurity situation is hampered by low levels of rainfall and poor access to markets whilst sections of the eastern and central corridor are hampered by stability issues resulting from armed conflicts and natural disasters. Overall, 199,755 people, representing 7.2 percent of the entire population are food insecure (both severely and moderately food insecure) with the proportion of the food insecure population at its highest in the Tamale metropolis and lowest in the Zabzugu and Tatale-Sanguli districts. The top 10 food-insecure districts have significantly high levels of food insecurity - a likely indication that their condition is chronic. The other 16 districts, however, have improved their food security situation over the last four years.

4.1. Recommendation

Considering the current situation of food security in the study area, the following recommendations are being proposed.

In terms of food availability, the West Gonja, Mamprugu Moagduri, and Bole districts recorded the worst food rates. Consequently, targeted SNPs to strengthen food production such as the planting for food and jobs, and the provision of irrigation infrastructure through the one village, one dam programmes will be very useful in improving food availability within these districts.

Due to the low level of food access in the West Gonja, Sawla-Tuna-Kalba, Bole, and North Gonja districts, intensifying the Livelihood Empowerment Against Poverty, Schools Feeding/Capitation grant and the Nation Builders Corps (NABCO) programmes will go a long way to increase residents' access to acquire supplementary foods to complement local food production and protect them against shocks from floods, droughts or pest infestation that may hamper their ability to cultivate food for domestic consumption.

The poor situation of food utilization within the North Gonja, Kumbungu, East Gonja, Sagnerigu, and Tamale will also benefit greatly from an intensification of the National Health Insurance Scheme (NHIS), CHPS (Community-Based Health Planning and Services) and the free Senior High School programme. Additionally, strengthening the community-led total sanitation and expanding water access in these districts will see them attain quality and healthier lifestyles.

With regards to food stability, districts such as the Bunkpurugu-Yunyoo and Nanumba North which scored the lowest rates are inherently affected by increases in food prices, loss of household food stocks, and poor health and hygiene conditions of household members. Households are therefore likely to rely on livelihood coping strategies like selling of their productive assets, withdrawal of children from school, selling of lands, and spending of savings. These practices in the long term weaken their productive potential and further increase their susceptibility to future shocks. To mitigate the effects that residents within these districts encounter, it is imperative that they are supported to diversify their income and food sources. Safety net policies as NAFCO (National Food Buffer Stock Company) will support and enhance food production systems, enhance market governance, and improve rural development. Finally, strengthening the presence and activities of the National Disaster Management Organisation (NADMO) will ensure affected districts put in place resilience strategies and mechanisms to improve their capacity to adequately respond and cope with risks they encounter.

5. References

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