

Geographical Information System (GIS): A panacea for Food Insecurity in Nigeria (A review)

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Abstract: The effects of food insecurity is hitting hard on both the developed and developing countries of the world. This is even more pronounced with the changes in the world climatic environment. The consequences are famine caused by wide-spread hunger, malnutrition and poverty mostly witnessed by people; many of which are found in the Sub-saharan Africa to which Nigeria belong. To fight food insecurity, many approaches such as Agricultural Production Monitoring (APM), Market Information system (MIS), Social Monitoring of the Most Vulnerable Population or The Vulnerability Group and Food and Nutritional Surveillance System have been employed by researchers. These system are not with their inherent shortcomings, on which is the gathering, collation, processing and storing of bulky data for present and future purposes. In recent times, Geographic Information System (GIS) and remote sensing have been reported to be of great use in various disciplines including the area of food security. In this review, an attempt was made to elucidate the importance of GIS in agriculture, thus using it as a tool in fighting food insecurity in Nigeria.

Keywords: GIS, Food insecurity, Effects, Remote sensing, Nigeria.

1. INTRODUCTION

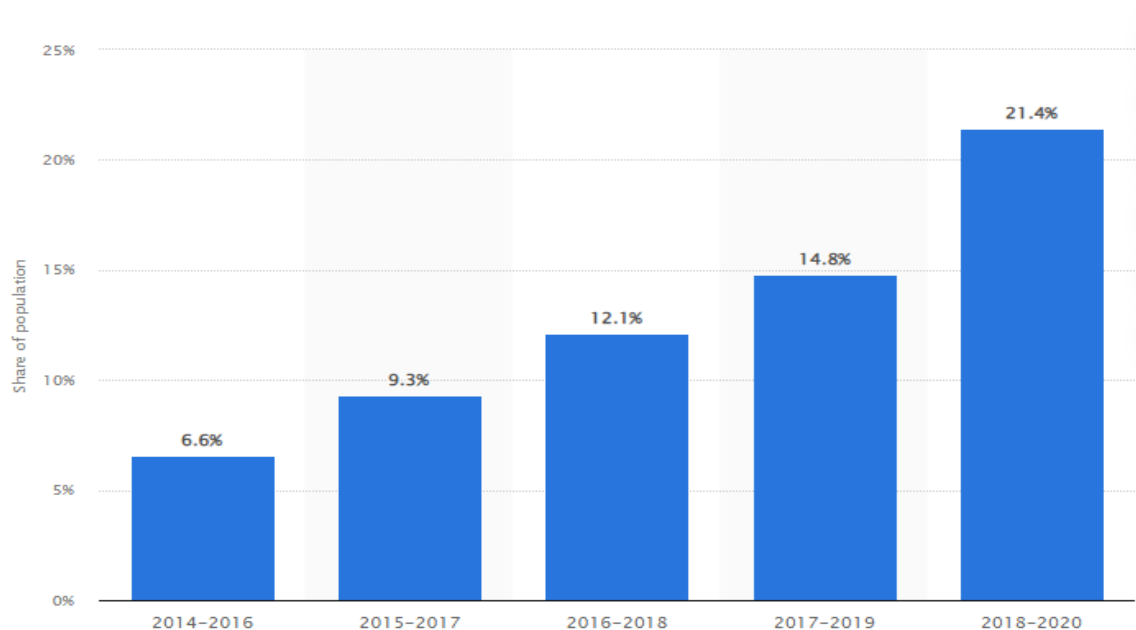
There is a general consensus that food plays a pivotal role in human existence and survival. The present food economy does not deliver enough food to major parts of the growing world population despite enormous growth rates. Food security has become a major issue of concern in both developing and developed nations and this highlights major inequalities as well as paradoxes and tensions between scarcity and affluences.

The food system can be considered as a prism of interface between sustainability and equitability. A food system governs what we eat; and there has been increasing concerns at all levels of governance and in different policy sectors, civil society, academia and business that the food system is not sustainable and endangers both the health and future of the planet. "Food systems encompass activities related to the production, processing, distribution, preparation and consumption of food; and the outcomes of these activities contributing to food security (Dogondaji, 2013). The outcomes also contribute to environmental and other securities concerns (e.g. income) (Ahsan, 2008).

During the past years, the agricultural sector moved from a relatively neglected position towards the center of climate change discussions. Over time, how to adapt agricultural food systems to increasing climate changes has suddenly become one of the main challenges in the sustainable development agenda. Climate is a particularly important driver of food system performance at the farm end of the food chain, affecting the quantities and types of food produced and the adequacy of production-related income. Extreme weather events can damage or destroy transport and distribution infrastructure and affect other non-agricultural parts of the food system adversely.

The absence of food security and associated coping strategies are increasingly being studied in Africa. Food insecurity has been identified as one of the major challenges of most African governments influenced by an increasing number of people suffering and living in poverty, high level corruption, incidences of conflicts/terrorism, and unfavorable climate change in the region.

Nigeria has a very high number of people living in extreme poverty globally and is facing the challenge of food insecurity, especially in the northeastern and north-central states where conflicts/insurgency, kidnapping, armed banditry, cattle rustling and weather extremes are aggravating the food insecurity situation (Ayinde *et al.*, 2020). In order to develop a sustainable food system that is socially equitable in spite of the challenges posed by climate change, holistic and strategic approaches will be required. Key elements of this is greater collaboration among climate, agriculture and food security communities, and consideration of interdependencies across whole food systems and landscapes (Hall and Dorai, 2010).



Source: Statista 2021

Figure 1: Prevalence of severe food insecurity in Nigeria from 2014 to 2020

Problems

Food security is a must-have for humanity's survival and economic activity, which include food production. Food is unique among commodities in that it is required for survival and existence. In Nigeria, there has been a high level of food insecurity for the past four decades (Figure 1) as a result of neglect in food production as oil has become the primary export product, and as a result of neoliberal economic policies such as devaluation of the naira, trade liberalization, and government withdrawal from economic activities, ethnic and religious conflicts; disasters such as flooding and drought have also contributed to food insecurity. Food is distinct from other commodities in that everyone requires it for survival, and it is an essential component in a nation's desire for prosperity. Unfortunately, peasant farmers produce the majority of Nigeria's food needs due to a lack of capital, skills, energy, and other viable elements to produce vast quantities of food to fulfill the rising population's demands. As a result, food insecurity is a perennial and double-digit problem in Nigeria.

Food inflation in Nigeria averaged 12.07 percent from 1996 to 2021, according to 'Trading Economics,' an independent economy forecasting consortium, with a high of 39.54 percent in September 2001 and a low of -17.50 percent in January 2000. In March of 2021, it reached 22.95 percent, then dropped to 17.76 percent in June. Food insecurity, which is strongly linked to malnutrition, makes life difficult for the underprivileged. Nigeria has 70.8 million hectares of agricultural land, however only 34 million hectares are arable (land that can be used for farming). Large swaths of potential crop land remain uncultivated, while the population suffers from hunger and poverty. Even though the agriculture sector employs 35% of the population and 70% of households engage in crop farming (Nations Encyclopedia,

2011), farm output is insufficient to feed the masses, especially when compared to countries like Canada, where agriculture employs only 0.79 percent of the population but is one of the world's largest food producers and exporters. Many people go hungry or are malnourished on a daily basis because they do not have access to food or cannot afford it.

Nigeria's escalating food problem is exacerbated by rising security threats and institutional weaknesses. Even while climate change has an influence on the environment and farming communities, war and conflict have had disastrous consequences in recent times. The conflict between farmers and herders is commonly cited as one of the major reasons for food insecurity in the country. Farming has become unsafe as a result of attacks on farmers, and the destruction of farmland has added to the problem. Farmers in the Northeast are disproportionately affected by the insurgency; 10.6 million people require immediate assistance, but only 7.8 million can receive it. According to a Cadre Harmonisé research from November 2019, an estimated 2.6 million people in Adamawa, Borno, and Yobe states endure extreme food insecurity, a decrease of over 300,000 individuals from June 2019. However, if no humanitarian assistance is offered, an estimated 3.6 million people in the three states will be extremely food insecure from June to August 2020.

The country's population increase is having a negative impact on the agro-ecological systems. Deforestation, desertification, soil degradation, erosion, flooding, general habitat loss, and natural resource depletion are only a few of the country's serious environmental issues. Sandy desert is growing southward at a rate of 0.6km per year in the country's northern region, while the rainforest habitat in the south has reduced from almost 10% of the country's size in 1934 to just 5% now. All of these are important issues, but they are made worse by the fact that they have an impact on the country's food security. Specifically, it has been observed that the nation's overall agricultural potentials are in peril as a result of 'rising heat' and water stress as a result of heat. The significance of this is that the impact has the potential to seriously jeopardize the country's food security as well as household food security.

Food demand in Nigeria has outpaced food supply (Idrisa *et al.*, 2008), and the CBN (2001) backs this up by stating that the annual rate of increasing food production of 2.5 percent does not match the annual population growth of 2.8 percent. Most Nigerian farmers are under-informed, lack adequate supplies of agricultural inputs, machinery, and extension services, and have a high level of illiteracy and lack adequate knowledge of modern agricultural practices that can boost production and bumper yields to meet Nigeria's growing population's ever-increasing food demand. Adoption of contemporary technology and practices is, once again, a serious barrier in Nigerian agriculture. Food wastage has also been identified as a threat to Nigerian food security. According to Igberaese and Okojie-Okiedo (2010), Nigeria experienced 0.81 million metric tonnes of food wastage between 1995 and 2000, which would be greatly reduced if storage facilities were in place. Food security is impossible to accomplish in a wasteful culture. If a coordinated effort and solutions are not put in place now, food security in Nigeria would be at a very low and problematic level by 2050 (Adebola *et al.*, 2011), affecting not only health but also the economy and social order.

This study therefore makes an attempt at proffering solutions to the data challenges and complexity involved in developing precise answers for food security in Nigeria and Africa at large.

2. METHODOLOGY

This present study makes use of reports, articles relating to the topic with materials sourced from google scholar, researchgate, scopus and google search engines. This was achieved using keywords such as Food security, GIS, Nigeria and Africa.

Effects of Food Insecurity

Malnutrition and other negative nutritional effects have been related to food insecurity. Households were largely food insecure in terms of having enough food all year, having continuous access to favourite meals, and eating a diverse range of foods. When food was scarce, this meant that a higher percentage of households ate less food or skipped meals each day (Regassa, 2011). Food insecurity in terms of availability is widespread among farming households since they frequently sell a major portion of their food during harvest season to fulfill family requirements, purchase inputs, and pay off debts. This leaves little food, which is usually insufficient for year-round home usage. Low income also contributes to the limited variety of foods consumed. Also, a lack of variety in the foods consumed is owing to a lack of funds to acquire non-cultivated foods. This scarcity of food in terms of quantity and availability to a limited food variety is likely to have a negative impact on nutritional status.

In the study of Efuruke & Thomas (2020) to assess the state of household food insecurity, dietary diversity of households, nutritional status of households as well as the relationship between food insecurity and nutritional indices of households in Northwestern Nigeria, the correlation of food insecurity to nutritional indices revealed that nutritional status and household diet diversity were inversely and significantly related to household food insecurity. Food insecurity was found to be significantly correlated to stunting rate, height for age and wasting, weight for height of children less than five years of age.

Malnutrition is strengthened by food insecurity, which leaves children weak, susceptible, and less able to fight common childhood diseases such as diarrhoea, acute respiratory infections, malaria, and measles. Food insecurity has negative consequences for both adolescents and adults. Low energy levels, growth failure, delayed maturation, impaired cognitive ability, poor learning capacity, reduced ability to resist infections and diseases, reduced life expectancy, increased maternal mortality, and low birth weight are all symptoms of food insecurity. Furthermore, it may lead to political instability in the food-insecure region since people who are food insecure may experience emotions of alienation, tension, and worry, as well as lower productivity, lower labor participation and school performance, and lower income levels. The dynamics of the household may also play a role.

Donatus *et al.* (2017) examined the implications of food insecurity and poverty on Nigeria's national security. The economic calamity wreaked on Nigeria by the actions of hungry and dissatisfied youths has been noted as cause for alarm. Nigeria has seen an increase in malnutrition, hunger, and poverty as a result of the collapse of agriculture owing to over-concentration on crude oil. Food consumption has outpaced overall availability in recent years, drawing international attention to the issue. A mismatch between the 'ought' and the 'is' of collective value satisfaction causes stress, according to the relative deprivation theory. Men are prone to agitation as a result of this disparity, which might lead to violence. This helps to explain why the poor and hungry are more likely to be victims of crime and violence. As a result, it is critical to revive the agricultural sector and restore to traditional governance (which appropriately provides for citizens).

Tools for Assessing Food Insecurity; Towards a Holistic Approach

The first step at proffering solution to a problem is through identification of the problems and its consequences which has been earlier discussed. Many approaches have been used by researchers in a bid to study and thus offering answers to the many questions posed by food insecurity. To solve the problem of food insecurity in Nigeria, food security assessment which is essentially a prediction of food availability in predefined future time framework must be carried out. This helps to establish availability or deficiency of food, thereby facilitating planning and implementation of strategies to mitigate the problem of hunger. According to Hagai (2014), Food security assessment essentially boils down to predicting food production availability for a given future period of time, which includes spatial identification of areas expected to have food surpluses as well as areas expected to have low food production in the pre-specified future time frame, in order to facilitate equitable food distribution to the people when that time comes. For assessing food security, the following systems are commonly adopted by researchers:

- a. Agricultural Production Monitoring (APM): this is usually done in conjunction with monitoring livestock farming.
- b. Market Information System (MIS): This system is used to track domestic and international trade (imports and exports).
- c. Social Monitoring of the Most Vulnerable Populations or Vulnerable Groups: This focuses on monitoring of poverty-prone areas, as well as monitoring of vulnerable groups.
- d. Food and Nutritional Surveillance Systems (also known as food and nutrition monitoring) FNSS, which monitors the health and nutritional status of populations in general, depending on the scenario.

However, with growing concerns on factors contributing to food security in Nigeria in particular and Africa in general, coupled with the challenges of collating data in solving these concerns, thus creating solutions for the present and predicting future challenges in the food sector. Global Information System is now being exploited in this area.

Global Information System (GIS): An alternative solution

A geographic information system (GIS) stores and links cartographic map characteristics with spatially referenced, spatiotemporal data on socioeconomic and other factors. GIS technologies have become routine instruments in humanitarian catastrophes in the poor world, particularly for tracking instances of tuberculosis and malaria (Park & Baro 2003). GIS is particularly effective in rapid assessments to determine the scope and location of a disaster as well as the resources required for relief efforts. Improvements in famine early warning systems, assessments, monitoring, and evaluation will be possible with more GIS tools integrated into prevention and relief activities.

Remote sensing affords us the capability to literally see the invisible. We can begin to see components of the environment on an "ecosystem basis," in that remote sensing data can transcend the cultural boundaries within which much of our current resource data are collected. Remote sensing also transcends disciplinary boundaries. It is so broad in its application that nobody "owns" the field. Important contributions are made to-and benefits derived from-remote sensing by both the "hard" scientist interested in basic research and the "soft" scientist interested in its operational application (Lillesand, 2008).

Remote sensing is an essential tool of food security because it facilitates observations across larger extents of Earth's surface than is possible by ground-based observations. This is accomplished by the use of cameras, multi-spectral scanners, RADAR and LiDAR sensors mounted on air- and space-borne platforms, yielding aerial photographs, satellite imagery, RADAR and LiDAR datasets. Data available from remote sensing vary from the very high resolution datasets produced irregularly over extents no larger than a single state or province (by aerial photography, imaging, LiDAR, and by high resolution satellite sensors such as IKONOS and Quickbird), to regional datasets produced at regular intervals from satellites (e.g., Nigerialsat1, Landsat, SPOT), to the lower-resolution (> 250 m) datasets now produced across the entire Earth on a daily basis (e.g., MODIS).

GIS serves for capturing, storing, analysis, and visualization of data that describe a part of the Earth's surface, the technical and administrative entities, as well as findings of geoscience, economics, and ecological applications (Bartelme, 1989). In the view of Miller (2000), the relationship between remote sensing and Geographic Information Systems is that remote sensing provides useful information or data in the form of satellite images and aerial photographs that can be integrated and analyzed in a GIS interface to provide useful spatial information usually in the form of maps and temporal changes over large geographic areas, affecting the structure and function of the environment. In other word, remote sensing is a requisite for GIS to work. GIS provides spatial information usually in the form of maps and temporal changes over large geographic areas affecting the structure and function of the environment. Therefore, remote sensing provides the data usually in form of images necessary for GIS to function.

GIS; a model for resolving problems associated with Food insecurity

Abubakar (2015) examined the Land use-land cover over Nigeria between 2001 and 2009; the Land use-land cover changes that have taken place within the periods and the implications the land use-land cover changes had on the study area. The study was the first in the study area that combined Remote Sensing and GIS techniques to investigate LULC changes, LULC transformation and even future prediction of the LULC scenario up till the year 2020. The study used Combined terra and aqua MODIS land level 3/level 4 yearly tiled products, MCD12Q1-level 3 yearly land cover type at the scale of 250m. It was found out that there was continuing decrease in the water bodies which posed serious implications for agriculture in terms of food security, water availability for different uses and infrastructural development in term of electricity. The work further highlighted that the loss of forest and grassland is an indication of disturbance and consistent perturbations created by pressure on the existing ecosystems leading to reduction in soil nutrients, decrease resilience and stability and loss of agricultural lands.

Remote sensing can also be used to track vegetation dynamics, especially at large scales (Barbosa *et al.*, 2006; Gaughan *et al.*, 2012). The Normalised Difference Vegetation Index (NDVI) is still the most well-known and widely utilized of the spectral indices generated from remote sensing that identify vegetated areas and their condition (Bulcock & Jewitt, 2010; Sims & Colloff, 2012). Plants' differential reflectance for different sections of the solar radiation spectrum is used to calculate NDVI. Internal mesophyll structures in healthy green leaves absorb photosynthetically active radiation (PAR) for energy in photosynthesis, while internal mesophyll structures in the leaf deflect light in the near-infrared area to keep the plant from overheating (Bulcock & Jewitt, 2010).

NDVI is a good indicator of the ability of vegetation to absorb PAR and thus of land cover that consists of unstressed vegetation. It is calculated by taking the difference between the remotely sensed visible (red) and near-infrared bands and normalizing it over the sum of the two (Otto et al., 2011). NDVI values have been linked to a variety of vegetation structures and functions, including biomass (Cho *et al.*, 2007), primary productivity (Goward & Dye, 1987), Leaf Area Index (LAI), leaf cover, chlorophyll per unit ground area, green biomass, and green vegetation factor (Hansen & Schjoerring, 2003), and Leaf Area Index (LAI), leaf cover, chlorophyll (Bulcock & Jewitt, 2010). The NDVI readily saturates and is not a strong predictor of high temperatures. However, NDVI still retains ecological relevance as an indicator of green biomass change Wang *et al.*, (2003).

Eckert & Shetty (2011) quantified and mapped food system accessibility in Toledo, Ohio by using geographic information systems to measure the accessibility of each block group to retailers selling a variety of fresh foods to see if spatial accessibility to food outlets carrying nutritious and healthy options is a problem in Toledo. The findings showed that one's race, economic level, or other demographic variables had little bearing on the likelihood of living in a low-access region. As a result, socioeconomic characteristics are not strong indicators of where accessibility is hampered in Toledo, but certain neighborhoods do have both low-income residents and poor accessibility rates. This kind of data can help lead discussions about local food systems planning and highlight areas where a large number of residents may be facing food insecurity in Nigeria.

3. SUMMARY

GIS is becoming a more important tool in efforts to better understand the connections between food availability, agricultural areas, and the effects of climate change on agriculture productivity. The ability to enhance sustainable practices and appropriately plan for threats to food security requires a deep grasp of these relationships. On a global scale, proper plans for existing farmlands, as well as evolving production systems, can ensure food security. Annually, flooding devastates the Nigerian population and severely hurts local farmers thereby resulting in ongoing food security challenges. However, geospatial intelligence is uniting the population to tackle these recurring threats. Using GIS technologies to analyze satellite data can help track climate change, monitor rainfall, and keep track of soil fertility, all of which can help identify possible food shortages in a specific location.

In order to further solve the problems associated with food insecurity in Nigeria, Agricultural agencies and knowledge experts will have to leverage the power of technology and media to reduce the problems faced by the extension of the traditional service in rural areas. Digitization has steadily transformed African farming system. Online platforms such as Farmconnect can help farmers with accessible services. These services include voice messages and SMS extension advice. This helps farmers obtain information about how to access markets and extension services. We must ensure that the benefits of digitisation are enjoyed by smallholder farmers and rural populations. Smallholder farmers, most of whom have access to less than two acres of land, produce more than 80% of the food available most especially in Sub-saharan Africa.

4. CONCLUSION

From this study, the following can be concluded:

1. Food insecurity is a major problem that affects the general households in Nigeria. Prevalence of food insecurity among the urban poor is high. However, even among the urban poor, disparities exist in food security status. It can be deduced that malnutrition is a major effect of food insecurity in Nigeria. Regions having population with low educational attainment were more likely to be food insecure than those with at least some basic education. Households with more members are likely to be food insecure than those with a smaller number of members. The incidence of food insecurity was also found to be high among households with poor water and sanitation facilities. The urban poor face unique challenges that are different from those faced by their rural counterparts.
2. Regarding modeling of Food Security assessment using GIS techniques: Food security assessment using GIS modeling is relatively faster and convenient, food security prediction through GIS modeling is highly scalable thus potential for integration of other related datasets e.g. from emerging satellite images with enhanced high spatial and radiometric resolutions into the prediction process which all together can improve the reliability of the results.

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