



# **INTERNATIONAL JOURNAL OF SOCIAL SCIENCES**

Vol. 13, No 2, April - June 2019

**FACULTY OF SOCIAL SCIENCES, UNIVERSITY OF UYO, NIGERIA**



**International  
Journal of  
Social Sciences**

## **Timescale Changes in suitability units of arable land in Akwalbom State, Nigeria**

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### **Abstract**

*This paper examined the accompanying changes in per capita arable land between 1986 and 2013 and their effect on food production. Land suitability map, satellite imageries and population data were acquired for the study. Spatial coverage of water, forest, farmland, urban land uses and accompanying human population within different land suitability units were estimated. It was observed that arable land in moderate suitability units increased by 20% with accompanying overall decreased from 0.22 to 0.11 ha per person. Deforestation accounted for increases in arable land use while losses in arable land translated to gains in urban land use. The direct consequence of the losses to urban land use is not reduction in food production. Suitability constraints associated with geomorphology notwithstanding, approximately 90% of the study area were assessed either moderately or marginally suitable for sustainable arable crop production. Geomorphology and development are responsible for concentration of approximately 62.4% of the population within approximately 55.6% of the land. The availability ratio of arable land in 2036 will be 0.00487 ha per person with resultant food insufficiency, escalating erosion and pollution.*

**Keywords:** Land use, land suitability, remote sensing, sustainable environment, Arable land

### **1. Introduction**

Land suitability is the fitness of a given tract of land for a defined use (FAO, 2007). The FAO land suitability classification delineates and groups land into a categorical format which emphasizes suitability for arable crop production in a hierarchical manner with accumulation of constraints as the capacity for optimal sustainable benefits decreases from the optimum. In unplanned and developing systems with weak or absence of environmental laws, land is allocated to uses arbitrarily and indiscriminately without consideration of the suitability and possible consequences.



Arable land implies a kind of land that is used for the cultivation of temporary crops, temporary meadows (mowing or pasture), market or kitchen gardens and temporary fallow (Alexandratos and Bruinsma, 2012). In some developing systems, the predominant land use is the cropping-bush fallow-cropping closed system operated with the primitive hand tools of hoes and machetes, described as a sedentary form of shifting cultivation. Such method of farming may not be classified as shifting cultivation in its strict sense as increasing population has drastically decreased the length and frequency of the fallow periods. According to Ogban *et al.* (2004 and 2005) fallow periods in unplanned and developing systems such as Akwa Ibom State have become shortened to less than 4 years from 7-15 years. The bush-fallow-cropping areas are therefore classified inclusively as arable land.

Akpan *et al.* (2011), Ebukiba (2010) and Barasa *et al.* (2010) reported that household size, type of crops grown, land tenure system, agricultural extension activities, weak environmental laws and policies are significant predictors of land use and cover change in developing systems as found in Nigeria and Uganda. For instance, in the tropics, land-use and cover change are largely driven by extensive agricultural practices, high population growth rates, infrastructural development and weak environmental laws and policies (Geist and Lambin, 2002; Makalle *et al.*, 2008). The exponential population growth and shifting cultivation are causally linked to deforestation and environmental degradation (Jarosz, 1993). However, most countries in Africa and Latin America have increased their food production through both agricultural intensification and extensification (Lambin *et al.*, 2003). The combination of intensification, extensification and urban sprawl impacts the forests, per capita arable land and sustainable production capacity in systems characterized by low input production, land tenure, weak extension, weak environmental laws and policies (Obi *et al.*, 2008; Udo *et al.*, 2011; Obi and Udo, 2011).

Low input production systems often imply low output (Poux, 2007). In the study area, the major arable crops that could be grown sustainably and profitably include cassava, yams, cocoyam, maize, rice and vegetables (Ebukiba, 2010). Yet these crops have been reported to be produced at low efficiency of resources (Etim *et al.*, 2013; Basse *et al.*, 2015). Comparing yields of yam, cassava, maize and rice in the farmers' fields with expected, Ibia (2012) reported potential yield that is approximately 58.5%, 71.25%, 77.5% and 53.2% respectively less than optimal. Then a combination of population increase, unplanned development, urban sprawl, intensification and extensification in low input - low output production systems renders decreases in the per capita arable land detrimental to sufficiency in food production and environmental sustainability.

The objectives of this study were to evaluate the trends in land use changes on different land suitability units, estimate the changes in per capita arable land (ha) between 1986 and 2013 and assess their effect on food production in Akwa Ibom State, Nigeria.

## **2. Description of the Study Area**

The study was carried out in Akwa Ibom State, southeastern Nigeria. The State is located between 4° 30' and 5° 30' N and 7° 28' and 8° 20' E, and covers an area of approximately 8412 km<sup>2</sup> out of Nigeria's 912,000 km<sup>2</sup> total area. The southern boundary

of the State is the coastline on the bight of Bonny, bounded on the east by Cross River State, north and the north-west by Abia State and on the southwest by Rivers State (Fig. 1). Most inhabitants are employed as civil servants with the State acting as major agent of growth and development. Apart from civil service, other occupations are low input subsistent agriculture and artisanal fishing (Ekerete and Ekanem, 2014). Major crops grown are cassava, yams, cocoyam, maize, rice, green vegetables, tomatoes, melon, pineapples, oil palm, cocoa, citrus, plantains, bananas and coconut (Peters *et al.*, 1989, AK-SEEDS, 2004). Akwa Ibom State, being the foremost crude oil producer in Nigeria, generates considerable financial resources from revenue achieved in the oil market. This singularly made enormous financial resource available both for the State and few individuals. In 1986 (i.e. prior to the establishment of Akwa Ibom State in 1987), the population of the settlements within its bounds was 2,100,565 and has grown to 3,902,051 in 2006 and to a projected total of 5,272,029 in 2015 at a growth rate of 3.4% (NPC, 2010; MED, 2014).

The climate is characterized by distinct rainy (March/April to October) and dry (November to March) seasons. Rainfall distribution in a year is bimodal (with peaks in July and September) and high intensity with annual precipitation sums varying between 2000 mm in the northernmost part and 4000 mm along the coast (Udosen, 2014). Temperature is uniformly high averaging between 28°C and 30°C and relative humidity is high (approximately 75%). The area is characterized by secondary forest of predominantly wild oil palm trees of various densities of coverage and woody shrubs such as *Chromolaena odorata* and various grass undergrowth such as *Imperata cylindrica* which are indicators of land degradation (Obi, 2000).

The predominant land use is subsistent cropping-bush fallow-cropping closed system and average farm size is less than 0.5 ha. Additionally, fragmentation of land among the community and family members does not enable farmers to accumulate more than this size of land in any one place (Ebukiba, 2010; Udoh *et al.*, 2011). However, a farmer could have several small parcels of farm scattered over a wide area.

Akwa Ibom State is underlain by a simple pattern of sedimentary geological formation. This comprises six geomorphic units including beach ridge sands (78974.2 ha), tertiary sandstones (143654.4 ha), strongly undulating coastal plain sands (35020.2 ha), gently undulating coastal plain sands (431320.5 ha), mangrove mudflat (54495.7 ha) and alluvium covering 97735.0 hectares (Ibia *et al.*, 2015). These respectively represented 9.4%, 17.1%, 4.2%, 51.2%, 6.5% and 11.6% of the study area. These geomorphic characteristics influence soil parent material, soil formation process and subsequently the land suitability evaluation (Mongera and Bestelmeyer, 2006; Udoh, 2014; Adefila, 2014). Petters *et al.* (1989) produced the soil map of the State and used the characteristics of the different soils units delineated to generate a land suitability map (Fig. 2).

### 3. Materials and Methods

The land suitability map of Petters *et al.* (1989) was readily available and was adopted for this study. This was possible because land characteristics utilized in the suitability evaluation are not dynamic and did not change within the time frame covered in this study. Land use changes were evaluated using a total of five (5) different satellite images captured in 1986, 2003, 2007, 2008 and 2013.

#### *Image acquisition and processing*

Landsat TM and ETM+ images with spatial resolution of approximately 30m by 30m (900m<sup>2</sup>) captured in January of 1986 and 2003 were acquired from the United States Geological Surveys (USGS) for use in the study. The image acquired in 1986 was selected as the base year (i.e. zero level infrastructural development period as a result of urbanization) since the State was created the subsequent year (1987). Additionally, NigeriaSat-1 images captured in December of 2007, 2008 and 2013 with spatial resolution of 32m by 32m were acquired and used for the study.

Many ancillary data sets were also obtained and used for accuracy assessment of the processed images. Such ancillary data were carefully chosen bearing in mind the years the satellite images were captured. While the land use/cover map of the CRBDA (1987), mapped from Landsat was used to assess the accuracy of the 1986 Landsat image, large-scale aerial photographs of 2002 were acquired from Akwa Ibom State Ministry of Lands and Housing for the Landsat data of 2003. The GPS points (x, y coordinates) for different land use and land cover types were randomly selected and utilized for accuracy assessment of the 2013 image. The images acquired and their classifications were used to evaluate effect of different land suitability units and accompanying human population growth on changes in land use and land cover as influenced by time (especially arable land use) within constrained spatial bounds. The periods corresponding to the acquisition of images used in the study were dependent on availability.

The steps involved in image processing firstly includes definition of the five land uses (water, forest, fallow, farm and urban), data acquisition, data enhancement, processing and integration. The next stage involved reconnaissance survey and development of the classification scheme according to the defined land uses which eventually leads to the first actual classification and verification through field checks. The information acquired from the field was used for modification of initial maps and subsequently production of the final land use maps.

### ***Land Cover Classification Scheme***

In 1987, prior to creation of Akwa Ibom State, Cross River Basin Development Authority (CRBDA) carried out an extensive land use and vegetation mapping of the area within the former Cross River State. The CRBDA land use and vegetation classification scheme was modified and simplified into five land use and cover classes defined by Anderson *et al.* (1976) and adopted for use in the study. The modified land use and cover classes (referred to as land use subsequently) include water, forest, urban or built-up, farm land and fallow.

### ***Image Enhancement***

In order to create subset images of the study area prior to actual enhancement and classification procedures, layer stacking and area of interest (AOI) tools were applied to the images. Since the images were captured during the dry seasons of their respective years, distortions due to weather and season were not taken into consideration. The images which were 100% cloud-free were subjected to principal component analysis (PCA). This is a spectral enhancement procedure which is often used to compress image data to reduce redundancy.

### ***Image Interpretation***

Supervised classification techniques were applied to derive meaningful classes from the images. Specifically, supervised signature extraction was adopted in conjunction with a maximum likelihood algorithm. In order to assess the accuracy of the classified images, the 1986 classified image was compared to a land use/cover map published by CRBDA in 1987, while the 2003 classified image was compared to aerial photographs of the area captured in 2002. GPS points were obtained from the field in order to ground truth the 2008, 2007 and 2013 image. The result of accuracy evaluation produced KAPPA estimate of strong agreement (Maingiet *al.*, 2002; Adam *et al.*, 2013). The land use/ land cover maps of the study area produced are presented as Fig. 3, 4, 5, 6 and 7 for 1986, 2003, 2007, 2008 and 2013 respectively

#### ***Per capita arable land of different suitability units***

The NPC (2010) report formed the basis for the projected population of Akwalbom State (2007 – 2015) by year, sex, residence, age group and Local Government Area utilizing overall growth rate of 3.4 per cent (MED, 2014). A combination of these was used to back project for 1986 population data. The Akwalbom State population data by residence for the different years (i.e. 1986, 2003, 2007, 2008 and 2013) were added separately to the land suitability map of Akwalbom State which was used to extract the human population of each land suitability unit as delineated in Fig. 2. The human population of each suitability unit represents the total number of people resident within the spatial coverage (i.e. bounds) of the unit (i.e. total population on the different land suitability units as classified). As an example, the population data points were added to the land suitability map of Akwalbom. The total population of each land suitability unit was used to determine the corresponding per capita arable land for each year (i.e. 1986, 2003, 2007, 2008 and 2013). The per capita arable land for the study area was compared with the 2012 estimated availability ratios of 0.20 and 0.21 for World and Nigeria respectively according to World Bank Group (2015) which continues to decline significantly (Bruinsma, 2009). Systematic analysis of local scale land use and population changes evaluated over a range of timescales will help in the establishment of pattern for prediction and provision of explanation for subsequent land use changes.



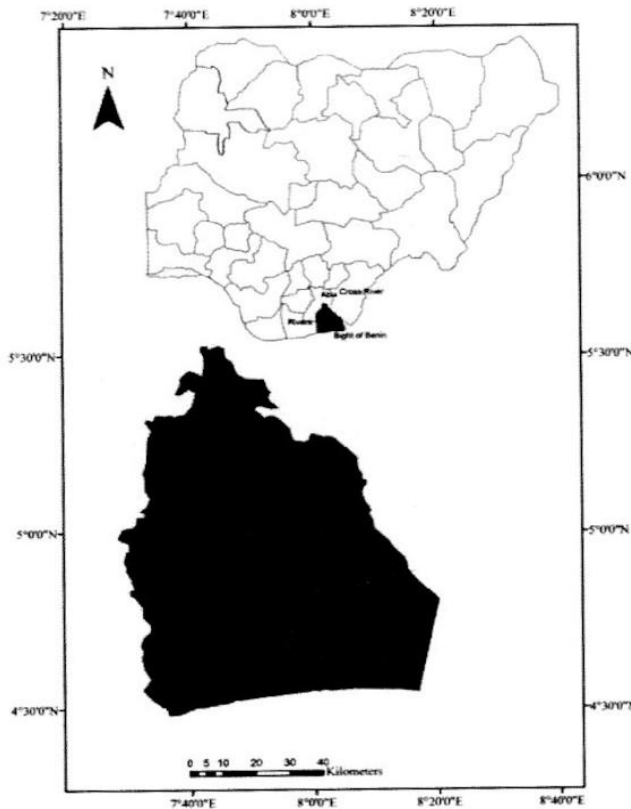


Fig. 1: Map of Akwalbom State (inset showing Akwalbom State in Nigeria)

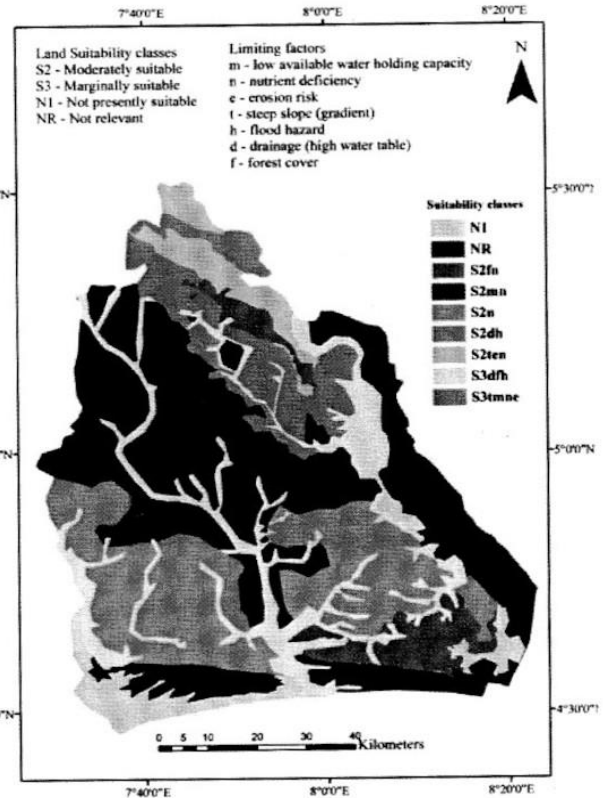


Fig. 2: Land suitability classification for arable cropping in Akwalbom State as defined by Petters *et al.* (1989)

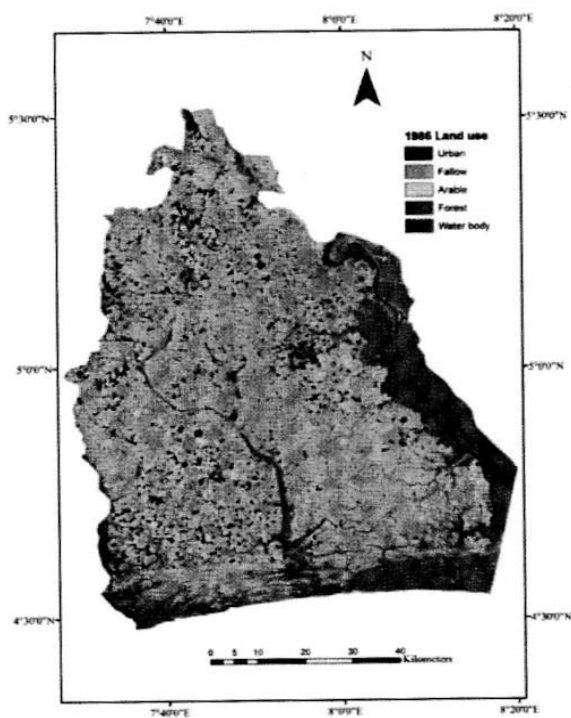


Fig 3: Land use and land cover classes of Akwalbom State in 1986

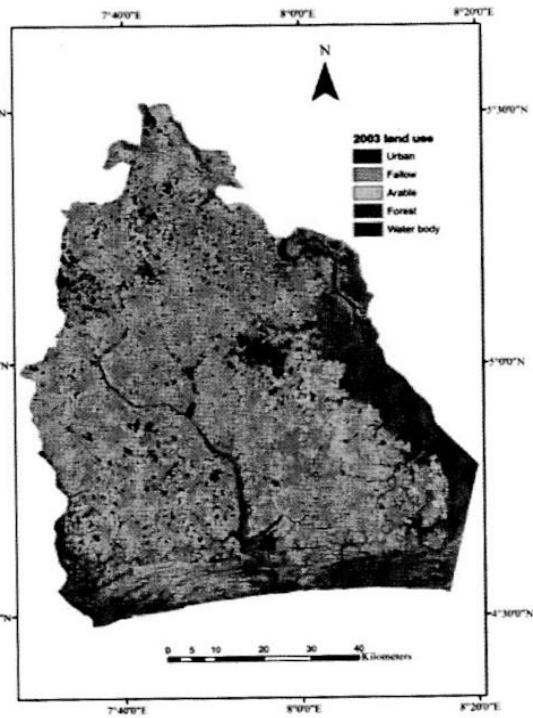


Fig. 4: Land use and land cover classes of Akwalbom State in 2003

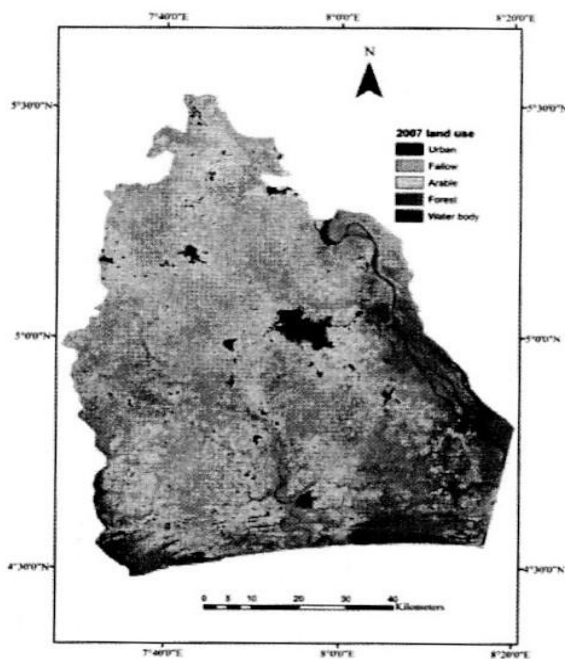


Fig. 5: Land use and land cover classes of Akwalbom State in 2007

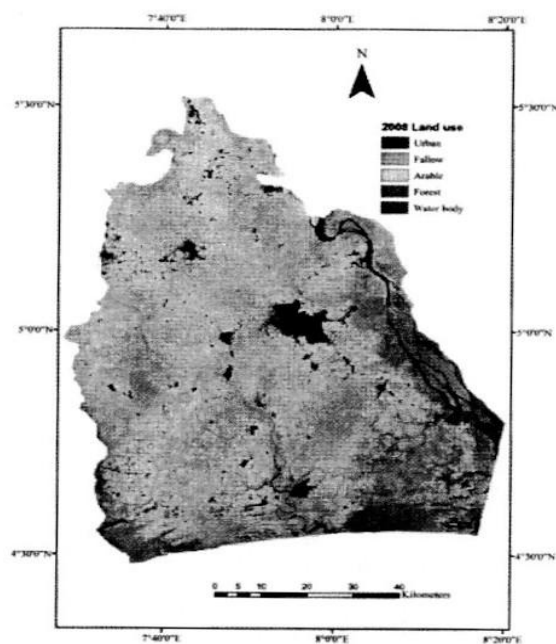


Fig. 6: Land use and land cover classes of Akwalbom State in 2008

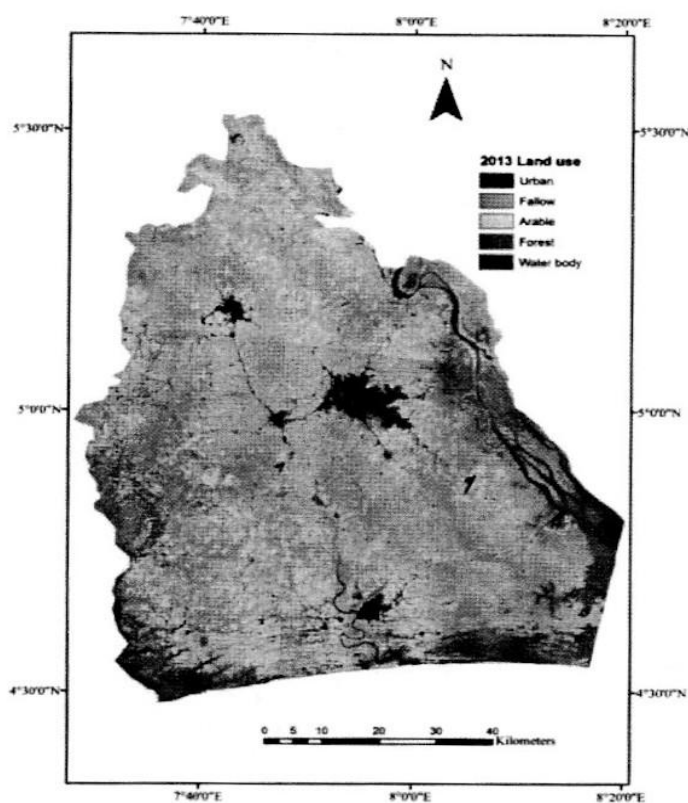


Fig. 7: Land use and land cover classes of Akwalbom State in 2013



#### **4 Result and Discussion**

##### ***Land use and land cover changes on different suitability units***

The spatial coverage of different land use and land cover types classified in the study area was as presented in Tables 1 - 5. The study revealed that in 1986 approximately 21.3%, 37.9%, 27.0% and 10.62% were forest, fallow, farmland and urban land use respectively and the rest were water. Subsequently, between 2003 and 2013 fallow and farm land use increased progressively to 41.9% and 30.5%, 44.5% and 35.5% respectively. Four suitability units were classified in the moderately suitable class which was the highest found in the study area. They include S2mn, S2n, S2dh and S2ten and cumulatively occupied approximately 68.1% of the State. The marginally suitable units include S3fdh and S3tmne which occupied approximately 20.8%. These imply that approximately 90% of the State is suitable (i.e. either moderately or marginally) for arable crop production with different degrees of limitations or constraints.

The spatial coverage of the different land units presented in Tables 1 to 5 indicated there was progressive reduction in the forest land use. There was also interchange between fallow and farm land use and progressive increase in size. Progressive increase in spatial coverage between 1986 and 2013 was also observed in urban as recorded in arable land use. These were indications that losses experienced in forest manifest in increases in arable while losses in arable translated to gains in urban land use. The assumed zero level of infrastructural development refers to period that has not manifested the effect of State creation. Normally creation of State is characterized by rapid infrastructural development which is an incentive for population growth as a result of migration especially to the Capital City.

It was equally observed that locations classified as presently not suitable (N1) and not relevant (NR) as a result of inundation of water at different intensities are currently minimally, but progressively under fallow, farm and urban land uses. The relative spatial coverage of arable land use in the study area is estimated as its extent in relation to others within a single suitability unit. Apart from S2fn that had relative spatial coverage of less than 60 percent from 1986 to 2008, which subsequently increased to 70% in 2013, the arable land use in the various moderately suitable units had relative spatial coverage that increased from approximately 74% in 1986 to 94% in 2013 (Fig. 10). In the marginally suitable units, the relative spatial coverage of S3tmne and S3fdh increased continuously from 55% to 79% and from 71% to 91% respectively between 1986 and 2013. This indicates extensification in agricultural practice even within locations with low capacity for crop production and high tendency for land degradation due to the unsustainable condition of the land as evaluated.

**Table 1: Distribution of land uses (hectares) on the suitability classes in AkwaIbom State in 1986**

| Landuse | N1       | NR       | S2fn     | S2mn     | S2n      | S2dh     | 2Sten    | 3Sfdh    | S3tmne   | Total     |
|---------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|
| Water   | 3554.264 | 16546.56 | 1648.434 | 807.06   | 669.0725 | 1.903115 | 0.777492 | 2472.169 | 6.243145 | 25706.49  |
| Forest  | 17707.54 | 39743.36 | 20588.98 | 31040.49 | 18896.53 | 2938.943 | 3877.098 | 38729.14 | 6679.434 | 180201.52 |
| Fallow  | 4455.946 | 5489.93  | 20697.51 | 113405.1 | 88268.55 | 7452.424 | 15736.14 | 37352.03 | 26066.15 | 318923.79 |
| Farm    | 1497.148 | 2702.957 | 8509.674 | 90844.4  | 66047.92 | 2854.533 | 12467.21 | 23875.49 | 18208.17 | 227007.50 |
| Urban   | 766.5724 | 1359.752 | 3240.865 | 36263.03 | 21504.58 | 746.404  | 4281.312 | 9779.841 | 11418.34 | 89360.70  |
| Total   | 27981.48 | 65842.57 | 54685.46 | 272360.1 | 195386.6 | 13994.21 | 36362.54 | 112208.7 | 62378.34 | 841200.00 |

**Table 2: Distribution of land uses (hectares) on the suitability classes in AkwaIbom State in 2003**

| Land use | N1       | NR       | S2fn     | S2mn     | S2n      | S2dh     | 2Sten    | 3Sfdh    | S3tmne   | Total     |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|
| Water    | 2960.318 | 17040.42 | 2068.523 | 1046.179 | 798.4147 | 2.44852  | 1.346106 | 2603.218 | 9.42274  | 26530.29  |
| Forest   | 18476.34 | 38633.31 | 20670.53 | 35473.77 | 24642.26 | 3006.132 | 5370.196 | 42765.87 | 8457.431 | 197495.85 |
| Fallow   | 4042.727 | 6334.727 | 20448.52 | 129393.9 | 96301.76 | 7485.16  | 17526.84 | 39680.12 | 31574.31 | 352788.01 |
| Farm     | 2419.544 | 3704.831 | 11151.73 | 103184.4 | 72159.94 | 3423.588 | 13092.54 | 26311.69 | 21271.21 | 256719.46 |
| Urban    | 82.56502 | 129.261  | 346.1464 | 3261.893 | 1484.267 | 76.89048 | 371.618  | 847.7565 | 1065.965 | 7666.36   |
| Total    | 27981.5  | 65842.55 | 54685.45 | 272360.1 | 195386.6 | 13994.22 | 36362.54 | 112208.7 | 62378.34 | 841200.00 |

**Table 3: Distribution of land uses (hectares) on the suitability classes in AkwaIbom State in 2007**

| Land use | N1       | NR       | S2fn     | S2mn     | S2n      | S2dh     | 2Sten    | 3Sfdh    | S3tmne   | Total     |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|
| Water    | 2959.611 | 16902    | 1628.602 | 1156.073 | 780.7529 | 2.297663 | 1.903115 | 2029.521 | 8.076634 | 25468.8   |
| Forest   | 15251.08 | 26307.72 | 22817.41 | 40928.59 | 44161.97 | 64.1489  | 643.4385 | 30709.16 | 2359.085 | 183242.6  |
| Fallow   | 4977.585 | 14886.93 | 17391.01 | 119300.4 | 91519.69 | 6949.027 | 14077.78 | 49495.26 | 31752.37 | 350350.1  |
| Farm     | 3755.693 | 5257.749 | 11032.57 | 98363.57 | 55505.53 | 6176.71  | 20287.52 | 24872.09 | 23383.98 | 248635.4  |
| Urban    | 1037.523 | 2488.149 | 1815.862 | 12611.41 | 3418.691 | 802.0237 | 1351.908 | 5102.611 | 4874.806 | 33503.0   |
| Total    | 27981.49 | 65842.55 | 54685.45 | 272360.1 | 195386.6 | 13994.21 | 36362.55 | 112208.6 | 62378.32 | 841200.00 |

**Table 4: Distribution of land uses (hectares) on the suitability classes in AkwaIbom State in 2008**

| Land use | N1       | NR       | S2fn     | S2mn     | S2n      | S2dh     | 2Sten    | 3Sfdh    | S3tmne   | Total     |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|
| Water    | 3406.367 | 13014    | 1739.052 | 1113.636 | 748.8641 | 2.193224 | 1.601402 | 2045.547 | 7.50802  | 22078.767 |
| Forest   | 12150.68 | 20823.04 | 16852.38 | 22541.91 | 22853.9  | 181.7475 | 659.2088 | 20845.92 | 1600.125 | 118508.92 |
| Fallow   | 5420.953 | 20638.99 | 19332.24 | 102129   | 90130.41 | 4019.518 | 9673.777 | 50332.6  | 23385.81 | 325063.29 |
| Farm     | 4757.184 | 7030.35  | 13379.57 | 126305.2 | 74162.6  | 8927.338 | 23544.22 | 31854.67 | 30776.3  | 320737.4  |
| Urban    | 2246.302 | 4336.166 | 3382.207 | 20270.39 | 7490.869 | 863.434  | 2483.727 | 7129.927 | 6608.59  | 54811.613 |
| Total    | 27981.49 | 65842.54 | 54685.45 | 272360.1 | 195386.6 | 13994.23 | 36362.54 | 112208.7 | 62378.34 | 841200.00 |

**Table 5: Distribution of land uses (hectares) on the suitability classes in AkwaIbom State in 2013**

| Land use | N1       | NR       | S2fn     | S2mn     | S2n      | S2dh     | 2Sten    | 3Sfdh    | S3tmne   | Total     |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|
| Water    | 3507.325 | 15429.45 | 1784.878 | 964.5659 | 816.0069 | 2.436915 | 1.380919 | 2177.778 | 7.937382 | 24691.756 |
| Forest   | 13044.58 | 17283.02 | 10191.99 | 26137.64 | 22760.41 | 216.6766 | 579.0923 | 17199.32 | 1298.214 | 108710.94 |
| Fallow   | 5005.285 | 26017.36 | 25082.08 | 121243.6 | 90994.97 | 8195.277 | 15087.73 | 54795.33 | 27700.26 | 374121.86 |
| Farm     | 4668.028 | 5981.339 | 15953.26 | 108653.8 | 76238.06 | 4899.685 | 20116.81 | 33466.51 | 28778.21 | 298755.74 |
| Urban    | 1756.262 | 1131.402 | 1673.256 | 15360.47 | 4577.189 | 680.1431 | 577.5374 | 4569.739 | 4593.725 | 34919.722 |
| Total    | 27981.48 | 65842.57 | 54685.46 | 272360.1 | 195386.6 | 13994.22 | 36362.55 | 112208.7 | 62378.34 | 841200.00 |

**Per capita arable land on the different land suitability units**

The land suitability units within which the highest concentration of people were found included S2mn (41.2%), S2n (20.4%) and S3dfh (20.4%) accounting for approximately 82% of the population of the Akwalbom State (Table 6). These are equally land suitability units that had the highest spatial coverage of urban land use and highest relative spatial coverage of arable land use. Additionally, these are locations that enjoy the highest concentration of development (such as urbanization) process in the State. The per capita arable land (i.e. arable land in hectare per person) is the total spatial coverage of arable land use per person within an area with definite territorial or defined boundaries. The per capita arable land of Akwalbom State in 1986 (i.e. before the creation of the State in 1987 or at zero period of infrastructural development) was approximately 0.22 hectare per person and decreased progressively to 0.16, 0.13, 0.13 and 0.11 ha per person in 2003, 2007, 2008 and 2013 respectively (Fig.8). These changes translated as shown in Table 7 to approximately 0.06 ha per person loss between 1986 and 2003 (i.e. 0.0036 ha per person per annum), 0.035, 0.040 and 0.016 ha per person between 2003 and 2007, 2003 and 2008, 2008 and 2013 respectively (i.e. 0.0088, 0.0059 and 0.0032 ha per person per annum respectively).

**Table 6: Distribution of population on the different land suitability classes between 1986 and 2013 in Akwalbom State**

| LSC    | Years   |         |         |         |         |
|--------|---------|---------|---------|---------|---------|
|        | 1986    | 2003    | 2007    | 2008    | 2013    |
| N1     | 24190   | 37196   | 46608   | 48181   | 56948   |
| NR     | 57982   | 88190   | 110446  | 114238  | 135024  |
| S2fn   | 86731   | 139210  | 174428  | 180325  | 213137  |
| S2mn   | 864596  | 1323205 | 1657656 | 1714015 | 2025898 |
| S2n    | 429288  | 657854  | 824187  | 852152  | 1007210 |
| S2dh   | 6508    | 10067   | 12618   | 13040   | 15413   |
| S2ten  | 55141   | 84555   | 105938  | 109528  | 129458  |
| S3dfh  | 428297  | 653236  | 818204  | 846171  | 1000140 |
| S3tmne | 147832  | 227159  | 284633  | 294250  | 347792  |
| Total  | 2100565 | 3220671 | 4034719 | 4171901 | 4931020 |

**Table 7: Change in the arable land in hectare per person between 1986 and 2013 in Akwalbom State**

| Period    | Arable land (ha) per person |                  |
|-----------|-----------------------------|------------------|
|           | Cumulative change           | Change per annum |
| 1986-2003 | 0.0609                      | -0.0036          |
| 2003-2007 | 0.0352                      | -0.0088          |
| 2003-2008 | 0.0297                      | -0.0059          |
| 2008-2013 | 0.0158                      | -0.0032          |

The distribution of arable land in hectare per person among the various land suitability units shown in Fig. 9 revealed that apart from NR characterized with preponderance of water that had 0.12 hectare per person in the base year (1986) which increased to 0.20, others manifested decreases. The location that experiences lower



inundation such as N1 compared to NR manifested decreases in per hectare arable land per person from 0.21 in 1986 to 0.15 in 2013. The highest arable land per person was found in the moderately arable suitability class within the study area. Their arable land per person in decreasing order was S2dh, S2ten, S2n, S2fn and S2mn with 1.36, 0.44, 0.31, 0.29 and 0.20 respectively in 1986 which decrease progressively over the years to 0.73, 0.23, 0.14, 0.17 and 0.10 respectively in 2013 at similar rates. The locations that corresponded to marginally suitable class equally had 0.12 and 0.26 arable land per person in 1986 respectively for S3fdh and S3tmne which decreased respectively to 0.08 and 0.14 in 2013 (Fig. 11).

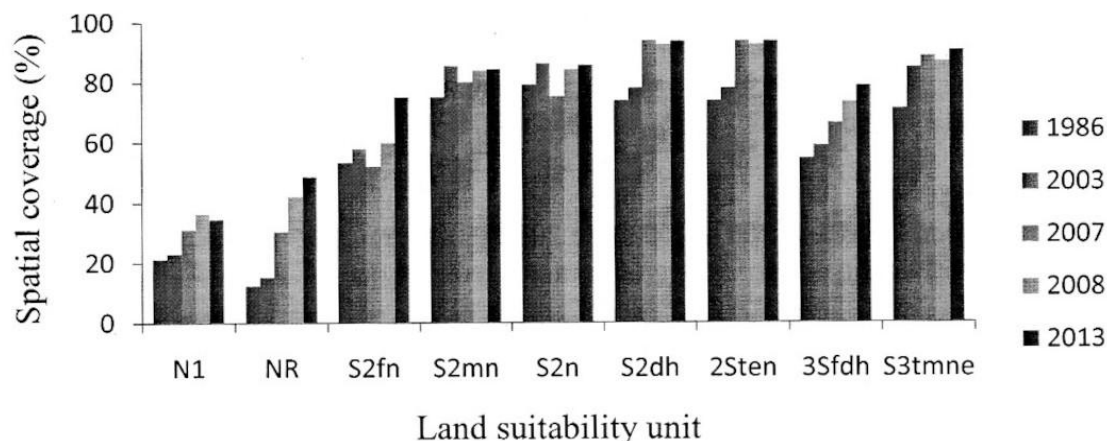


Fig. 8: Spatial coverage of arable land use in the various land suitability units

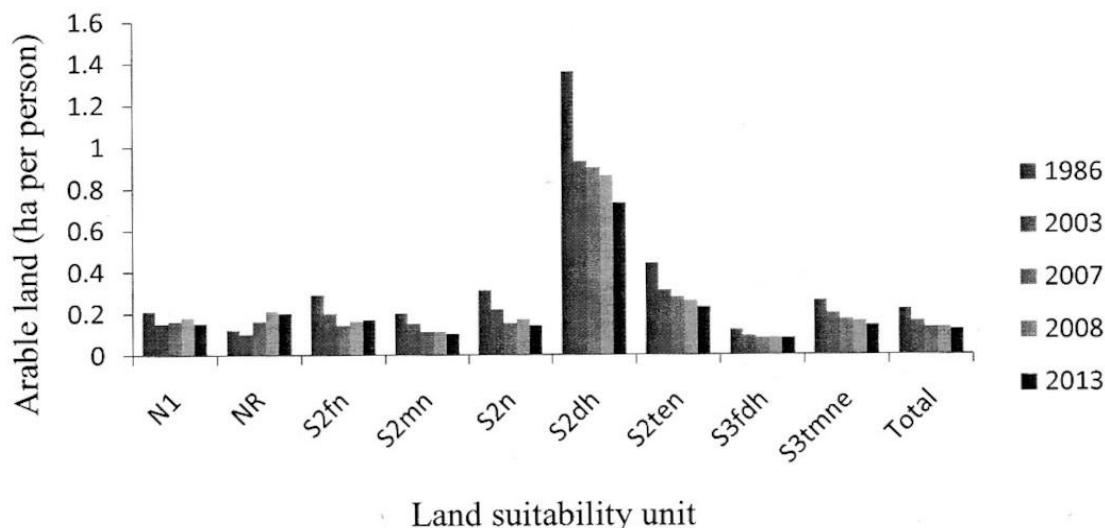


Fig 9: Distribution of arable land in hectares per person for different land suitability units between 1986 and 2013 in Akwalbom State

#### ***Trends in land use and cover changes***

The comparison of spatial coverage of fallow and farmland uses within the study area from 1986 to 2003 and from 2003 to 2013 (i.e. 17 and 10 years interval respectively), revealed that there was increases of 4.0% and 6.6% for fallow and 2.5% and 8.5% for arable land use, implying that higher increment was recorded in farmland

use compared to fallow. This indicated a progressive increase in allocation to farmland use with time (Udoh *et al.*, 2011) without commensurate increase in length of fallow period (Ogban *et al.*, 2004 and 2005) and adequate fertilizer application to increase yield (Etimet *et al.*, 2013; Basseyet *et al.*, 2015), and the consequence is land degradation (Obi, 2000). Ituen (2015) using area-specific change detection procedure (point-by-point) in the study area between 1986 and 2003 reported interchange between fallow, farmland and urban use and progressive increase in spatial coverage, and that losses in forest were increases in arable while losses in arable translated to gains in urban land use.

### ***Suitability units and changes in land use and cover***

Limitations or constraints notwithstanding, approximately 90% of the study area were assessed either moderately or marginally suitable for sustainable arable crop production. Major caveats are associated with the geomorphology of the State. The moderately suitable units found to possess the largest extent of arable and urban land uses was found on gently undulating coastal plain sands (guCPS) that covers approximately 51% of the study area. The major factor that attracts urban land use is the gentle undulating nature of the terrain. Uyo capital territory falls within guCPS geomorphic unit and thus provides major attraction for population increase and urban sprawl (Chen, 2007; Thuo, 2010). Udoh and Essien (2015) reported that ecological zone and such ecological variables as rainfall, nature of terrain and distance from Local government headquarters significantly influence urban sprawl and development in Akwa Ibom State.

The process of urbanization is responsible for reduction in the spatial coverage of urban land uses in locations that has geomorphic characteristics associated with hydromorphism, topographic constraints and inundation. These conditions were found in different degrees in N1, NR, S2dh, S2ten, S3fdh and S3tmne. Meanwhile, Udoh and Essien (2015) reported that the characteristic of mangrove mudflat (N1) and alluvial (S3dfh) geomorphic units are unsuitable for human habitation as the poorest housing condition would be encountered in such units. The implication is that apart from S2fn, S2mn and S2n, other locations possess the conditions that are not suitable for human habitation. Therefore geomorphology and development are responsible for concentration of approximately 62.4% of the population within approximately 55.6% (i.e. S2n and S2mn) of the land of the State. Yet the loss in arable land is very minimal compared with the accompanying increase in population. Chen (2007) had already reported that conversion to urban and industrial uses in China took up a comparatively small share of total cultivated land loss. Yet, urbanization should still be considered as a great threat to future agricultural production for several reasons including land degradation, waste disposal and pollution (Atser and Ofem, 2014).

### ***Development, arable land use and food sufficiency***

Development that affects ecological dynamics of an environment could be a remarkable transformation that involves interchange of land uses and accompanying modifications of ecosystem processes. The transformation process originated from many decentralized and local interactions that occur in real time with consequent changes within a complex dynamic system involving social, political, economic, demographic, technological, cultural, and biophysical processes. The result is existence of new forms of environment through ongoing processes intrinsic to the system (i.e. degradation in a negative dimension). Naturally complex systems exhibit coherent behaviours generated

in the relationships between components, constraints and the environment and no single element has causal priority. When such complex systems self-organize, they are characterized by the relative stability (aggradations) or instability (degradation) of their states. Development can be envisioned, as a series of evolving and dissolving patterns of varying dynamic stability, rather than an inevitable march towards maturity. These complex events of dynamic environmental systems exhibit changes which occur over different time scales (nested timescales).

The population of the study area increased by 57.4% between 1986 and 2013 within a definite spatial area that does not have capacity to increase and the inherent resources are non renewable. These resulted in the reduction of per capita arable land from 0.22 to 0.11 ha per person (i.e. 52.4%) within the same period. The world and Nigeria arable land in hectare per person was estimated to be 0.20 and 0.21 respectively in 2012 which is comparable with the study area's 1986 rating which has decreased by approximately 50 per cent in 27 years (i.e. 1986 – 2013). The implication is that with the current trend, within the next 27 years arable land in hectare per person would have decreased with another 50% assuming that population would have more than doubled. Considering the rate of decrease in arable land per person per annum, it was observed that within the 27 year intervals (between 1986 and 2013) that the decrease of arable land per person per annum is approximately 0.005 indicating that in approximately 20.5 years (2036) the rate of available arable land within the study area will be 0.00487 ha per person. Perspective of decreasing length of fallow period (Ogbanet *al.*, 2005) due to extensification (Udohet *al.*, 2011), nutrient mining effect of intensification (Udoh, 2011; Ibia, 2012), low efficiency of resources (Etimet *al.*, 2013; Basseyet *al.*, 2015) and commensurate low output of low input system (Obi and Udoh, 2011) presents grim future in food production and sufficiency. This future appears even more severe if the present scenario is compared with the projection for annual world agricultural production with anticipated increase of approximately 60 percent between 2005 and 2050 consisting of a 77 percent increase in developing and 24 percent in developed countries (Alexandratos and Bruinsma, 2012).

### ***Urbanization, land scarcity and environmental sustainability***

Although urbanization is not directly implicated as a major source of land scarcity within the study area, it is still inexorable as a major contributor to land degradation, environmental and soil quality deterioration. For instance in Akwa Ibom State, torrential rainfall is experienced for up to 8 months within a year, which far exceeds infiltration rate and results in surface or overflow (Obi, *et al.*, 2014), weak structural stability of soils (Ogbanet *al.*, 2013) and high erosivity (Nwaukwa and Udosen, 2007) which predisposes the environment to high rate of erosion and preponderance of gullies. The number and size of gullies have been reported to increase as urbanization increases (Udosen, 2014).

The continuous increase in the proportion of urban population and associated livelihood pattern results to commensurate increase in the proportion of both domestic and industrial waste and problems associated with their disposal especially in an improperly planned development with weak or nonexistent environmental laws and policies. Urban solid waste constitutes a major environmental problem not just because of its ever-growing volume but also because of the treat its improper handling and disposal poses to human health. Leachates from municipal solid waste generally contain such heavy metals as cadmium, copper, zinc and nickel in concentrations that are deleterious



to biota and human life (Udosenet *al.*, 2012, Mbonget *al.*, 2014). They constitute a problem because they are not usually eliminated from the ecosystem by natural processes and they are rich in minerals and organic substances. The greater problem however arises when leachates from refuse dumps find their way to the underground water system. Aster and Ofem (2014) reported that the concentration of heavy metals from municipal solid waste on vegetables and soil samples within Uyo, were at hazardous levels. This is with the consideration of growing importance of urban agriculture and temptation to exploit the high quantity of readily and freely available organic matter content of the wastes.

## **5. Conclusion**

The per capita arable land decreased from approximately 0.22 to 0.11 ha per person between 1986 and 2013. Point-by-point change detection revealed interchange between fallow, farmland and urban use and progressive increases in spatial coverage. It was also found that the losses in forest land use were increases in arable while losses in arable translated to gains in urban land use. The rate of gain in urban land use is not significant to be regarded as major constraint to food production but rather for sustainability of the environment. Geomorphology and development are responsible for concentration of approximately 62.4% of the population within approximately 55.6% (i.e. S2n and S2mn) of the land of the State. Considering the current rate of decrease, it was predicted that by 2036 the availability rate of arable land will be 0.00487 per ha per person which suggests that the reality of food sufficiency is becoming more elusive and the problems of erosion and pollution associated with urbanization will increase.

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