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Spatiotemporal Dynamics of Agricultural Land Loss in Offa LGA: Implications for Food Security

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Abstract—In developing countries, urban sprawl is one of the primary drivers of agricultural land loss. In the long term, increasing urbanization and rising population pose a significant risk to food security and sustainable agriculture. This study therefore assesses and presents the spatiotemporal dynamics of agricultural land loss in Offa Local Government Area of Kwara State, Nigeria using Geographic Information System (GIS) and Remote Sensing (RS) tools. Also, it discusses the impact of urban sprawl on food security, as it concerns the study area. Changes in agricultural land cover were detected using Landsat images. The research findings show a significant increase in agricultural land loss as a result of urbanization in the past three decades where built-up areas were discovered to increase rapidly while agricultural land cover declined as a consequence. In total, over 23sqkm of agricultural land was lost in the study area over the study period. Thus, food production and the livelihood of producers are currently put at risk. In response, innovative agricultural approaches as well as efficient development control mechanisms were recommended to promote food security in the face of growing agricultural land loss and population increase.

Keywords— Urbanization, Food security, Landsat images, Land cover change, GIS

I. INTRODUCTION

The twenty-first century is characterized by significant innovations in finance, industry, economy, and agriculture [1]. Nonetheless, over one billion people suffer globally from acute malnutrition and chronic hunger due to lack of food [2-4]. Largely, food insecurity is experienced more in sub-Saharan Africa, South America, and South Asia [1]. Between 1999 and 2009, food insecurity rose from 10.1% to 14.7%. This suggested that an additional 4.6% was added to the existing stock of households that had trouble getting sufficient and safe food that meets their dietary needs. While the 0.2% decrease in food insecurity experienced in 2010 had no significant effect, particularly in the aforementioned food-insecure regions [4, 5].

The current issue of climate change, extreme weather events, along with the declining stock of natural resources, and land cover changes put more pressure on future food supply/demand and global food security [2, 4, 6]. Moreover, with the persistent increase in population, feeding 8.6 billion people by 2030 is likely going to put additional pressure on land and water resources. Noteworthy is the current pace of urbanization and associated demographic changes which increase the risk of food insecurity due to an expected agricultural land loss.
The Millennium Development Goals (MDGs) recognized the importance of urbanization in the socio-economic development of nations [7]. But then, the ongoing Sustainable Development Goals (SDGs) acknowledge the relationship that exists between urbanization and food insecurity, poverty, and diminishing natural resources [8]. Recently, the adverse impacts of urban sprawl, particularly on food systems have drawn the attention of policymakers and researchers. They have come to understand that addressing the disruption in our food supply chain resulting particularly from rural-urban transformation cannot be overemphasized. To address this challenge, many studies have taken the side of urban resilience, focusing on urban agricultural development and the evolution of food systems under urban sprawl [9, 10]. Besides, studies in this area have reported that notable conversion of agricultural land to urban "built-up" areas is more pronounced in developing countries due to the absence of concrete land-use plans and weak enforcement of laws and regulations [11]. No doubt, Nigeria is the most populous African nation and one of the most urbanized countries in Africa with an estimated annual urbanization rate of 3.5% which has witnessed tremendous urban

expansion over the years, consequently losing more than 400,000 hectares of vegetation yearly [12].

As regards Kwara State, the declaration of Offa as a Local Government Headquarter in 1991 has stimulated rapid urban expansion and developmental activities, which consequently influence agricultural land conversion for housing development, road construction, and other infrastructure. In dealing with the foregoing challenge, decision-makers at all levels need reliable and timely information to understand, monitor, and predict impacts of urbanization on agricultural land, and hence, food security [1]. However, Remote Sensing and Geographic Information Systems (RS and GIS) have been widely applied and recognized as a potent tool in monitoring and mapping urban expansion, and land cover changes [13-19]. This study, therefore, presents a comprehensive analysis of the spatiotemporal dynamics of agricultural land loss in Offa Local Government Area of Kwara State using Landsat satellite data for different years (1991, 2000 and 2019). Again, it sought to contribute to a better understanding of the plausible impact of urban sprawl on food security, in the case of Nigeria.

The paper is organized as follows: Section I contains the introduction, Section II explains the research methodology used in the study, Section III describes results and discusses implication for food security and Section IV concludes the research work with recommendations.

II. METHODOLOGY

Study Area

Offa Local Government Area (LGA) is located in Kwara State, Nigeria, approximately between Latitudes 8^0 5' 0" N and 8^0 13' 45" N, and Longitudes 4^0 36' 45" E and 4^0 46' 15" E (Figure 1). According to the 2006 National Population Census conducted in Nigeria, the population of the study area was given at 88,975 [20]. Relatively, Offa is one of the rapidly growing urban centers in Nigeria with a higher population growth rate than its other counterparts in the country. Similarly, it has also experienced spatial growth at a fast pace since 1967 [21].

Largely, the occupational characteristic peculiar to its residents is farming. This is encouraged by the identified soil characteristics in the study area which are of medium to high productivity due to their long period of metamorphic activities [22]. Along with other food and cash crops, Sweet potatoes are largely produced in Offa. Cattle, goats, and sheep are also raised in its environs.

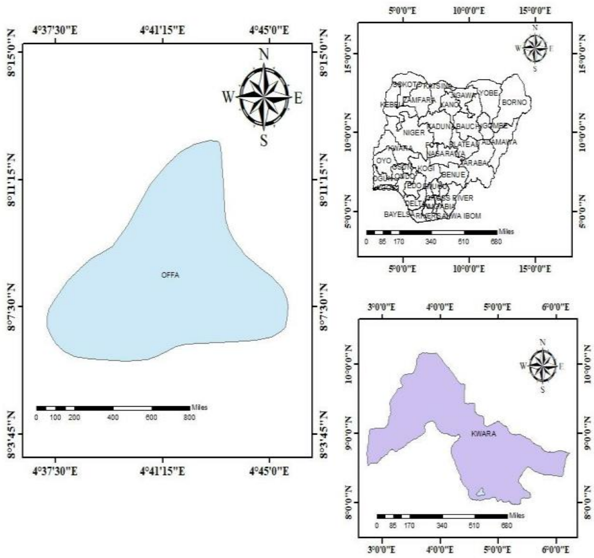

Figure 1. Offa in its National, Regional and Local Settings

Methods

Changes in agricultural land cover were detected using Landsat TM (1991), ETM+ (2000), and OLI_TIRS (2019) images (Table 1) that were downloaded from the United States Geological Survey's Earth Explorer website [23]. Since these images were free and open-source, they became a cost-effective option for the authors. However, pieces of literature used were derived from relevant dissertations, conference papers, journal articles, and textbooks, amongst other secondary data.

Using the "Extract by Mask" Tool on ArcMap 10.4, the study area was extracted off the downloaded satellite images where Offa Local Government Area shapefile represents the feature mask data. The supervised classification technique (using the Maximum Likelihood Algorithm) was used to classify the images where five land cover classes (built-up area, agricultural land cover class, riparian zone/gallery zone, water body, and bare land) were identified from the visual and digital interpretations of the satellite images. Finally, accuracy assessment was carried out using historical Google Earth images, informed knowledge of the area, and GPS coordinates. ArcMap 10.4 was used to produce land cover maps for the years 1991, 2000, and 2019 respectively.

Table 1. Summary of Landsat Images Acquired for the Research

S/N	Satellite Number	Sensor type	Band	UTM Zone	Datum	Scale/ Resolution	Sources/ Year
1	Landsat 5	TM	4,3,2	31N	WGS 84	30m	1991
2	Landsat 7	ETM+	4,3,2	31N	WGS 84	30m	2000
3	Landsat 8	OLI_TIRS	4,3,2	31N	WGS 84	30m	2019

Source: Authors' Lab work, 2020

III. RESULTS AND DISCUSSION

Figures 2, 3, and 4 present the results of land cover classification for 1991, 2000, and 2019 respectively. The pixel statistics of land use in Landsat TM 1991 presented in Table 2 (see Figure 2) shows that the area covered by the built-up area is 3.39sqkm (2.67%). Agricultural land cover class and riparian zones accounted for 70.4592sqkm (55.41%) and 28.854sqkm (22.69%) respectively, while the water body and bare land respectively amassed 6.21% and 13.02% of the entire area. This result implies that as of 1991, Offa LGA was characterized by a rustic landscape. Therefore, much urban development had not taken place in the study area. Also, the proportion of area cultivated in 1991 shows that the study was largely predominated by active farmers.

In 2000 (Figure 3), the agricultural land cover class was still the dominant land cover class constituting 50.94% (64.809sqkm) of the study area. There was an obvious decline in agricultural land cover class. At this point, the built-up area almost quadrupled its initial area coverage in 1991, representing 11.5182sqkm (9.06%) of the entire land cover class. However, the water body, bare land, and riparian zone amassed 14.19sqkm (11.16%), 16.64sqkm (13.08%), and 20.00 (15.73%) respectively.

The 2019 land cover result (Figure 4) shows that the built-up land cover class has increased to 18.33sqkm (14.42%) of the study area. The proportion of agricultural land cover class has reduced to 47.08sqkm (37.02%). The other land cover classes which are water body, bare land, and riparian zone collectively amassed a total of 48.56%. The increase in the total acreage of the built-up area (often at the expense of agricultural land cover class) continued unabated over the study period.

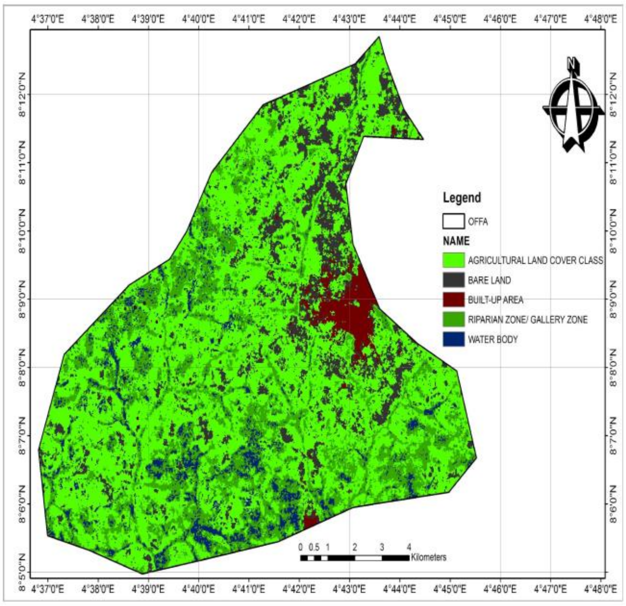

Figure 2. Land Use/Land Cover of Offa, 1991

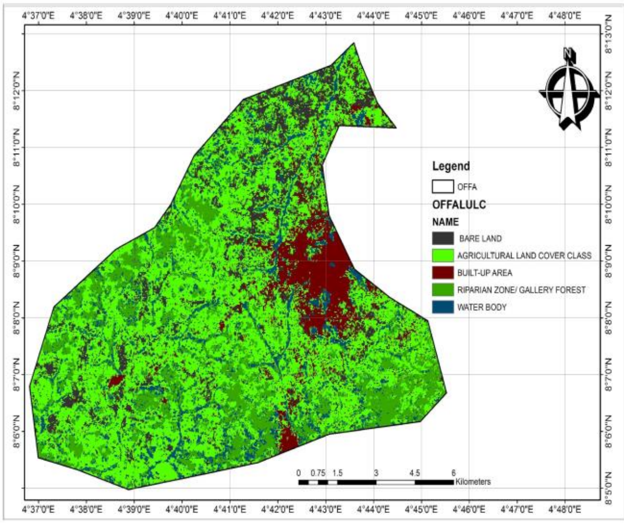

Figure 3. Land Use/Land Cover of Offa, 2000

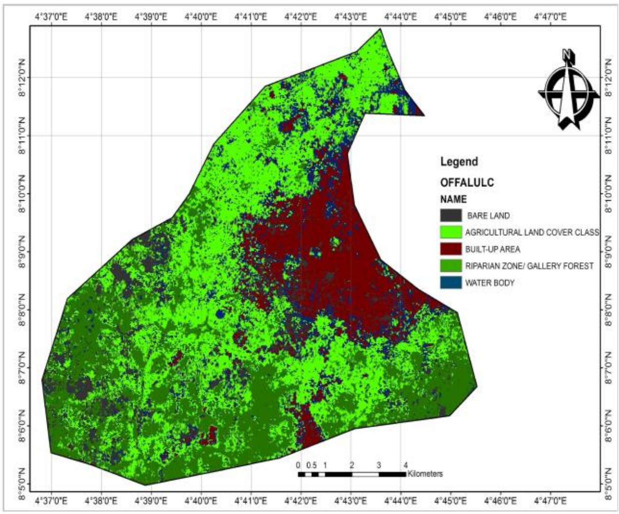

Figure 4. Land Use/Land Cover of Offa, 2019

A graphical representation showing the relationship between agricultural land cover class and the built-up area in Offa LGA during the study period is presented in Figure 5. It shows that agricultural land diminishes as the built-up area increases. Accordingly, a nearly direct relationship between agricultural land loss and urbanization is brought into a clearer focus.

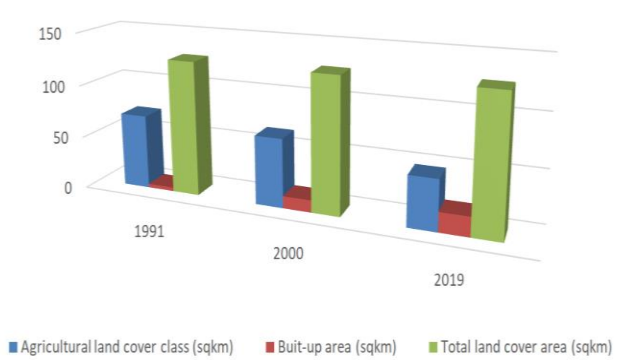

Figure 5. Areas Occupied by Agricultural Land Cover and Built-up Area in Offa for the Years 1991, 2000 and 2019

Table 2. LULC Distribution between 1991 and 2000

	1991		2000		1991-2000	
LULC Classes	**Land cover (sq.km)**	**%**	**Land cover (sq.km)**	**%**	**Net Change (sq.km)**	**Net Change (%)**
Built-up	3.3912	2.67	11.5182	9.06	8.127	239.65
Agricultural Land	70.4592	55.41	64.809	50.94	-5.6502	-8.02
Riparian Zone	28.854	22.69	20.0088	15.73	-8.8452	-30.66
Water Body	7.8948	6.21	14.1876	11.16	6.2928	79.71
Bare Land	16.5663	13.02	16.6419	13.08	0.0756	0.46
Total	127.1655	**100**	127.1655	**100**		

Source: Authors' Lab work, 2020

Table 2 shows the changes (in sqkm and percentage) in land cover that have occurred between 1991 and 2000. The result shows the net change in each of the land cover classes in the study area. The net change of the built-up area over the study period was 8.127sqkm. Accordingly, the compound rate of change of the built-up area was 0.903sqkm/yr. This implies that the rate of change in built-up areas for every year between 1991 and 2000 has increased significantly at a compound rate of 14.56%/year. This shows that there was a rapid rate of urbanization in the study area between 1991 and 2000.

Furthermore, 5.6502sqkm of agricultural land was lost between 1991 and 2000. Consequent to this, a decrease in agricultural land cover class was at a compound rate of -0.63sqkm/yr (-0.92%/year). It can be inferred that the conversion of farmland and wetland to other non-agricultural uses was mainly driven by urbanization.

Table 3 shows the changes in land use that have occurred between 2000 and 2019 in sqkm and percentage. It was observed that between 2000 and 2019, the built-up area net gain was 6.81sqkm, while agricultural land cover experienced -17.03sqkm net loss. Overall, the results revealed that there has been a consistent decrease in agricultural land cover class and increment in the built-up area. The rapid population growth and growing infrastructure development are exposing the study area to both a direct and indirect impact of urban-oriented activities with more alarming significance on agricultural land loss and reduction of the farming population. This is a cause for concern, particularly with food insecurity as the world's agricultural sector is required to produce nearly 70% more food compared to the current level by 2050 [24].

Table 3. LULC Distribution between 2000 and 2019

	2000		2019		2000-2019	
LULC Classes	**Land cover (sq.km)**	**%**	**Land cover (sq.km)**	**%**	**Net Change (sq.km)**	**Net Change (%)**
Built-up	11.5182	9.06	18.3321	14.42	6.81	59.12
Agricultural Land	64.809	50.94	47.0817	37.02	-17.03	-26.28
Riparian Zone	20.0088	15.73	32.8023	25.79	12.79	2.06
Water Body	14.1876	11.16	15.8886	12.49	1.701	12.00
Bare Land	16.6419	13.08	13.0617	10.28	-3.58	-21.51
Total	127.1655	**100**	127.1655	**100**		

Source: Authors' Lab work, 2020

Implications for Food Security

The obvious decline in Agricultural land cover seen between 1991, 2000, and 2019 (Figure 2, 3, 4) in Offa LGA harmed the goal of achieving food security in Kwara State and will continue to reduce food production and supply if adequate interventions are not made. The loss of cultivable soil to urban development will limit farmers' productivity and in turn, leads to food scarcity, thus food prices will soar high. Besides, the occupants of Offa LGA who are predominantly farmers stand a chance of also losing their source of livelihood to urbanization processes. Also, the arable land, water resources and biodiversity required to produce quality food are declining at a very fast pace. Hence, all effort to localize food production as well as reduce importation, poverty and malnutrition amongst households in Offa LGA is seen to be hampered by industrialization actions. Although previous studies have affirmed the importance of infrastructural projects such as roads in the scaling up of food production and supply in a developing country [25-27]. Nonetheless, inconsistencies in government policies and lack of proper planning regarding rural-urban development have birthed several infrastructural projects built on land/ soil most suitable for agriculture. Aside from the direct impact suffered from losing agricultural lands to urban development, other indirect impacts can be more devastating towards food security. For instance, some infrastructural projects built in the way of erosion end up eroding top soils causing nutrient depletion due to disruption of nutrient cycles [28]. Unfortunately, the extent of a nation's food insecurity is regularly published rather than the condition and availability of good soil and agricultural land resources. Thus, in the quest to feed our teeming population lies the need to design and implement effective policies to help protect agricultural land resources judiciously.

IV. CONCLUSION AND RECOMMENDATIONS

This study showcases the ability of GIS and Remote Sensing in analyzing the interactions between urban sprawl and agricultural land loss in Offa Local Government Area, specifically between 1991, 2000, and 2019 using Landsat images. The study results suggest that the study area is experiencing agricultural land loss due to urban sprawl.

The proliferation of non-agricultural activities driven by unplanned urbanization could impair the incredible efforts of agricultural innovations in combating food insecurity and further intensifies agricultural land loss. Therefore, agricultural land with high productivity potentials must be effectively protected from urban development and other invasions through the development of potent land-use policy. Such a policy should include development control mechanisms and strict administrative measures. As it stands, aside from sustained urban planning policies and regulations, we must fortify our food system and build resilience against the drastic agricultural land loss by exposing farmers to innovative approaches to food production that address the problems of land availability and recent ways of managing the little land and water resources efficiently to help improve food security. For instance, there are approaches where food is grown in multilayered artificial structures in urban environments under controlled environmental conditions. In this regard, vertical farming is reported to efficiently utilize limited land spaces and also conserve water. Another example is the rooftop farming approach, this can be designed and set up on top of houses to grow vegetable crops as well as the rearing of livestock required to supplement household diets. Also, soilless farming such as hydroponics and aeroponics are trending agricultural practices. These aforementioned agricultural systems help to grow crops with little or no soil requirements. Water used is often recycled, thus producing food over a smaller land footprint. With these measures, urbanization threat on agricultural land and food security could be minimized. Finally, it is high time we understood that the integration of Agroecology principles and practices with inclusive rural-urban planning remains essential to achieving food security.

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