LANDUSE/LANDCOVER CHANGES AND ITS IMPLICATIONS ON THE BIOPHYSICAL ENVIRONMENT IN ASHAKA AREA OF GOMBE STATE

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Abstract

This study was conducted to analyse the various landuse and landcover changes due to limestone mining activities and their effects on the biophysical environment in Ashaka Area of Gombe State. Remote sensing/Geographical Information System techniques and ground truthing involving field observations using Garmin 72 Handheld GPS receiver were employed for the data collections. Landsat imageries and Spot Xs for four epochs, i.e., Landsat MSS, 1972; Landsat TM, 1987; Spot Xs 1994 and Landsat ETM, 2005 were used for digital data analysis and interpretation of the Landuse and Landcover of the area. Results of the analysis show that the most extensive landuse was agriculture which covered 65.2% of the area in 1970, 68.4% in 1987 and 71.2% in 2005. Forestland recorded a decline in spatial coverage from 46.1Km^2 in 1970 to 26.2Km^2 in 2005. Grassland which covered 37.7Km^2 constituting 12.2% of the Landuse and Landcover classes in 1970 was decreased to 9.59Km^2 constituting only 3.3% of the landuse and landcover classes in 2005. Mineland occupied 1.1Km^2 indicating 0.4% of the classes in 1987 and slight increase of 0.1% in 2005 covering an area of 1.8Km^2 was revealed. Hence, implication for biophysical environment were analysed.

Key words: *Landuse/Landcover Remote sensing/GIS Environmental sustainability*

1. Introduction

Landcover may be defined as the biophysical earth surface while land use is often shaped by human, socio-economic and political influence on the Land (Negendra, 2003). Landuse could also refer to man's activities on land utilitarian in nature, where as Land cover means vegetation and man-made constructions (Ronade, 2006). Land use could further be explained as human employment of the land (Turner II *et al*..1995, Briassoulis, 2006) and Land-cover type (Skole 1994, Briassoulis, 2006).

Landuse and Landcover studies provide vital information for change detection on biophysical and socio-cultural environment. Landuse and Landcover studies have been identified as one way to detect Landuse changes and their impacts on biophysical, cultural and social environment. Results of such findings due to landuse changes are relevant for various decision-making process and policy development on sustainable landuse management. In addition, such studies can assist relevant agencies for proper and wise planning purposes and amelioration of adverse effects arising from negative human activities.

Land employed for various human use such as agriculture, settlement, forestry, grazing, construction, mining, etc., may result to changes in land structure and functioning (qualitative) and change in the area extent (quantitative) of a given type of landuse or cover. Turner II *et al*.; (1995 and Stole (1994) reported that Landcover change were categorised into two types; namely; conversion, which means a change from one cover type to another; and modification, which means alteration of structure or function without a complete change from one type to another; it could involve change in productivity, biomass or phenology (Skole 1994, Briassoulis, 2006).

Human Landuse, particularly over the past 50 years, has changed ecosystems more rapidly and extensively than in any comparable period of time in human history. This has occurred as a consequence of rapidly growing demand on natural resource (Watson and Zakri, 2003). It has resulted in degradation of the natural ecosystem functioning. Thus, to understand landcover and landuse change process and its implication for environmental and ecosystem functioning, it is important to recognize the services provided by the natural ecosystems, and to come up with a sustainable land use plan.

However, the study of the human impact on the environment and its functioning is a great challenge. The development of suitable and reliable indicators which can provide all essential information about the viability of a system and its rate of change and about how that contributes to sustainable development of the overall system is a key issue (Bossel, 1999).

Nowadays, this kind of assessment is greatly assisted by the data provided by the modern Earth observing systems. Remote sensing techniques together with Geographical Information Systems (GIS) increase the capability to analyse the dynamic environment by using qualitative, quantitative and spatial data.

Remote sensing (RS) and Geographic information system (GIS) are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analysis of Earth-system function, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localised ecological research and regional, national and international conservation and management of biological diversity (Wilkie and Finn, 1996).

According to James *et al.* (2001) reported that LUCC studies assist in understanding the driving forces of land use development in the past, managing the current situation with modern GIS tools, and modelling the future, we are able to develop plans for multiple uses of natural resources and nature conservation. Knowledge about land use and land cover has become increasingly important as all nations plan to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands, and loss of fish and wildlife habitats (James *et al.*, 2001).

Lee *et al.*, (1992) indicated the importance of understanding the implications of past, present and future patterns of human land use for biodiversity and ecosystem function is increasingly important in basic and applied ecology. To understand how Land Use Cover Change (LUCC) affects and interacts with global earth systems, information is needed on what changes occur, where and when they occur, the rates at which they occur, and the social and physical forces that drive those changes (Lambin 1997 in J. M. Read 2001). Despite ongoing research efforts on land-cover and land-use patterns, there remains a need for development of basic land-cover datasets providing quantitative, spatial land-cover information.

There is no previous study on landuse/landcover change around the neighbourhood of Ashaka Cement Factory. Landuse/Landcover auditing of the area is important for the purpose of assessing the nature of landuse conversions and their implications for sustainable development. This study, therefore, focuses on landuse/landcover changes of the Ashaka area and ascertain the nature, extent and magnitude of landuse/landcover changes to establish their implications for sustainable development.

2 Data and Methodology

The data set for this study is comprised of four satellite images: MSS images 27th August, 1972; Lansat TM of 10th July, 1987; Landsat ETM+ of 5th October, 2005; and SPOT XS image 1994.

2.1 Study Site Description

Ashaka is situated in the northern part of Gombe State approximately from latitude 10^{0}50′N to 10^{0}60′N and

Longitude $11^0 25'$E to $11^0 35'$E (Figure 1). It is about 112km from Gombe town.

Settlements within the study area are Badabdi, Feshingo, Darumpa, Bulturi, Jajami, Ashaka Gari, Juggol, Gongila and Bajoga. These settlements fall within the radius of 10 km from the plant and constitute the major communities around the plant.

The area is designated as Koppen's Aw climate with two distinct seasons, a wet season in summer and a dry season in winter. Like the rest of Nigeria, it is dominated by two air masses. These bring with them the rain bearing South-Westerly winds and the cold, dry and dusty North-easterly wind, locally known as the "harmattan". At different times of the year, one or the other of the winds prevail and the area experiences either rainfall or the dry harmattan depending on the advance or retreat of the other (Nyong and Kanaroglou, 1999).

Rainfall generally starts in early May and ends in late September. The annual rainfall could be as high as 800-900 mm during the month of August and as low as 250-350 mm during the first and the later period of the rainy season. The relative humidity is low. However, it could reach 60-80 per cent in the early morning hours during the rainy season. The average temperature is about 25^0C. The maximum annual temperature is 40^0C usually during the month of March to April. The minimum is 15^0C in December-January.

The types of soils in the study area are closely related to the parent rock. Where the parent rock is homogenous relatively simple soil association are recognised. The shale give rise to grey heavy loams and clay derived from homogeneous mudstones give rise to olive brown clay loam or loamy sand. The dominant soil type is grey mottled, sand and loams with some grey clay. The surface texture of the soils in the study area range from loamy sand, loam, sandy loam, sandy clay loam and sandy clay (Ashaka Environmental Audit Report, 2004). Continuous excavation of land for the extraction of mineral materials such as gypsum and limestone are one principal activity that has contributed to the disruption of the ecosystem thereby, modifying or changing the chemical and physical composition of the soils.

Ashaka Environmental auditing (2004) reports that the vegetation of the area is predominantly wooded scrubland. There is significant deterioration of natural vegetation of the area. The grasses are short and overgrazed with large exposed patches of bare soil susceptible to erosion. The large trees (7 to 20 meters high) are *Adonsonia digitata, Anogeissus leiocarpus, Sclerocaraya spp, Tamarindus indica* and *Balanites aegyptica.* The small trees (2 to 6 meters high) with short boles are Combretum glutuism, Acacia seyal and other thorny shrubs. There are several woody climbers like *Combretum micranthum,* and *Capparis corymbosa.* Fuel wood collection is particularly intense within the area.

2.2 Image Processing

The satellite images used have been othho-rectified and radiometrically corrected. Firstly, Remote sensing software: Earth Resources Data Acquisition System (ERDAS Imagine version 8.7) software was used for the processing of the images. The raw satellite image was converted from Tag image file format (Tiff) to img format using ERDAS in order to be compatible with other ERDAS Imagine files. The layers were stacked and subset to delineate the study area for classification (Boakye *et al.*, 2008). The UTM Zone coordinate was used to geocode the imported image. This was followed by georeferencing using the Traverse Mercator Projection with reference units in metres to allow compatible positioning of other metres.

Similar to the work carried out in Ghana by Boakye, *et al.*, (2008) the researcher made use of the visible portion of the electromagnetic spectrum. Band combination of red, blue and green was used to display the raw images in standard colour composites.

The spectral band combination for displaying images often varies with different applications (Trotter, 1998).This was necessary for the visual interpretation of the images. A band combination of red, blue and green (RGB) is often used to display images in standard colour composites for Land use and vegetation mapping (Trotter, 1998). In this study, the LandSat TM and ETM images and Spot Xs were displayed in a band combination of 1, 2 and 3 (red, blue and green) which is standard for visual interpretation of vegetation mapping in the tropics (Prakash and Gupta, 1998; Trotter, 1998)

Secondly, Arcview 3.2a software was used to open the subset image, altered the colour bands to enhance the image and subsequent interpretation of the various landuse/landcover classes. Thirdly, Arcinfo software was used to correct the delineated landuse/landcover by eliminating "overshoot" and "undershoot". This was made possible after the shaped files have been converted to Arcinfo files.

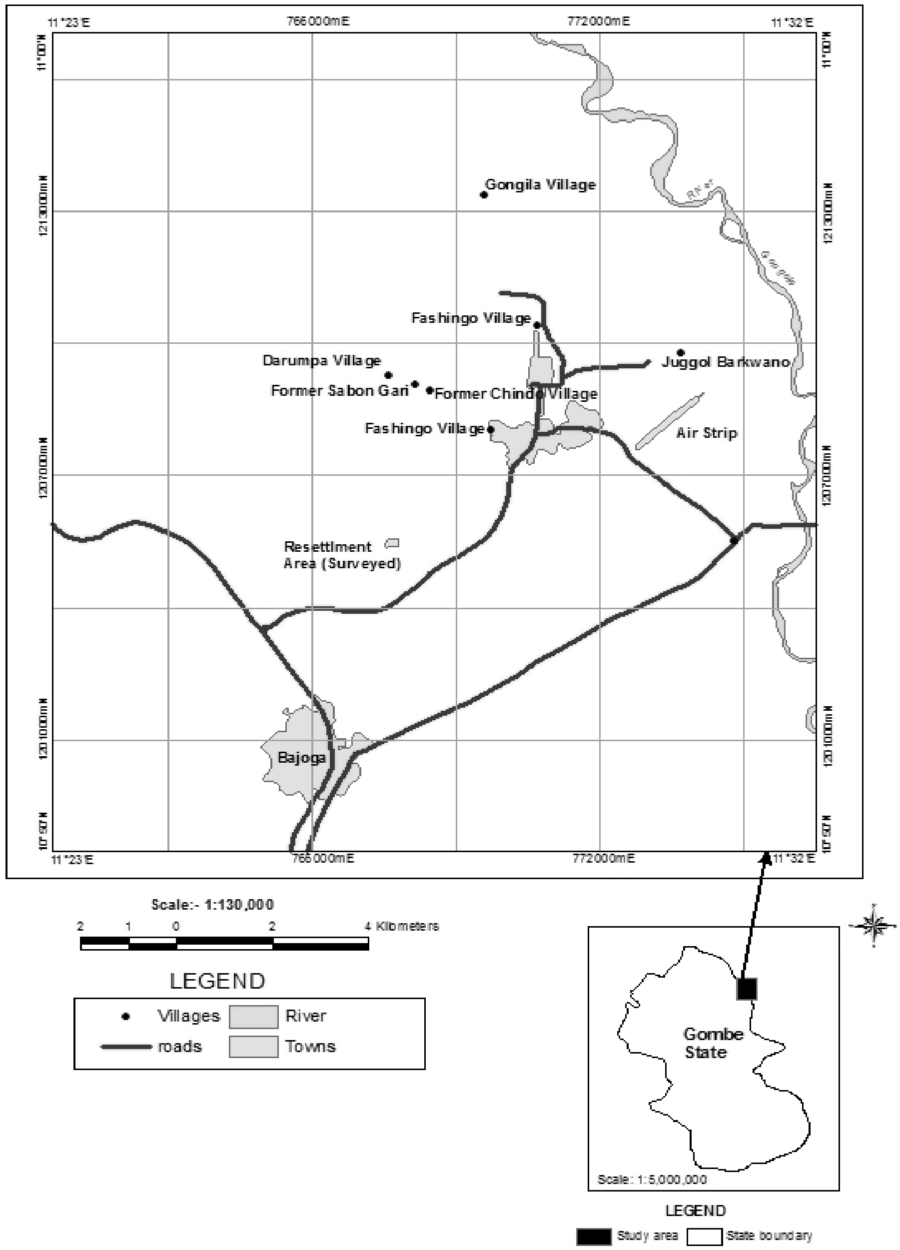

Figure 1: Study Area

Then the converted files were "clean". The "clean" files were built as lines and polygon that resulted to establishing a topology. Finally, the built lines and polygon was returned to Arcview software to create a database.
Each image (1972, 1987, 1994 and 2005) was geo-referenced and ortho-corrected using the basic topographic maps.

Since the Landsat TM images are affected by haze, a radiometric correction was accomplished using the ERDAS algorithm of Haze reduction.

Kappa coefficient is also applied to image classification evaluation. It estimates accuracy considering agreement that may be expected to occur by chance (Maingi *et al.*. 2002). Verbyla (1995), in Maingi *et al.*. (2002), gives a formula for computing K coefficient:

$$K = \frac{\text{Overall classification accuracy} - \text{Expected classification accuracy}}{1 - \text{Expected classification accuracy}}$$

2.2.1 Image Classification

Figure 2 provide a summary of the classification model adopted for the study. Ten different classes were identified (Table 1). Prior to the extraction of the thematic information from the satellite images, on sreen visual analysis was performed for each satellite image.

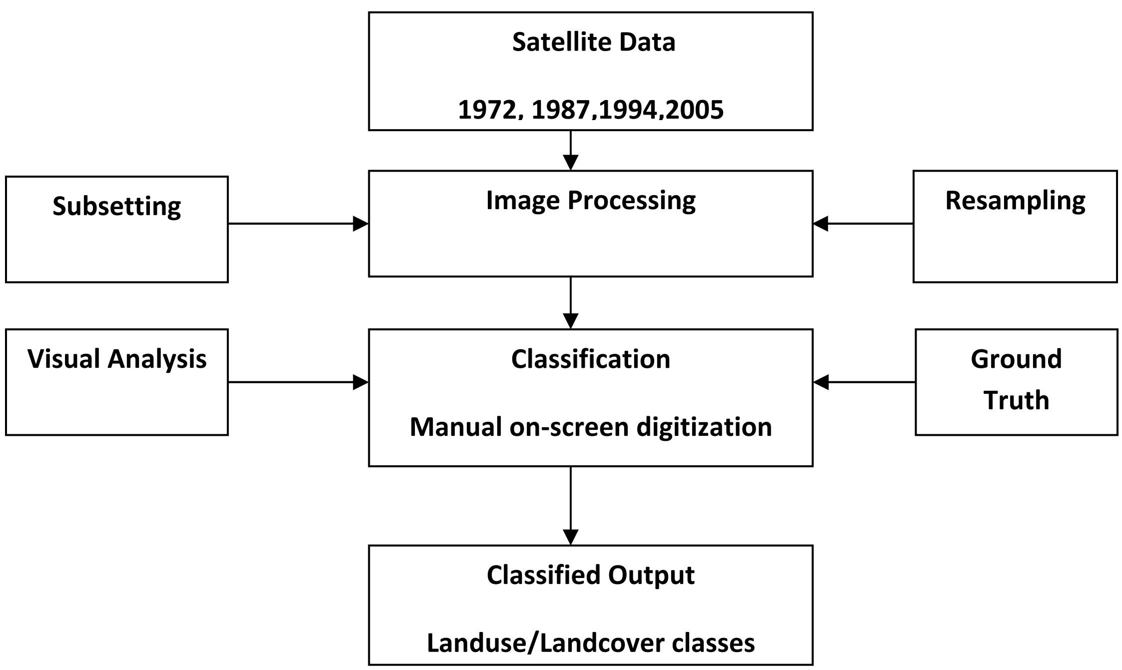

Figure 2: Image processing and Classification Model
Source: Adapted from Pushpam (2008)

Table 1: Classification Scheme used in the study

Class Name	Class Code	Class definition	Number of training samples
			1972 1987 1994 2005
Agric	Ag	Cultivated land and old tilling field	
Forest	Ft	Forest area dominated by woodland	
Grassland	Gl	Short grasses	
Plantation	Pl	Some patches of afforestation	
Raparian	Rp	Gallery vegetation along streams and river channels	
Water	Wt	Seasonal water bodies, rivers	
Mine	Mn	Dug mines/pits of limestone	
Bare	Br	Bare surface	
Airstrip	As	Airport concrete surface	
Built up	Bu	settlement	
Total	10		

Source: Author's Field Survey, 20013

2.3 Change detection

The method used in this research was that of classification comparison of landcover statistics. Landuse/ landcover analysis was carried out by simply extracting the statistical information from the polygonised thematic information of the land LULC generated from the satellite images. This method was adopted because the study sought to find out the quantitative changes in the areas of the various land cover categories. Using the post-classification procedure, the area statistics for each of the land cover classes was derived from the classification of the images for each date (1972, 1986, 1994 and 2005) separately, using functions in the Arcview and Arcinfo software. The areas covered by each landcover type for the various periods were compared.

3.0 Results and Discussion

3.1 Image classification

Image classification of Ashaka has been defined to have ten landuse landcover categories, which were presented in figure 3. The description of these landcover categories was presented previously in table 1. The landuse landcover classification for 1973 from MSS satellite image (Figure 3a) showed that majority of the study area was occupied under agriculture and forest accounting for 193.41 Km^2 (65.18%) and 46.06 Km^2 (15.52%) respectively. The satellite imagery from the image interpretation of MSS 1970 indicated absence of bare surface and mine lands.

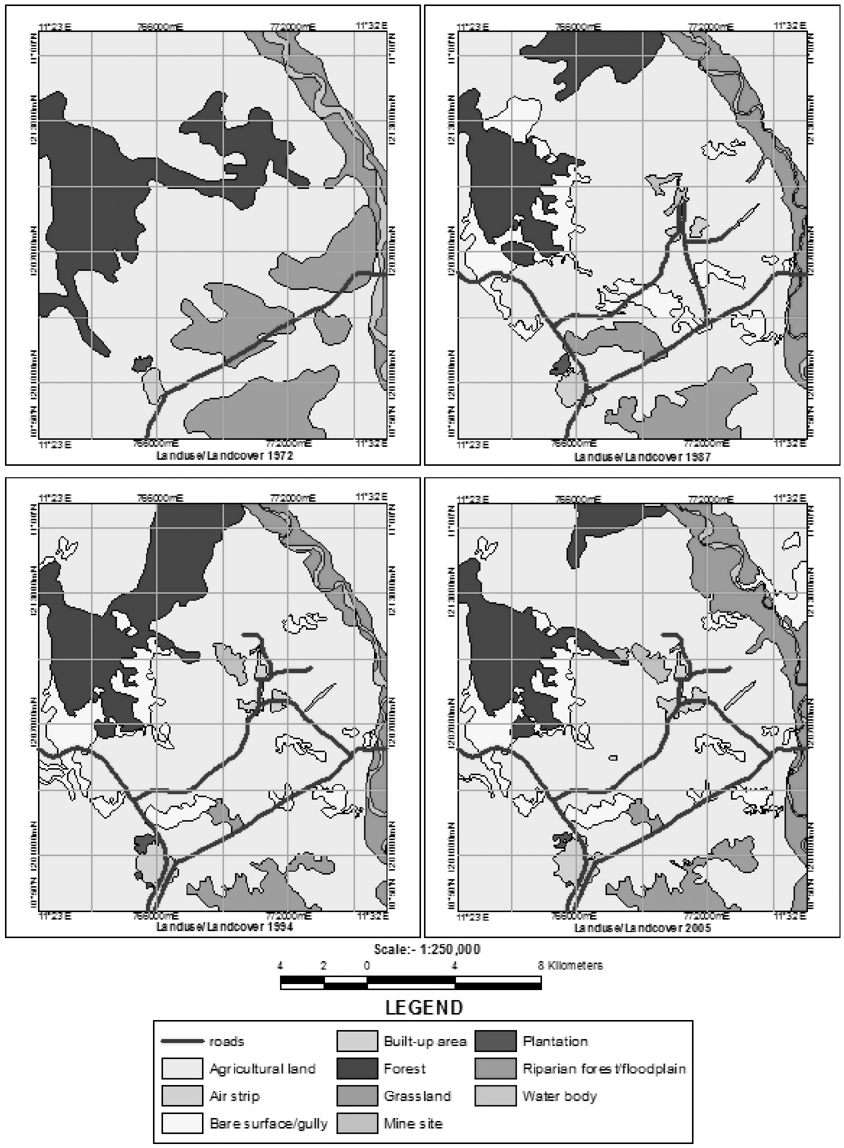

Figure 3: Classified images of LULC of Ashaka Area (a) 1972 (b) 1987 (c) 1994 (d) 2005
Source: Field Analysis, 2013

A total of ten landuse and landcover categories were identified and classified in the study. These were Agricultural land, Forest land, Grassland, Plantation, Riparian forest/flood plain, water body, mine land, Bare surface/gully, Airstrip, Built-up land. Figure 4 presents the result of the landuse and cover analysis:

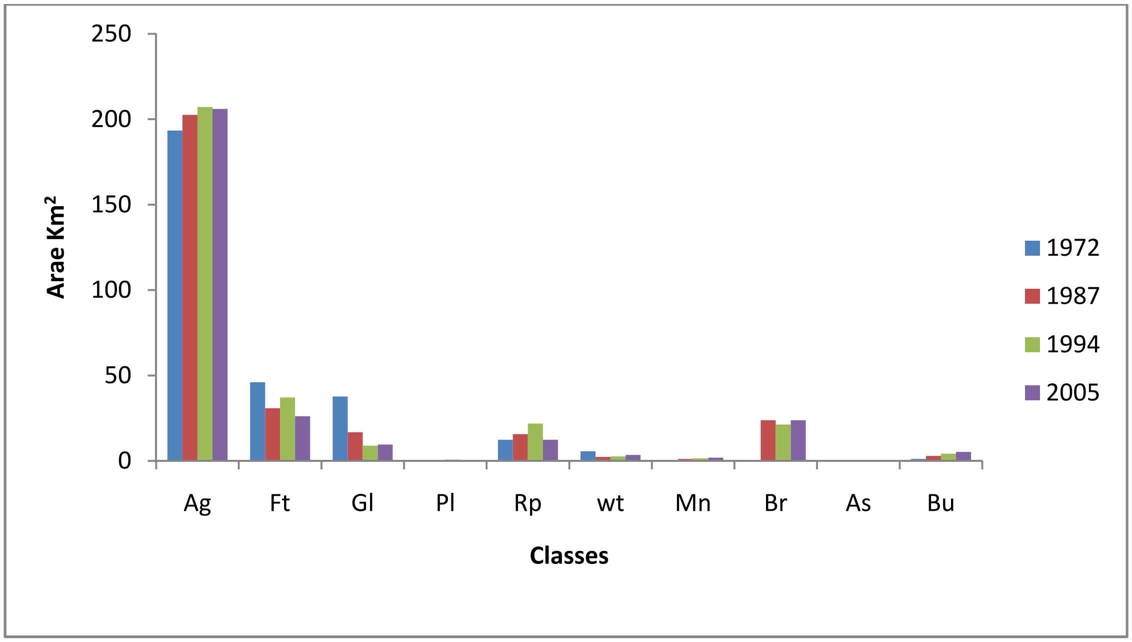

Figure 4: Landuse and Landcover Classes for the Ashaka area

The result visualised by a plotted graph (see figure 4) shows that the most extensive Landuse was agriculture, contributing 65.2% in 1970, 68.2% in 1987 and 71.2% in 2005. Population growth due to Ashaka cement factory has attracted huge numbers of migrants, hence results in increasing population density, especially some few kilometre radius around the factory site. This is adding pressure on land for both residential and agricultural purposes. The research has found that less than 5% of the inhabitants were engaged in the cement factory.

3.2 Change detection

Table 2 summarises Landuse/Landcover changes that have occurred from 1970 to 2005. As shown in Table 2, agricultural land has changed indicating 9.18 km^2 increase in the period 1970/1987 having 3.18% increased. Subsequent period have indicated a slight increase of 4.6 km^2 in the period 1987/1994. In 2005 a decreased of -2.86 km^2. Forestland has indicated a decreased of -15.17km^2 in 1987 compared to its total area of 46.06 km^2 in 1970. This decreased in forest land continuous in the subsequent periods (see figure 4). Grassland has decreased and changed indicating -20.88km^2 in 1987 compared to its size in 1970. This is kept decreasing in the subsequent periods indicating -7.94 km^2 in 1994 and -0.70 km^2 in 2005 (see Table 2). Bare surface/Gully indicates 23.83 km^2 increased in 1987.

Table 2, 3 and 4 compared the changes that have occurred between 1970 and 2005 of landuse cover categories from matrix result of change detection analysis.

Table 2: "From to" matrix result of change detection analysis

		1972										
		Ag	Ft	Gl	Pl	Rp	Wt	Mn	Br	As	Bu	Total
1987	Ag											202.59
	Ft											30.89
	Gl											16.83
	Pl											0.005
	Rp											15.66
	Wt											2.31
	Mn											1.12
	Br											23.83
	As											0.24
	Bu											2.94
	Total	193.41	46.06	37.71	0.44	12.39	5.6	0	0	0	1.14	296.415

Source: Field Analysis, 2013

Table 3: "From to" matrix result of change detection analysis

		1987										
		Ag	Ft	Gl	Pl	Rp	Wt	Mn	Br	As	Bu	Total
1994	Ag											207.2
	Ft											31.08
	Gl											7.89
	Pl											0.74
	Rp											19.86
	Wt											2.6
	Mn											1.52
	Br											21.26
	As											0.24
	Bu											4.19
	Total	193.41	46.06	37.71	0.44	12.39	5.6	0	0	0	1.14	296.58

Source: Field Analysis, 2013

Table 4: "From to" matrix result of change detection analysis

		1987										
		Ag	Ft	Gl	Pl	Rp	Wt	Mn	Br	As	Bu	Total
	Ag											206.06
	Ft											26.18
	Gl											9.59
	Pl											0.39
2005	Rp											12.37
	Wt											3.43
	Mn											3.84
	Br											23.83
	As											0.24
	Bu											10.49
	Total	193.41	46.06	37.71	0.44	12.39	5.6	0	0	0	1.14	296.42

Source: Field Analysis, 2013

3.3 Analysis of Landuse/ Landcover Change

3.3.1 Percentage Change

Table 5: Percentage change of LUCC in Ashaka

Landcover Class	1972-1987	1987-1994	1994-2005	1972-12005
Ag	+3.18	-0.55	+3.35	+5.98
Ft	-5.1	+1.71	-3.05	-6.44
Gl	-7.03	-2.77	+0.42	-8.84
Pl	-0.15	+0.24	-0.1	-0.01
Rp	+1.11	+1.87	-2.86	+0.12
Wt	-1.11	+0.07	+0.34	-0.70
Mn	+0.38	+0.13	+0.14	+0.64
Br	+8.04	-1.08	+1.3	+8.26
As	+0.16	+0.003	-0.01	+0.08
Bu	+0.61	+0.38	+0.46	+1.45

Source: Author's Field Survey, 2013

3.3.2: Rate of Change

Table 6: Percentage of LUCC in Ashaka

Landcover Class	1972-1987	1987-1994	1994-2005	1972-2005
Ag	0.612	0.659	-0.104	0.659
Ft	-1.01	0.884	-0.991	0.884
Gl	-1.39	-1.134	0.064	-1.134
Pl	-0.029	0.105	-0.032	0.105
Rp	0.218	0.886	-0.863	0.886
Wt	-0.219	0.041	0.075	0.041
Mn	0.075	0.057	0.029	0.057
Br	1.588	-0.367	0.231	-0.367
As	0.011	0.034	0.000	0.0345
Bu	-0.05	0.179	0.098	0.179

3.3.3 Trend of Change

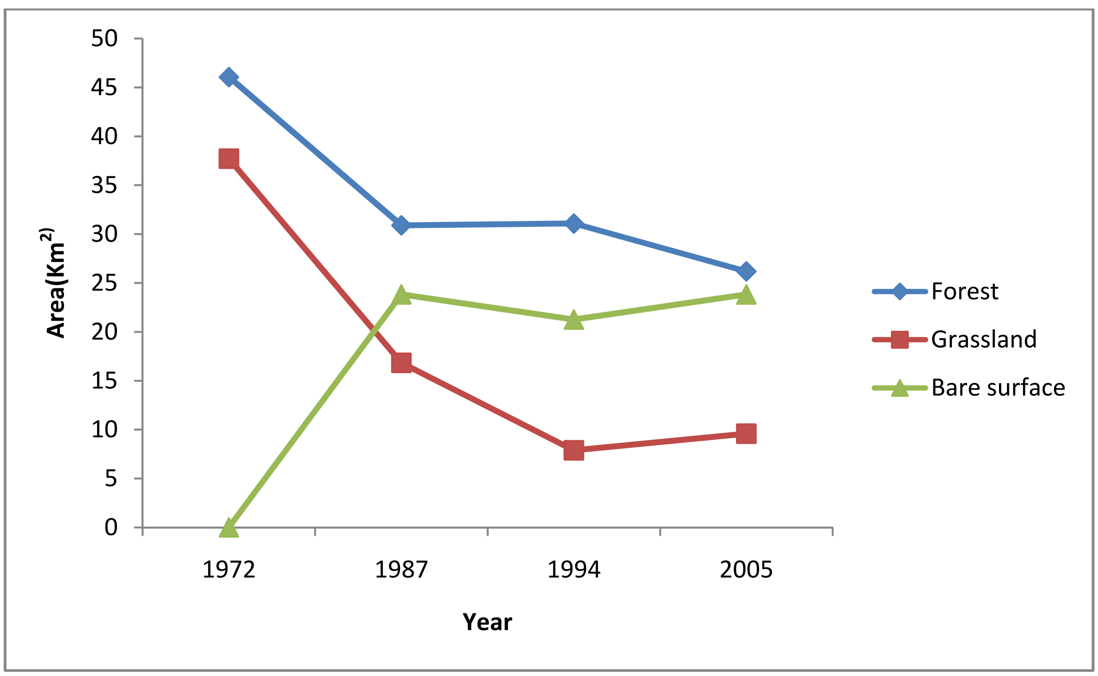

Figure 5a: Trend of LULC in Ashaka

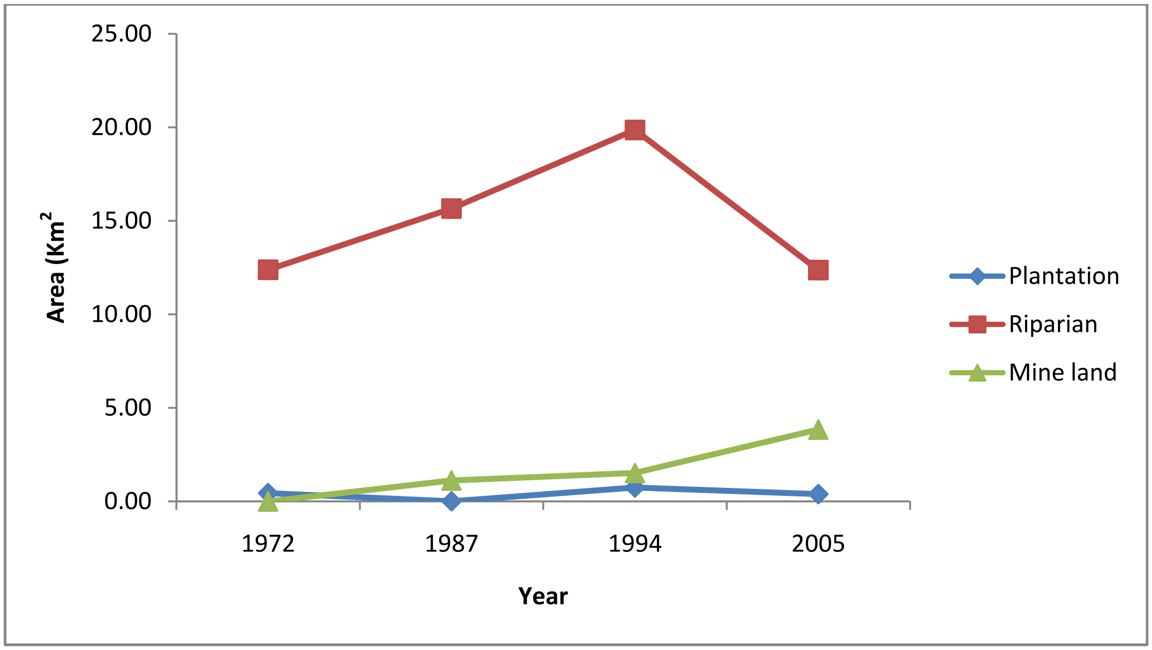

Figure 5b: Trend of LULC in Ashaka

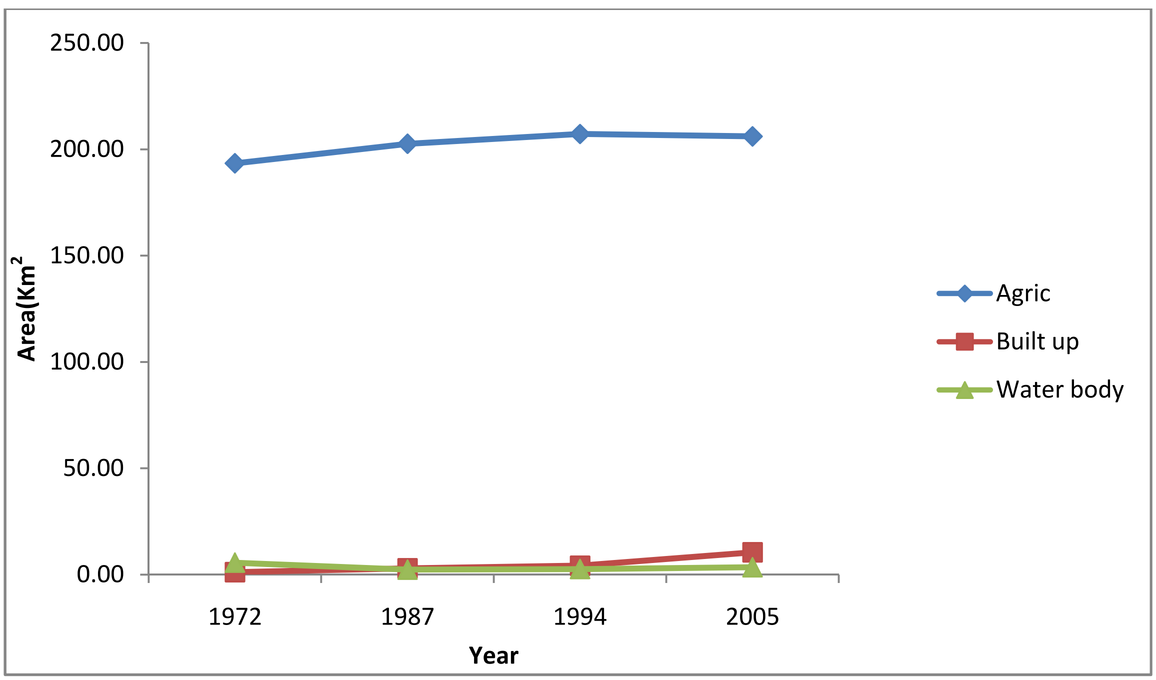

Figure 5c: Trend of LULC in Ashaka

3.4 Implication of Changes on Biophysical Environment

Environmental changes as an outcome of the dynamic interplay of socio-economic, institutional and technological activities will be said to be the causes of Landuse/Landcover changes as in the study area as observed by previous studies. Landuse/Landcover as a subset of environmental changes may be driven by factors including population growth, urbanisation, intensification of agriculture, rising energy use and industrial activities. Poverty still remains a problem at the root of several environmental problems.

Population is an important source of development, yet it is a major source of environmental degradation when it exceeds the threshold limits of the support systems (Cheng, 1999). In addition, unless the relationship between the multiplying population and the life support system can be stabilised, development programmes, howsoever, innovative are not likely to yield desired results. The increase in population of the Ashaka communities from 1963 to 2005 is shown in Figure 6

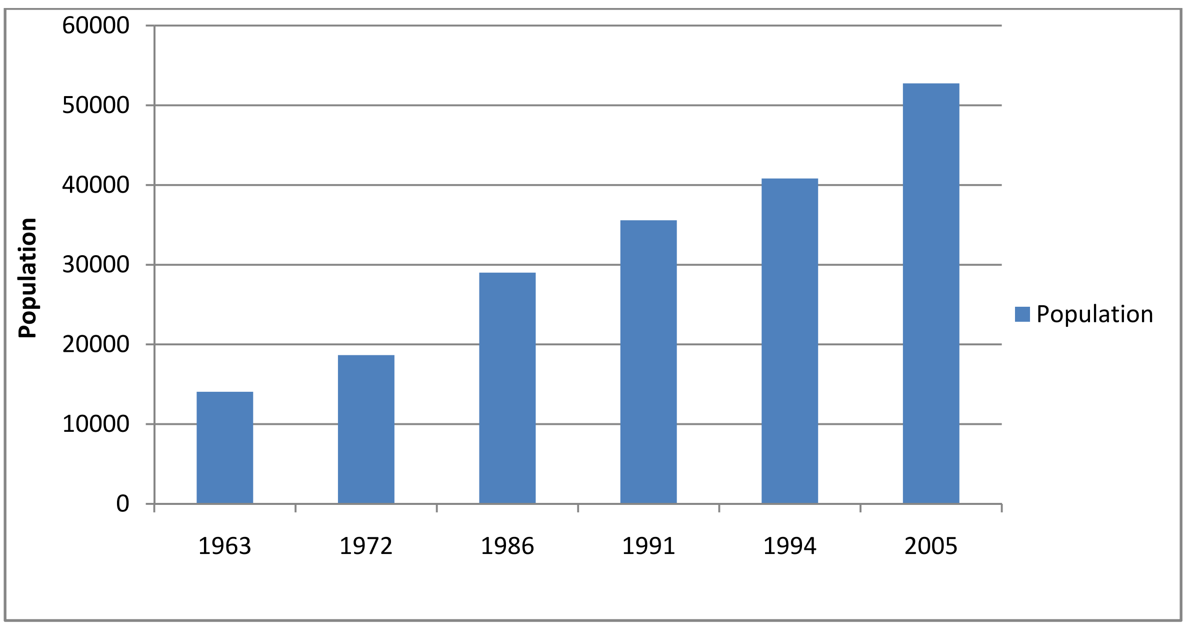

Figure 6: ***Population of the communities around the factory site over the years***
Source*: National Population commission, 1963, 1991*

Population impacts on the environment primarily through the use of natural resources (Limestone, gypsum and shale) and biological resources and production of wastes is associated with environmental stresses like loss of biodiversity, air and water pollution and increased pressure on arable land.

Vegetation in form of natural forest or crop plantation is usually the first casualty to suffer total or partial destruction or degradation during the exploration and exploitation of minerals in the locality as observed by Aigbedion *et al.*, 2007. The vegetation damage is more extensive at the time of mine development and mining operations and is more expensive when crop plantation is affected. This is reflected in forestland reduction of the period 1987/1970 and increased bare surfaces of the same period. Forestland is observed to have reduced significantly from a total area of 46.06 Km^2 in 1970 to 30.89% indicating a decrease of -15.17 Km^2 representing -5.1% of the total Landuse/Landcover classes. This reduction is continuous in the subsequent periods. The environmental audit (2004) has supported this assessment where was reported that there is significant deterioration of natural vegetation of the area. Also, that the grasses are short and overgrazed with large exposed patches of bare soil susceptible to erosion, fuel wood collection is particularly intense within the area. Grasses which are useful for soil stabilisation are increasingly diminishing from the area due to human activities as depicted from its conversion to bare surfaces/gully. The soils get more and more compacted by trampling and increasingly eroded (wind and water), making it increasingly difficult for plants to establish at all. Eventually grazing decreases vegetation cover, soil loss and compaction increases, water infiltration decreases and runoff increases. This eventually gave rise to overland flow creating gullies.

4 Conclusion

Environmental sustainability is key to sustainable economic growth and development. Landuse/landcover studies provide land-based information in order for wise-decisions and healthy policies to be made. It also helps in assessing both physical and socio-economic impacts mainly due to human activities. For this study, remotely sensed data (Lansat Mss 1972, Landsat TM 1987, SpoXs 1994 and Lansat ETM+ 2005) were employed to depict and analyse the various Landuse/Landcover categories and their quantitative changes from 1972-2005 in the study area. The monitoring of landuse activity to ascertain undesirable changes, over-exploitation of primary resources, decrease in forestland, increase bare surfaces/gullies and depletion of grassland resources as evidenced by changes in landuse/ landcover in this study are the major concerned of these findings. Therefore, up to date data on landuse/landcover is necessary for sustained and healthy biophysical environment.

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