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# The implication of agricultural land-use change on food security in Benue state, Nigeria

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**Abstract**

This study employed geo-physical Land Use Land Cover (LULC) satellite data and crop yield data to examine the trend of agricultural land-use change and how it affected food security in the Nigerian state of Benue. Satellite imageries were downloaded for the years 1980, 1990, 2000, 2010, and 2015 from the United States Geological Survey (USGS) website, while crop yield data from 1980 to 2015 were obtained from the Benue State Ministry of Agriculture. Satellite image datasets were analyzed using remote sensing and GIS techniques, and data extracted for a quantitative analysis while crop yield data and data on percentage changes in cropland/vegetation were analyzed using regression analysis. The results of the study showed that the trend of agricultural land-use change in Benue state, Nigeria is tending towards reduction in agricultural lands. While this negative trend was found to reduce the output of some crops (e.g. yam, maize and groundnut), it seemed to have also spurred an increase in the production of other crops with more economic value (e.g. rice and cassava) due to intensification. The study recommends that appropriate land-use policies should be put in place to prevent unguarded loss of agricultural lands so as to forestall looming food security crisis.

**Keywords:** Agricultural productivity, Food security, GIS, Land use change, Remote sensing.

## Introduction

Agriculture has been identified as one of the major users of land resources in the world, with about 37.7% total land area either under arable cultivation or permanent plantation (World Bank, 2013). In sub-Saharan Africa, the percentage of agricultural land is put at 43.8% of the total land area (Food and Agricultural Organization, 2014). However, current studies have recognized changes in the use of agricultural lands as the key driver that pose a challenge to global and local food security (Yan et al., 2009; Adamgbe and Ujo, 2012). In recent decades, progress in land-use research has improved understanding of how changes in the use of agricultural lands undermine agricultural productivity, drive soil degradation, and trigger biodiversity losses (Meyer and Turner, 1992; Lambin et al., 2000; Boissiere et al., 2009). While recent rate of changes have been more rapid than at any other time in human history, a new research direction has been called for that critically examines trends in agricultural land-use and how it affects food security (Jianlong et al., 2011).

Several new perspectives have begun to emerge in a way that show the dynamic trend of Agricultural Land Use Change (ALUC) – a feedback relationship that involves the conversion of agricultural lands to non-agricultural or reverse process of clearing natural vegetation for agricultural purposes (Josea and Padmanabhan, 2016). While some studies show that the trend of ALUC is moving towards agricultural land expansion (Johannsen and

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Armitage, 2010; Lubowski et al., 2006; Boateng, 2013; Gutzler et al., 2015), others are indicating that the trend is moving towards loss of agricultural lands (Atu et al., 2012; Alagbe et al., 2013; Dijk et al., 2013; Li et al., 2013; Belay, 2014; Doso, 2015). The former trend has direct environmental consequences, while the latter trend has more threatening implications for food security. This study aimed to ascertain the direction of ALUC in the Nigerian State of Benue, with a view to exploring its implications on food security.

Recent studies in Nigeria are pointing towards high rate of agricultural land reduction (Adamgbe and Ujo, 2012; Atu et al., 2012; Alagbe et al., 2013). These are evident in the manner in which agricultural lands are being lost to environmental degradations such as soil erosion, desertification, etc (Oyekale, 2012). Of more serious concern is the rate at which farmlands are being converted for other purposes such as urban infrastructures (housing and industrial structures), transportation infrastructures (mainly road construction), tourism and recreational amenities, etc (FAO, 2014; Saleh et al., 2014). Consequently, these land development projects have given rise to decrease in lands that are supposed to be used for food production (Ademiluyi et al., 2008). However, till date, few studies in Nigeria have investigated the trends of ALUC, especially in food producing areas of the country. Furthermore, while the pathways to and feedbacks from land-use and food security are dynamic (Figure 1), the framework for operationalising the relationship is largely absent in literature. Hence the need to understand the nexus between trends in ALUCs and food security become a critical research agenda for Nigeria (Oyekale, 2012).

To investigate the direction of ALUC, one requires a trend analysis and classification of the Land-Use and Land Cover (LULC) changes (Kidane et al., 2012). The use of remote sensing/Geographical Information System (GIS) technology enables an area to be classified into different land-uses (Belay, 2014; Vittek et al., 2014; Karlson and Ostwald, 2016). One of the major classes of the land-use classification is vegetation areas. According to Kidane et al. (2012), vegetation includes both cultivated (farmlands) and uncultivated (natural forests) covers. Conceptually, it represents the area of land covered with plants, which could either be forest trees or cultivated crops, or an area of land under which crops are grown or yet to be grown but nevertheless available for cultivation (Karlson and Ostwald, 2016). It therefore implies that any increase or decrease in vegetation cover will likely affect land areas available for agriculture. The overarching aim of this study is therefore to ascertain the direction of ALUC in the Nigerian State of Benue, with a view to exploring its implications on food security. To do this, the study will i) analyze the trend of ALUC in Benue State, and ii) determine the effect of ALUC on crop yield.

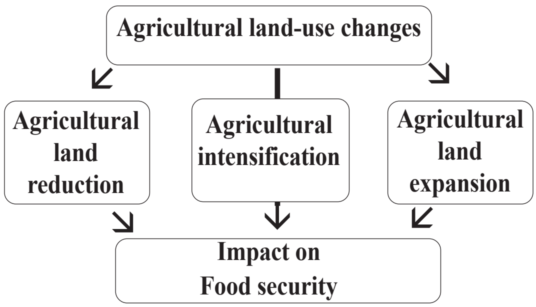


*Figure 1.* Concepts of ALUC and implication on food security

## Materials and Methods

### *Study Area*

The study area was Benue State in Nigeria. The state had experienced some environmental disasters such as flooding in the recent past which has somehow affected LULC changes (Benue State Government [BNSG], 2014). Benue state had a population estimate of 4,253,641 in the last 2006 national population census (National Bureau of Statistics, 2006). It is divided into three agricultural zones, which are: Central zone, Northern zone, and Eastern zone (Figure 2). The state lies between latitude 6°

25’ and 8° 8’ North, and longitude 7° 47’ and 10° 0’ East. The land area is estimated to be about 5.09 million hectares, which represents about 5.4% of the national land mass. Arable land in the state is estimated to be 3.8 million hectares (BNSG, 2014). Benue state’s location in the transition belt of north and south ecologies, its favorable rainfall pattern, and its sandy-loam shelf basement complex, and alluvial plains geologic formations account for its advantage to support a wide variety of crops (BNSG, 2014).

*Sampling Technique*

Purposive sampling was used to select two agricultural zones (Northern and Eastern zones) out of the three agricultural zones that make up Benue State. The selected zones constituted the most active farming population in the state, and were suitable for exploring the effect of ALUC on food security. From each of the two selected zones, two Local Government Areas (LGAs) were randomly selected for direct observations, giving a total of four sampled LGAs.

*Data Collection*

Primary data on LULC were obtained by ground truth exercise through direct observation from transect walks, and collection of the geographical coordinates using GARMIN GPS (Global Positioning Satellite Receiver). The coordinates were used as a reference system to represent the location of the satellites imageries in the GIS analysis.

Secondary data were collected from satellite imageries and crop yields from 1980 to 2015. While the satellite imageries were used for the GIS analysis of LULC changes, the crop yield data were used to ascertain the trend of food production and food security status. Satellite image of 1980 was downloaded from Landsat 3, satellite images of 1990, 2000, and 2010 were downloaded from Landsat 5, while satellite image of 2015 was downloaded from Landsat 8, for the four sampled LGAs- Makurdi, Gboko, Katsina-Ala, and Kwande), all from the United States Geological Survey (USGS) website (earthexplorer.usgs.gov). For the crop yield data, documented data on selected crop yields (yam, cassava, rice, maize, and groundnut) for the years 1980 to 2015 were obtained from the Benue State Ministry of Agriculture. As at 2015, the mean yield of yam, cassava, rice, maize, and groundnut production in Benue state stands at 10.88t/ha, 12.72t/ha, 1.72t/ha, 1.03t/ha, and 1.75t/ha respectively. These crops were selected because they are the most common crops grown in the area. Furthermore, Benue state is highest producer of yam in Nigeria, fourth in cassava production, fifth in rice production, and also produces appreciable quantity of maize and groundnut in the country.

*Data Analysis*

Satellite image dataset were analyzed using remote sensing and GIS techniques, and data were extracted for a descriptive quantitative analysis. Crop yield data and data on percentage changes in cropland/vegetation were analyzed using regression analysis. These varied analytical techniques are outlined below.

*Remote Sensing and GIS Technique*

Remote sensing and GIS technique was employed to determine the trend of LULC changes in the four sampled LGAs of Benue state from 1980 to 2010 at ten years intervals, and from 2010 to 2015 which is for five years to allow for up to date analysis of the LULC changes in the area. Analysis of satellite imageries using GIS/remote sensing technique generally involves two broad stages: data processing and data analysis.

In data processing, the first step was layer stacking, where ARC GIS 10.2 was used to create a composite band image with bands applicable to land-use changes investigation. These bands were bands 4, 3, and 2 representing near-infrared, red, and green colors respectively of the Landsat 3, 5, and 8 TM dataset. This gave a single layer multiband image which was suitable for land-use and vegetation cover studies. However, as most open source imageries were usually distorted by excessive cover, IDRISI Selva was used to correct the haze distortion so as to enhance the appearance of the images. Next, the geographic coordinate systems from the World Geodetic System were used to assign accurate spatial reference to the raster image (Landsat imageries) and for vector shape files that were created. The images were then extracted for analysis. The processed satellite imageries were analyzed using maximum likelihood classification into three LULC classes: cropland/vegetation areas, built-up areas, and wetland/water bodies. The results were assessed for accuracy. Using a scale range of -0.1 to 1, any scale above 0.5 to 1 indicated an accurate assessment while scale below 0.5 was considered inaccurate.

*Linear Regression Analysis*

Data on percentage changes in cropland/vegetation cover (proxy for ALUC) obtained from the LULC analysis, and time series data on yields for five different crops (yam, cassava, rice, maize, and groundnut) between 1980 and 2015 were analyzed using linear regression analysis. The functional form of the linear regression is represented as follows:

$Y = B_0 + BX + e$

Where:

Y = Dependent variable (Crop yields, million tonnes per hectare [Mt/ha])

$B_0$ = Intercept

B = Coefficient of explanatory variable

X = Cropland/vegetation cover (%) (log transformed)

e = Stochastic error term

**Results and Discussion**

*Trend of LULC changes from 1980 to 2015*

The results of the LULC classification for each sampled LGA are presented in Table 1 and Figure 3. The general trend of LULC changes of Benue state, Nigeria from 1980 to 2015 showed an overall increasing trend in built-up areas and a corresponding decrease in agricultural lands. This finding was consistent with several previous ALUC studies in different parts of west Africa which showed an overall decreasing trend in agricultural lands (Njungbwen and Njungbwen, 2011; Schueler et al., 2011; Alagbe et al., 2013; Saleh et al., 2014; Vittek et al., 2014).

*Table 1.* LULC distribution of the four sampled LGAs (1980-2015)

| | 1980 | | 1990 | | 2000 | | 2010 | | 2015 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Land-use/Land cover classes | Area (Ha) | % Cover | Area (Ha) | % Cover | Area (Ha) | % Cover | Area (Ha) | %%Cover | Area (Ha) | % Cover |
| | | | | | Katsina-Ala | | | | | |
| Built-Up/Land area | 39,435.21 | 47.3 | 36,881.46 | 44.2 | 42,365.25 | 50.8 | 52,365.25 | 62.8 | 58,895.25 | 70.6 |
| Wetland/Water Body | 27,844.20 | 33.4 | 5,493.06 | 6.6 | 19,653.57 | 23.6 | 12,653.17 | 15.2 | 12,653.17 | 15.2 |
| Crop land/Vegetation | 16,090.83 | 19.3 | 40,995.72 | 49.2 | 21,351.42 | 25.6 | 18,351.82 | 22.0 | 11,821.82 | 14.2 |
| Total | 83,370.24 | 100.0 | 83,370.24 | 100 | 83,370.24 | 100 | 83,370.24 | 100 | 83,370.24 | 100 |
| | | | | | Gboko | | | | | |
| Built-Up/Land area | 42,279.03 | 19.9 | 113,391.71 | 53.7 | 117,592.20 | 55.4 | 127,592.19 | 60.2 | 133,092.19 | 62.7 |
| Wetland/Water Body | 74,433.15 | 35.1 | 23,437.71 | 11.1 | 24,437.23 | 11.5 | 24,537.24 | 11.6 | 24,537.24 | 11.6 |
| Crop land/Vegetation | 95,393.43 | 45.0 | 75,276.18 | 35.5 | 70,076.18 | 33.1 | 59,976.16 | 28.3 | 54,476.16 | 25.7 |
| Total | 212,105.61 | 100.0 | 212,105.61 | 100.0 | 212,105.61 | 100.0 | 212,105.61 | 100.0 | 212,105.61 | 100.0 |
| | | | | | Makurdi | | | | | |
| Built-Up/Land area | 133,938.36 | 49.8 | 99,576.54 | 37.1 | 128,262.24 | 47.7 | 149,862.31 | 55.8 | 162,253.30 | 60.4 |
| Wetland/Water Body | 33,179.13 | 12.4 | 44,353.17 | 16.5 | 71,400.33 | 26.6 | 77,800.33 | 28.9 | 72,500.32 | 26.9 |
| Crop land/Vegetation | 101,624.67 | 37.8 | 124,812.45 | 46.4 | 69,079.59 | 25.7 | 41,079.52 | 15.3 | 33,988.53 | 12.7 |
| Total | 268,742.16 | 100 | 268,742.16 | 100 | 268,742.16 | 100 | 268,742.16 | 100 | 268,742.16 | 100 |
| | | | | | Kwande | | | | | |
| Built-Up/Land area | 55,754.55 | 18.2 | 81,984.24 | 26.8 | 75,380.85 | 24.6 | 84,480.99 | 27.6 | 116,351.05 | 37.9 |
| Wetland/Water Body | 93,729.06 | 30.6 | 85,151.97 | 27.8 | 94,087.17 | 30.7 | 99,087.18 | 32.4 | 90,077.12 | 29.4 |
| Crop land/Vegetation | 156,736.80 | 51.2 | 139,084.20 | 45.4 | 136,752.39 | 44.7 | 122,652.23 | 40.1 | 99,792.24 | 32.7 |
| Total | 306,220.41 | 100.0 | 306,220.41 | 100.0 | 306,220.41 | 100.0 | 306,220.41 | 100.0 | 306,220.41 | 100.0 |

Meanwhile, although the result of LULC classification indicated that the trend was shifting towards urban sprawl with a high dependence on agricultural land, there was a significant spatial and temporal variation in the land-use classes across the four LGAs of Benue considered in this study. For instance, Makurdi, which is the state capital, witnessed the highest rate of vegetation/croplands decline, while Katsina-Ala, which is a more rural area, recorded the least change in the decline of vegetation/croplands. Gboko, on the other hand, which is the industrial hub of the state in terms of number of commercial and extraction industries witnessed the highest rate of increase in built-up/ lands areas. This implied that although Benue state is an agrarian state, areas of high human settlement, urban development, and industrial activities witnessed decline of vegetation/croplands more than areas with less rate of urbanization and economic development. Consistent with this spatial variation was the analysis of drivers of ALUC by previous studies in other parts of Nigeria which showed that urban infrastructure (housing and industrial) was a major driver of ALUC (Njungbwen and Njungbwen, 2011; Alagbe et al., 2013; Saleh et al., 2014). However, the findings of most of the previous studies did not capture the spatial variation in the trend of LULC. Most of them were quick to conclude that an entire study area experienced a uniform trend in LULC. The result of this study showed that this generalization might be empirically faulty as different parts of an area can be experiencing different trends in LULC changes depending on the prevailing environmental and economic conditions of the area.

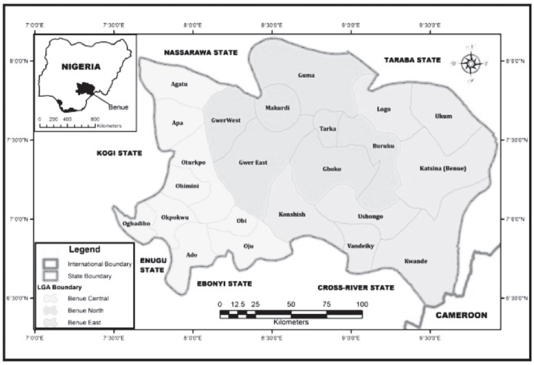


*Figure 2.* Map of Benue state showing the three agricultural zones and LGAs

*Effect of ALUC on crop yields*

The result of the regression analysis is summarized in Table 2. The entire regression for each crop was

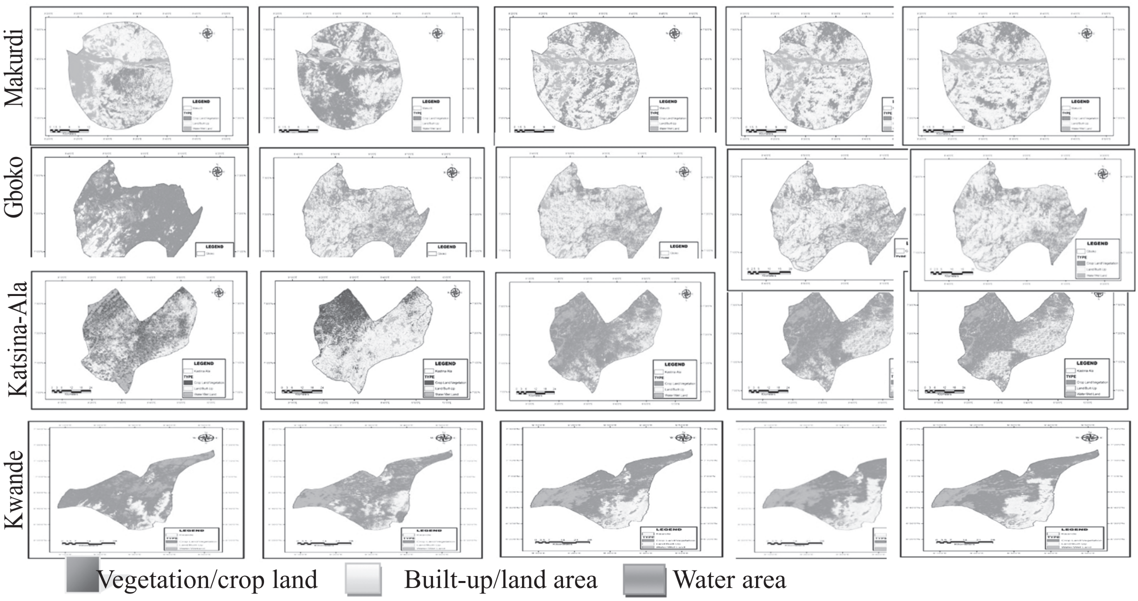


*Figure 3.* LULC changes of the four sampled LGAs from 1980 to 2015

*Table 2.* Summarised regression analysis result showing the effect of changes in cropland/vegetation cover on crop yields

| Crops | Constant | Coefficient | std. error | $t_{cal}$ | F-cal | Prob>f | $R^2$ |
|---|---|---|---|---|---|---|---|
| Yam | 8.905 | 0.113 | 0.017 | 6.551 | 42.913 | 0.000 | 0.558 |
| Cassava | 13.680 | -0.017 | 0.008 | -2.103 | 4.424 | 0.043 | 0.115 |
| Rice | 1.411 | -0.020 | 0.004 | 4.724 | 22.314 | 0.000 | 0.396 |
| Maize | 0.933 | 0.009 | 0.003 | 3.473 | 12.060 | 0.001 | 0.262 |
| Groundnut | 1.604 | 0.008 | 0.002 | 4.415 | 19.492 | 0.000 | 0.364 |

Source: Field survey, 2016

statistically significant at 5% probability level. This suggested that the changes in cropland/vegetation cover (ALUC) had significant effect on agricultural productivity (crop yields), although the nature and magnitude of the effect as shown by the coefficient (b) value varied for different crops.

This study uncovered that ALUC did not only drive decrease in agricultural productivity, but might also drive increase in the production of certain crops. Crops like rice and cassava were found to be increasing as cropland/vegetation areas were decreasing. This might be attributed to management and intensification practices for different crops. It was possible that farmers favored the production of these crops relative to other crops because of their high market value. Thus, as agricultural lands were decreasing in the area, the available lands were put into more intensive use for the production of these crops**,** thereby leading to increase in yields. Oni et al. (2009), in their economic analysis of agricultural production in Nigeria, found that crops with more market value like rice had higher yields than those with lower market values. The cassava value chain intensification intervention of the Benue state government may also have contributed to the increasing yields of cassava (Phillips et al., 2009). These suggested that although decrease in agricultural lands decreased overall yields of some crops, it also spurred intensification and yield increase in the production of other crops, especially those with more economic values.

This raises the issue of agricultural intensification being able to ensure food security in the face of declining agricultural lands. The solution lies in the sustainability of intensification approach. Although agricultural intensification has been recognized as one of the major strategies to enhance food security, it is unlikely that it will guarantee food security with the declining trend of agricultural lands in the long run. This is because as agricultural lands continue to decline with a consequent increase in intensification, the available land will get to a point of diminishing returns, where every increase in intensification will lead to decrease in the marginal production output. Tilman et al. (2002) arrived at a similar conclusion when they found that intensive production is not a guarantee for agricultural sustainability and food security. This is coupled with the fact that agricultural intensification spurs environmental changes such as habitat alteration, land degradation, and loss of biodiversity (Vliet et al., 2015). These changes in turn have negative implications for food production. For instance, a degraded land lacks capacity to support efficient food production, while an altered soil habitat (e.g. through chemical pollutions) can increase the risk of disease outbreak. This suggests that although ALUC spurs intensification which increases agricultural productivity, it may not guarantee food security in the long run.

The food security situation in Benue state provides a clearer picture of this paradox. Although crops like rice and cassava have witnessed increase in yields in recent times, the increase has not been able to make up for the loss in other crops. Hence, the state still faces looming food security crisis. For instance, at the household level, Ahungwa et al. (2013) found that about 63.3% of farming households in Benue were food insecure. At the state level, Abu and Soom (2014) reported that the overall agricultural production in Benue has significantly declined between 1960 and 2011. As the food production hub of Nigeria, the overall decline in Benue's agricultural productivity has implications for national food security, and might not be unconnected to FAO (2014) report which shows a decreasing trend in Nigeria's agricultural production and a consequent increase in food importation (FAO, 2014). This probably explains why to date Nigeria remains heavily dependent on imported food to feed its large populations, a situation which perfectly describes national food insecurity (Ihemeje et al., 2014). Although several factors may be responsible for the downward trend in food production, it may not just be a mere coincidence that Benue witnessed a downward slope in food production at the same time it was experiencing loss of agricultural lands. This suggests that the latter may partly be responsible for the occurrence of the former.

The recent changes experienced in the use of agricultural lands have generated concerns about its impacts on food security. This study has added further empirical content to the mass body of literature on ALUC by analyzing the trend of ALUC in Benue State of Nigeria**,** and how these changes affect food security. The results of the study show that the trend of ALUC in Benue state, Nigeria**,** is tending towards reduction in agricultural lands. While the trend of agricultural land reduction has negatively affected the yields of some crops (e.g. yam, maize and groundnut), it seems to have also spurred an increase in the production of certain other crops with more economic value (e.g. rice, and cassava) due to intensification. Nevertheless, this increase may not guarantee food security if agricultural lands continue to decline. The declining agricultural lands further imply loss of livelihood resources for the local farmers.

Following the findings of this study, appropriate land-use policies are needed to prevent unguarded loss of agricultural lands to urban development. Agricultural lands should be well defined in the urban and regional master plan of the area and protected by law against encroachment of any form. Furthermore, the farmers are encouraged to diversify the crop enterprises so as not to be discouraged by the decreasing output of crops affected by ALUC. Finally, owing to the fact that the pathways to and feedbacks from land-use changes and food security are dynamic, further research is recommended to develop a more robust model for quantifying a relationship that will capture all other factors that affects food security other than ALUC.

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