Biofuel Production Induced Land-use Land-cover Change in Selected Geopolitical Zones of Nigeria

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Abstract

Biofuel production activities have been reported in Nigeria but with not much focus on the environmental impacts. The study was restricted to three geographical zones of Nigeria where industrial-scale biofuel production activities have been reported. An *in-situ* visit to each zone was used to select the Area of Interest (AoI), which comprised of an industrial-scale production activity and its environment. The AoI was clipped on Landsat 2006 and NigeriaSat-X 2012 images. The feature space of the AoI was classified into the different land use and land cover classes to derive the change statistics. Changes in the vegetation density of the AoI were also carried out. The results showed increased human presence and decreased vegetation in the three zones, while there was an increase in the area occupied by farm land or cultivated areas and bare ground. The study concluded on the need for an early monitoring of the biofuel production activities in Nigeria so that the country can maximize the benefits.

Keywords: biofuel, classification, environmental impact, NDVI, satellite images

1. Introduction

Human-induced environmental changes are of concern today because of the deterioration of the environment and impact on human health (Jat et al., 2008). The overexploitation of land resources through deforestation, pollution, increases in population and land degradation pose additional threats to the environment. According to IPCC (2007), human activities remain the topmost drivers of increased atmospheric concentration of CO₂ over time and further warned of a temperature increase of over 2°C. In particular, impacts of biofuel feedstock production on land include direct and indirect land use change and the displacement of food production (Pena et al. 2011). The focus on LULC studies by several researchers (El-Raey et al. 2000; Hathout, 2002; Sudhira et. al., 2004; Martinuzzi et. al., 2007) is because of their adverse effects on the ecology of an area and vegetation. In Asia, the assessment of the effects of biofuel feedstock expansion on forests showed an estimated 59 and 56 % of oil palm expansion in Malaysia and Indonesia respectively (Koh & Wilcove, 2008). This leads to a secondary impact in reduction of species richness and in the prevalence of species of high conservation value (Fitzherbert et. al., 2008). Even with the scarcity of data on biofuel activities in Africa, a few documented reports have shown impact on forested land for feedstock plantation development (ABN, 2007; Nhantumbo & Salomao, 2010; Mortimer, 2011). As biofuel production activities increase, more forested land will be cleared to meet the various national biofuel production and fossil fuels blending targets. A study on Brazil revealed that for the country to meet its 2020 biodiesel consumption target, an additional 10.8 million hectares (ha) of land would be cleared to cultivate soy (Lapola et. al., 2010). Therefore, the study of land-use/land-cover (LULC) changes becomes very important in order to have proper planning and utilization of natural resources and their management (Asselman & Middelkoop, 1995).

In 2007, Nigeria took a major step towards developing and implementing a national biofuel programme as part of other efforts to tap into the benefits of biofuel production (NNPC, 2007). Biofuel production-induced changes in land use and land cover impact local livelihood, land access and ownership (Friis & Reenberg, 2010), food provisioning and pricing (Rathmann et al., 2009; Ewing & Msangi, 2009). There are reports of biofuel

production in some geopolitical zones of Nigeria (Agba et al., 2010; Izah & Ohimain, 2013), but limited data exist to demonstrate the implications on the LULC and vegetation change. This study aimed to assess the LULC and vegetation changes of the surrounding environment of an industrial-scale production activity in selected zones of Nigeria. The period of assessment covered a year before and five years after the introduction of the national biofuel policy in 2007. In multi-complex environmental studies, the conventional methods for gathering data and analysis are often inadequate (Maktav et. al., 2005). This is so because many problems in environmental issues often present great complexity in handling the associated multidisciplinary datasets. Therefore, this study made use of remote sensing and geographic information system (GIS) tools, relevant for analyzing and understanding the Earth's spatio-temporal physical processes (Hudak & Wessman, 1998).

2. Biofuel Production and Landuse/ Landcover Change

The penetration of biofuel feedstock into rural communities and forested landscapes in many poor countries is due to the embracement of biofuel production by government as a means of developing the rural economy (Andrade & Miccolis, 2010). Much of the land use change is attributed to the developing countries where governance is weak; and large tracts of land could be accessed at much lower cost (Mathews, 2007), with little or no regard to the people or environment. These are believed to have placed biofuel firmly on the map of global land use change. The geo-spatial data processing requirements include geometric/radiometric corrections, data normalization, image enhancement, image classification and classification accuracy assessment (Lunetta & Elvidge, 1998). Accurate classifications are imperative to guarantee precise change-detection results. Accuracy assessment was critical for a map generated from any remote sensing data. Error matrix is the most common way to present the accuracy of the classification results (Fan et al., 2007). Overall accuracy, user's and producer's accuracies, and the Kappa statistic are derived from the error matrices. The Kappa statistic incorporates the off-diagonal elements of the error matrices and represents agreement obtained after removing the proportion of agreement that could be expected to occur by chance (Yuan et al., 2005).

Within the operational sector of biofuel production, a number of rules, standards and certifications exist to streamline activities along the line of best practices. A number of initiatives are reported to be developing criteria and indicators for biofuel certification (Vis et al. 2008; Woods & Diaz-Chavez, 2007). Few among them include the Roundtable on Sustainable Palm Oil (RSPO) and Forest Stewardship Council (FSC). The standards are made up of varying sets of Principles that spell out exhaustive thematic areas of attention and accompanying sets of Criteria that explains how the themes under the Principles will be achieved. However, the one specific to biofuel production is the Roundtable on Sustainable Biofuel (RSB).

2.1 Roundtable on Sustainable Biofuel

The Roundtable on Sustainable Biofuel (RSB) is an international, multi-stakeholder initiative that was established in 2006 to achieve global consensus around a set of principles and criteria for sustainable liquid biofuel feedstock production, processing and biofuel transportation/distribution (http://rsb.epfl.ch/). The first draft copy of RSB containing the principles for sustainable biofuel production, first published in 2007 passed through a revision by a Working Group made up of stakeholders, consequent upon which the criteria for achieving the principles were suggested. Following other stakeholders' consultations on the draft Principles and Criteria, the RSB released 'Version Zero' in 2008, which went through field testing and pilot projects in 2009 before receiving the RSB Steering Board's validation into operational Version 2.0 of the RSB Standard (Ismail et al., 2011). The RSB Standard fully operates as biofuel certification standard and it is made up of Principles and Criteria with associated guidance document, detailed compliance indicators and the glossary of terms. The RSB Standard revolves around the following twelve principles: Legality; Planning, Monitoring and Continuous Improvement; Greenhouse Gas Emissions; Human and Labor Rights; Rural and Social Development; Local Food Security; Conservation; Soil; Water; Air; Use of Technology, Inputs and Management of Waste; and Land Rights. The criteria on the other hand spell out the direct activities that farmers and producers can undertake to prevent unintended backlashes arising from biofuel production. Within the purview of the RSB Standard, the four operators identified in biofuel production are the Feedstock Producers, Feedstock Processors, Biofuel Producers and Biofuel Blenders, with each operator falling under different sustainability requirements.

Other initiatives include the Roundtable on Sustainable Palm Oil (RSPO), the Roundtable on Responsible Soy (RTRS), the Better Sugar Cane Initiative (BSI) and the Sustainable Agriculture Network (SAN). Though not focused specifically on biofuel, a number of agricultural land forestry standards have also been developed, including Good Agricultural Practices (GAP), Forest Stewardship Council (FSC) and Fairtrade (Harrison et al., 2010, Cushion et al., 2010), as well as national guidelines on how agriculture, knowledge, science and technology can ensure future food production and sustainable agricultural systems (IAASTD 2008).

2.2 Environmental Impacts of Biofuel Production

Several doubts have been raised as to whether biofuel were really as GHG-friendly or-neutral as they were initially claimed to be (Achten et al., 2008; Plevin et al., 2010; Lapola et al., 2010). Biofuel may result in multiple negative consequences including deforestation, uncertain economic benefits, land speculation, and land expropriation. Forest conversion and plantation development as currently practiced are considered significant sources of green house gas (GHG) emissions (German et al., 2011). Reijnders and Huijbregts (2008) posited that the biofuel capacity for GHG emission reduction may not be easily assumed given the potentially significant GHG emissions from land use change, fossil fuel usage, both in cropping and processing and marketing associated with biofuel feedstock cultivation. Palm oil plantations established on former tropical forest lands in Malaysia and Indonesia would need to run for over 300 years for the initial carbon debt to be repaid (Fargione et al., 2008). In Southeast Asia, palm oil is the leading vegetable oil (Carter et al., 2007) and its industrial plantations are believed to become a key driver of deforestation in a future when tightening climate policies push up the demand for bioenergy and biofuel go up (Persson & Azar, 2010). While feedstock plantations, such as palm-based, can play an important role in mitigating climate change, providing alternative sources of energy, and contributing to economic development and poverty alleviation; there are unintended social, economic and environment implications. Whether biofuel production reduces or increases emissions will depend on the production pathway, as under certain production pathway scenarios, biofuel production could lead to increase in emission rather than its reduction (Searchinger et al., 2008; Plevin & Mueller 2008). The potential of biofuel cutting down on emissions is an impetus for a supportive policy for sustainable biofuel activities in Nigeria and that which will enjoy a widespread public support.

3. Methods

3.1 The Study Area

Nigeria's territorial boundary is divided into six geo-political zones out of which biofuel production had been reported in some local communities of three - namely, the South West, North Central and North West (Highina et. al., 2011; Oshewolo, 2012). The South West zone lies between Longitude 2° 31' and 6° 00' E and Latitude 6° 21' and 8° 37' N. The mean monthly temperature ranges from 18 to 35 °C depending on whether it is wet or dry season (Shaib et al., 1997), while the annual rainfall ranges between 1500 mm and 3000 mm. The vegetation is of fresh water swamp and mangrove forest, lowland forest and derived and southern Savannah towards the northern boundary. The North Central zone extends roughly from Longitude 7° 30' and 10° 00' E and Latitude 6° 50' and 9° 30' N (Falaki et. al., 2013). It is an ecological transition zone between the arid north and the moist south with temperature fluctuating between 18 - 37 °C while rainfall ranges annually from 1000 mm to 1500 mm. The main occupation of the people is predominantly rain-fed agriculture. The area boasts of one of the longest stretches of river systems in the country with great potential for a viable fishing industry and dry season farming through irrigation. The North West zone lies between Longitudes 4° 8' and 6° 54' E and Latitudes 10° 00' and 13° 58' N. The climate of the zone is controlled largely by the dry and dusty air mass originating from the Sahara desert, and the warm air mass originating from the Atlantic Ocean. The temperature is between 35 and 45 °C. The rainy season starts about mid-May in the south and about mid-June in the northern districts; and ends about late September in the northern districts and early October in the southern districts.

3.2 Data Analysis

The data used are 30m spatial resolution bands 3, 4 and 5 of Landsat Enhanced Thematic Mapper (ETM+) 2006 imageries, with Path 191/Row 055 for South West; Path 190/Row 054 for North Central; and, Path 188/Row 052 for North West; 22m resolution NigeriaSat-X colour composite for South West; North Central; North West; and the Global Positioning System (GPS) data of the production activities and the surrounding bio-physical features. Due to the problem associated with cloud in optical satellite sensors data capture (Globus *et al.*, 2003), which renders observation useless (He & He, 2013), only the dry season imageries, with less cloud effect were acquired. The Landsat and SRTM DEM data were downloaded from www.landcover.org/, while the NigeriaSat-X imagery was obtained from the National Space Research and Development Agency (NASRDA), Abuja. The area around one commercial-scale production activity in each of the three zones was selected. The Area of Interest (AoI) for each zone was defined and clipped on the multi-date Landsat and NigeriaSat-X imageries. The NigeriaSat-X imagery was resampled to the same pixel size (30 m) as the Landsat imagery. Field information about previous land cover, cultural land use system in the respective AoI and the GPS points of features acquired around each of the selected activities were used to determine the thematic classes; identify the corresponding spectral signatures on the imageries; and generate the training sites. The maximum likelihood classification algorithm was used for supervised classification of the AoI for each of the three zones to produce the LULC multi-date maps. Image

classification accuracy and error matrix evaluations were performed using randomly sampled 256 points from the reference image to estimate the mean accuracy (Congalton, 1991). The change statistics, accuracy assessment report and Kappa statistics for each sub-map were calculated according to German et al. (2011). The vegetation density mapping was carried out using the Normalized Differential Vegetation Index (NDVI) in Erdas Imagine 9.2 remote sensing software package. The relevant bands for the NDVI analysis were the visible red (620–670 nm) and NIR (841–876 nm) of the multi-date imageries using the formula:

NDVI = (NIR-R) / (NIR+R) ... (Wardlow et al., 2007; Sahebjalal & Dashtekian, 2013).

Where NIR represents the spectral reflectance in near infrared band and R represents red band. The LULC and vegetation density Maps will be produced in ArcGIS 10.3 software package.

4. Results and Discussion

4.1 Land Use/Land Cover Change Analyses

The results of the LULC change classification analysis (Figures 1 to 6) in the three zones are summarized in Tables 1, 2 and 3 respectively. The land area covered under the classification was 11097.00 ha for the Allied Atlantic Distillery Limited; 11913.30 ha for Eco Afrique Farms; and, 17041.32 ha for Hafiz Ringim Farm. Around the activities of the AADL between 2006 and 2012 (Table 1), a high increase of 36.99 % was recorded for built up, which signifies an upsurge in human presence. This may have been responsible for the observed deforestation (-7.65 %), resulting to increases in areas of low vegetation cover (4.87 %) and farmland (17.72 %). The reduction in the area cover by bare ground (-24.77 %) could have been partly taken over by built up, farmland and low vegetation, which were observed to have increased during the years under review. Area covered by water with vegetated surface or wetland, also recorded an increase of 4.58 %. This increase may not be unconnected with the peculiar climatic condition of the area that is characterized with the presence of large bodies of water in the nearby Lagos and Badagry outside other smaller water bodies dotting the landscape. In Table 2, the area covered by built up increased by 33.68 % and at an annual rate of 5.61 % between. The increase in built up, which indicated an increase in human population and by implication, other associated human activities around Eco Afrique Farms Limited may have been part of the factors responsible for the decrease in the area covered by vegetation (-10.11 %). Vegetation loss in and around Eco Afrique was observed from the result to have decreased at an annual rate of -1.69 %. Increase in human population and the observed decrease in vegetal cover of the area may have been responsible for the increase observed in the area covered by Farmland (5.11 %); and consequently, the decrease in the area covered by bare surface (-12.12 %) as they may have been taken over for farming purposes. The increase in the area covered by water (97.89 %) between 2006 and 2012 could be attributed to the flooding event of 2012 that inundated the major water bodies in that ecological-zone.

The results of the LULC change statistical analysis for the area around the Hafiz Ringim Farm, shows in Table 3 that the built up theme was made up of both the major/minor settlements as observed during the field survey. The result shows a minor increase (0.68 %) in the area covered by the major settlement from 2006 to 2012 representing an annual rate of 1.10 %, compared to the increase in area covered by minor settlements (175.2 %) and at an annual rate of 29.20 %. Minor settlements in this study area include unplanned urban-sprawl areas, other smaller communities of locals, make-shift habitations of migrant farmers and herdsmen, and farm settlements. The result showed a decrease in the area covered by water (-22.95 %), which may be inferred as a plausible reason for the low activity in irrigated farming (-23.96 %); but activities will usually increase during the dry-season to facilitate dry-season farming. Overall, within the same period, farming activities increased, given the increase of 18.30 % in the area engaged for cultivation; and the reduction of 90.92 % in the bare surface may have contributed into the land engaged for farming purposes. This may be because the month of March, for which the NigeriaSat-X image of 2012 used in this analysis was acquired, represents the peak of dry-season farming in the North.



Figure 1. LULC Classification of AADL and Environ in 2006



Figure 2. LULC Classification of AADL and Environ in 2012

	Area Covered		Difference Increase/		Annual	
	(Ha)		(2012-2006)	Decrease	Increase/Decrease	
Land Features	2006	2012	(Ha)	(%)	(%)	
Water	1187.55	1241.91	54.36	4.58	0.76	
Farm Land	2118.87	2494.26	375.39	17.72	2.95	
Forest	2757.06	2546.19	-210.87	-7.65	-1.28	
Bare Ground	2390.58	1798.38	-592.20	-24.77	-4.13	
Low Vegetation	1881.09	1972.62	91.53	4.87	0.81	
Built Up	761.85	1043.64	281.79	36.99	6.17	
TOTAL	11097.00	11097.00				

Table 1. LULC change analysis of the environment of AADL



Figure 3. LULC Classification of Eco Afrique Jatropha Farm and Environ in 2006



Figure 4. LULC Classification of Eco Afrique Jatropha Farm and Environ in 2006

Table 2. LULC change analysis of the environment of Eco Afrique Farm

	Area Covered		Difference	Increase/	Annual
	(Ha)		(2012-2006)	Decrease	Increase/Decrease
Land Features	2006	2012	(Ha)	(%)	(%)
Water Body	200.16	396.09	195.93	97.89	16.32
Vegetation	4046.04	3636.90	-409.14	-10.11	-1.69
Bare Surface	1993.41	1751.76	-241.65	-12.12	-2.02
Farm Land	5095.44	5355.54	260.10	5.11	0.85
Built Up	578.25	773.01	194.76	33.68	5.61
TOTAL	11913.30	11913.30			



Figure 5. LULC Classification of Hafiz Ringim Jatropha Farm and Environ in 2006



Figure 6. LULC Classification of Hafiz Ringim Jatropha Farm and Environ in 2012

	Area Covered		Difference	Increase/	Annual	
	(Ha)		(2012-2006)	Decrease	Increase/Decrease	
Land Features	2006	2012	(Ha)	(%)	(%)	
Major Settlement	161.82	162.92	1.10	0.68	0.11	
Minor Settlement	821.88	2261.56	1439.68	175.17	29.20	
Water Body	1028.61	792.54	-236.07	-22.95	-3.83	
Irrigated Farm	3847.59	2925.62	-921.97	-23.96	-3.99	
Bare Surface	2132.46	193.68	-1938.78	-90.92	-15.15	
Cultivated Area	9048.96	10705.00	1656.04	18.30	3.05	
TOTAL	17041.32	17041.32				

Table 3. LULC	change anal	vsis of the	environment	of Hafiz	Ringim Farm
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4.2 Accuracy Assessment and Error Matrix

The 256 random points generated for the 2006 and 2012 images of the respective zones surveyed were compared with the ground-truth sampled data using the error matrix, to show the accuracy and reliability of the classification. It has been reported that at least 250 reference pixels are needed to estimate the mean accuracy of a class to within plus or minus five percent (Congalton, 1991). The user's and producer's accuracies, as well as the overall accuracy and Kappa statistic for each of the classifications were then derived from the respective error matrices. The computed overall accuracy assessment and specific kappa values of each of the multi-date imageries for each area in the three zones are presented in Table 4. In thematic mapping from remotely sensed data, the term accuracy is an expression of the degree of 'correctness' of a map or classification. Classification accuracy assessment is widely accepted as a fundamental component of thematic mapping investigations (Cihlar, 2000; Justice et al., 2000) and it represents the degree to which a classified image agrees with reality (Smits et al., 1999).

Kappa coefficient is a standard means of assessment of image classification accuracy. Kappa reflects the difference between actual agreement and the agreement expected by chance. Kappa of 0.72 means there is 72 % better agreement than by chance alone. Kappa statistic measures the difference between the true agreement of classified map and chance agreement of random classifier compared to reference data (Lillesand et al., 2004). Therefore, kappa values of more than 0.80 indicate good classification performance, while Kappa values between 0.40 and 0.80 indicate moderate classification performance and Kappa values of less than 0.40 indicate poor classification performance (Lillesand et al., 2004).

erall Classification Accuracy	Overall Kappa Statistics
(%)	
78.13	0.7286
91.80	0.8993
89.06	0.8383
91.80	0.8774
83.17	0.8101
82.64	0.8231
	erall Classification Accuracy (%) 78.13 78.13 91.80 89.06 91.80 83.17 82.64

Table 4. Summaries of the Accuracy Assessment Process of the LULC Classification

4.3 Vegetation Density Mapping

The results of the estimation of the quantity of vegetation around AADL, Eco Afrique and Hafiz Ringim Farms are presented as vegetation density maps in Figures 7 to 12. The NDVI uses the difference between Near

Infrared (NIR) reflectance and red reflectance, which is large for vegetation (with the maximum value of +1) but small (with the minimum value of 1) for other common surface materials. Increasing positive values indicate increasing green vegetation density/vegetated surface, while negative values indicate decreasing green vegetation density/non vegetated surface, such as water, bare land, ice, snow and clouds. Values for AADL, which varied from -0.07 to +0.45 in 2006 and -0.07 to +0.23 in 2012 showed a decrease in the vegetated surface. The values for Eco Afrique Farms Limited varied from -0.09 to +0.46 in 2006 and -0.02 to +0.51 in 2012, revealed an increase in the vegetated area. The values for Hafiz Ringim Farm which varied from -0.36 to +0.55 in 2006 and -0.02 to +0.26 in 2012 showed a decrease in the vegetated area.



Figure 7. Vegetation Density Change map of AADL in 2006



Figure 8. Vegetation Density Change map of AADL in 2012



Figure 9. Vegetation Density Change map of Eco Afrique Farms in 2006



Figure 10. Vegetation Density Change map of Eco Afrique Farms in 2012



Figure 11. Vegetation Density Change map of Hafiz Ringim Farms in 2006



Figure 12. Vegetation Density Change map of Hafiz Ringim Farms in 2012

4.4 Land-use/Land-cover Change

The land use/cover classification maps showed similar land use/cover patterns in the three locations. Information derived from satellite remotely sensed data remains one of the primary sources of knowledge for operational monitoring of vegetative and other forms of land covers (Ardavan et al., 2011). Medium resolution satellite

imageries, such as Landsat images are historically reputed for high quality performance in first level classification system (Anderson, 1976; Sahebjalal & Dashtekian, 2013). First level classification system broadly classify land features into thematic classes as urban/built up, non-urban and water/wetland. Urban/built up comprises of areas of intensive use with much of the land covered by structures. The results of the overall accuracy assessment and Kappa values of the both the Landsat and NigeriaSat-X imageries are very high.

Areas covered by vegetation decreased around AADL in the South West and Eco Afrique Farms in the North Central. The pattern around Hafiz Ringim Farms in the North West further showed peculiar land uses /covers such as irrigation farming and rice paddies, and rampant minor migrant settlements. This is unlike the southern part where agricultural practices are mainly rain-fed and incidents of migrant settlement were not observed.

The analysis also offered an important tool and opportunity for assessing changes that occur within the human-environment system at different spatial and temporal scales (Lambin, 1997), showing the various dimensions of the biofuel producing industries' and human interactions with their immediate environments (Lopez et al., 2001). Areas covered by settlement/built up increased around the biofuel production activities in the three zones, which indicated the effect of the industries and human activities that are reportedly the most important factors in the changing face of the Earth (Mas et al., 2004; Zhao et al., 2004; Dwivedi et al., 2005; Mamman & Liman, 2014). The classification of satellite imagery data offers a suitable tool to derive land cover-land use maps and statistics. Comparing between classified images of two different years provide the basis to discern those areas that depict changes of land cover/land use during the study period. Remote sensing information when combined with other related technologies such as the Global Positioning System (GPS) and GIS is able to provide the basis of information for sound planning and decision taking in a cost-effective way (Franklin et al., 2000).

4.5 Vegetation Density Mapping

The accuracy of derived NDVI depends largely on many factors that include the analyst's familiarity with the pattern and distribution of different land cover components and the ability to identify their spectral and spatial patterns on the remote sensing imagery. Accordingly, Sahebjalal and Dashtekian (2013), categorized values of derived NDVI as low density when they vary from 0.1 to 0.2, medium density from 0.2 to 0.3, high density from -0.3 to 0.4 and very high density from 0.4 and more, while according to Ardavan (2012), dense vegetation cover varies from +0.27 to +0.74. The 2012 values clearly showed lower densities than the values derived for 2006 around the AADL and Hafiz Ringim Farms, except in the case of Eco Afrique that showed higher vegetation density in 2012 than in 2006. This will likely represent an error due to topographic background adjustment conditions (Liu & Huete, 1995) and possibly, the increased soil moisture content that may have occurred from the extensive flooding event witnessed in the area in 2012. With previous works (Sellers, 1985; Myneni et al., 1995) relating NDVI directly to the photosynthetic capacity and hence energy absorption of plant canopies, the created NDVI images could be used to identify the pattern of changes that had occurred between the two different dates. Considering the application principle of NDVI values, which range from -1 to +1, the interpretation of these produced maps showed a great decline in the vegetation densities in the three locations, and that there is no 100 % canopy or foliage cover at any of the study locations.

5. Conclusion

The land use/ land cover change analysis around a selected industrial-scale biofuel production activity in each of the zones showed significant effects on the immediate environment, evidenced in the decrease or increase in some bio-physical features. Increases in human settlements, farmland and bare surface were observed, while vegetation/forest decreased, which signified significant land use/ land cover change and a shift to decreasing vegetation density from 2006 to 2012 in the study locations. Big potential for production of bioenergy exist in Africa, going by the estimated non-protected grassland and woodland areas suitable for biofuel feedstock cultivation. However, continuous land use/ land cover changes and loss of vegetation portend grave implications to both the environment and people if not monitored; and it is a reality that Nigeria cannot ignore.

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