Competitive Land Use/Cover of Kumasi and its Environs Based on Satellite Imagery Studies

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Abstract

Man has been altering land cover since pre-history through the use of fire to hunt for game and since the advent of plant and animal domestication, through the clearance of patches of land for housing, agriculture and livestock. In the past two centuries the impact of human activities on land has grown enormously, altering entire landscapes, and ultimately impacting the earth abiotic components (climatic and edaphic factors) and other biotic components. Land-use and land-cover changes are local and place specific, occurring incrementally in ways that often escape our attention. Yet collectively, they add up to one of the most important facets of global environmental change. This study used the techniques of satellite imagery (Landsat images) and GIS to analyze the extent of land use /cover and land change between the years 1986 - 2010 in Kumasi and its environs of Ghana. Within this twenty year interval, the images were analyzed by comparison and contrasting to ascertain how the land-cover and land use have changed over the years.

Key Word*s: Remote Sensing, Land use, Land cover, Deforestation, Change Detection, Population*

Introduction

Remote sensing is generally defined as the collection and interpretation of information about an object, area, or event without being in physical contact with the object. Aircraft and satellites are the common platforms for remote sensing of the earth and its natural resources (Sanderson, 2010). This has been used extensively in monitoring the changing pattern of forest cover. It offers an accurate means of measuring the extent and pattern of changes in forest cover conditions over a period of time (Miller et al, 1998). Remote sensing and GIS provide fundamental tools for the inventory and analysis of natural resources for regional, rural and local planning, management and development at both the small as well as the large scales in undeveloped and developing parts of the world (Teotia & Santos, 2010). Satellite data have become a major source in forest change detection because of the repetitive coverage of the satellites at short intervals (Mas, 1999). Studies by Yang and Lo, (2002) explained that Forest cover is altered principally by anthropogenic influence and any idea of global change must include the prevalent influence of human action on land surface conditions and processes.

Land use is the term that describes the human uses of the land, or immediate actions modifying or converting land cover. It includes such broad categories as human settlements, protected areas and agriculture. Land cover on the other hand refers to the natural vegetative cover types

that characterize a particular area. These are generally a reflection of the local climate and landforms, though they too can be altered by human actions. Examples of broad land cover categories include forest, savannah, desert or steppe, which in turn can be sub-divided into more refined categories representing specific plant communities (Anderson et al., 1976). Land cover is dynamic and varies at different spatial and temporal scales (Cihlar, 2000); yet, its role in the structure and functioning of the earth system is fundamental. The array of ecosystem services it offers include, provisioning services (e.g. food), regulating services (e.g. climate regulation), cultural services (e.g. recreation and ecotourism) and supporting services (e.g. biogeochemical cycling) (Millennium Ecosystems Assessment, 2005). Thus, land cover modifications or conversions through human or nature's agency can have profound impacts on climate, hydrological and biogeochemical cycles, biodiversity, soil quality and human wellbeing (Foody, 2002; Lambin, Geist, & Lepers, 2003; Overmars & Verburg, 2005). This justifies the importance of land use and land cover change research in the context of global environmental change and sustainable development.

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). It is an important process in monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution of the population of interest. Accurate and up-to-date land cover change information is necessary to the understanding and assessing the environmental consequences of such changes (Giri et al, 2005). In particular, land use/land cover (LULC) changes in tropical regions are of major concern due to the widespread and rapid changes in the distribution and characteristics of tropical forests (Myers 1995; Houghton 1994).

Study Area

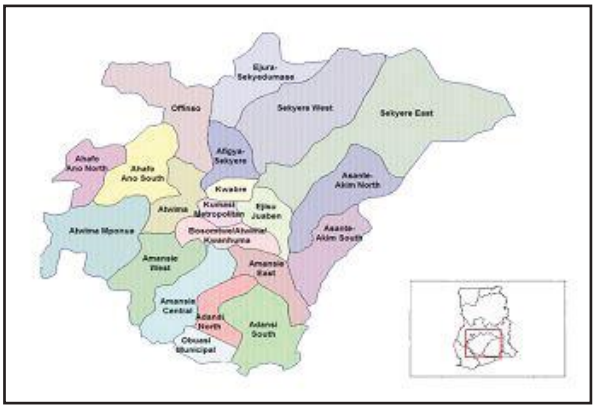

Figure 1: Ashanti Region

Ashanti Region, with Kumasi as its capital, lies approximately at the centre of Ghana (Figure 1). It covers an area of 24,390km^2 representing 10.2 percent of the land area of Ghana. Ashanti Region has abundant food and is endowed with large deposits of gold and bauxite. Other mineral deposits of economic value found in the Region include manganese, iron, silica, clay and limestone. Traces of copper, platinum, lithium, tin arsenic and mica are also found (www.ghanaweb.com). It is the most populous region in Ghana. According to the 2010 Population and Housing Census, the Region recorded a total of 4,780,380 representing 19.4 percent of national total of 24,658,823 (GSS, 2013).

The Kumasi Metropolis and its environs are supplied with portable drinking water from two surface water treatment plants; Owabi (latitudes 6º 47' 42.7" and 6º 42' 6" North and longitudes 1º 43' 16.8" and 1º 35' 29.4") and Barekese headworks (- 6°44'; 1° 42'W) located 10 km and 16 km respectively from Kumasi. The study area covers the districts of Atwima, Kwabre and Kumasi Metro. The Owabi Headworks is surrounded by a wildlife sanctuary which is the smallest of the four wildlife protected areas in Ghana. It is about 13km^2 in size, and lies approximately 23km northwest of Kumasi.

Materials and Methods

Data employed in estimating the land cover change were extracted from three cloud-free Landsat Thematic Mapper (TM) and two Landsat Enhanced Thematic Mapper (ETM) images obtained in 1986, 2007 and 2010. All the three imagery were registered to the Universal Transverse Mercator (UTM), Zone 31 geographic projection. The Landsat Thematic Mapper satellite imagery was pre-processed to convert the image to reflectance or the correction of sun angle and seasonal differences. The Satellite image was first geometrically corrected to orient the pixels to the real world and geo-referenced using crossroads, landmarks and settlements. ERDAS imagine and ArcGIS were used for this part of the study. Supervised classification was employed. This paper addressed land use and land cover changes over a 24 year that is 1986 to 2010 in Kumasi and its environs within the Ashanti Region. The dynamics of forest conversion to agricultural land and expanding human settlements were visualized and their combined effect on the Owabi and Barekese headworks. The spatial distribution and patterns are the primary focus of this study. Special attention is given to the effect of these changes on the Barekese and Owabi Headworks. Within the scope of this paper, the concept behind the process of mapping land use and land cover change over time begins with mapping the present (2010 satellite imagery), then looking back in time to the immediate past (2007) and finally, at the past (1986 satellite imagery) to assess for change detection.

Results

Figure 2 shows Kumasi and its environs including the Owabi and Barekese Headworks geo-referenced to road networks and towns. Figure 3 show the area of interest cut out. Figures 7 and Table I indicate the massive loss of forest cover to mostly Farmland and Settlements.

The land use/cover map for 1986 (Figure4) showed the Kumasi metropolis and its environs very green. 68.70 percent of the land cover is forest (Figure 4, 7, Table 1). The agriculture is the next in rank. Most of the populations are subsistent farmers. This explains why the agricultural lands are in clusters, where they appear as a big mass, they subdivided into small farms. Settlement takes the 10.36 percent. The Barekese and Owabi head works and other water bodies' take with 0.23 percent.

The land use/cover map for 2007 (Figure5) shows the Kumasi metropolis has lost more than 50 percent of it forest cover. Agriculture has also increased and has taken much of the forest. Housing and social amenities (Settlement) have expanded in all directions (Figures 5, 7 and Table 1). Water's share of the land cover increases marginally 0.82 percent. However, serious encroachment is seen in the forests surrounding the two Owabi and Barekese headworks. The expansion of the city is getting closer to the two water bodies, indicating danger for water supply to Kumasi and its environs.

There is massive deforestation from 1986 to 2007 and even from 2007 to 2011 as Settlements and Farmland increase. There is a marginal increase in the water body from 1986 through to 2011. The immediate Forests around the Barekese and Owabi Headworks are fairly intact from all the scenes, but the forests which are not in it immediate vicinity are vanishing. The forests surrounding the headworks are now the only barrier to the water bodies.

The Change Detection for 1986-2007 (Figure 8 and Table 2) displays the extensive changes that have occurred on almost 50% of analyzed area (781.50 km^2) out of total area of 1403.65km^2. The biggest change was recorded as forested land gave way to agriculture. Forest lost out to settlement marginally, while Forest marginally increased at the expense of Agriculture.

Agriculture gave way to settlement slightly, while settlement lost out to agriculture by slightly. Less than one percent (0.2%) of settlement had been converted into Forest.

Table 2 and Figure 9 portray the changes that have transpired between 2007 and 2010. The biggest change was again recorded as forested land gave way to agriculture. Forest lost out to Settlement, while forest increased its share at the expense of agriculture at 25.56 percent. Agriculture gave way to settlement marginally while settlement lost out to agriculture by 14.28 percent. Less than one percent (0.2%) of settlement had been converted into Forest.

The Population Census of Ghana from 1960-2010 (Table III and Figure X) indicate a very fast growing population. The highest increase between censuses over the 50-year period was 53.8 percent and this happened between 1984 and 2000. The Ashanti Region's (where Kumasi and its environs including the Barekese and Owabi headworks are located) share of the population is the highest and keeps increasing as the years pass by.

Figures, Tables and Art work:

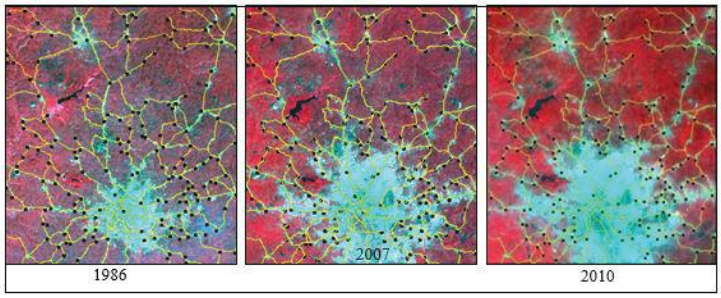

Figure 2: Landsat TM 1986, ETM 2007 and ETM 2010

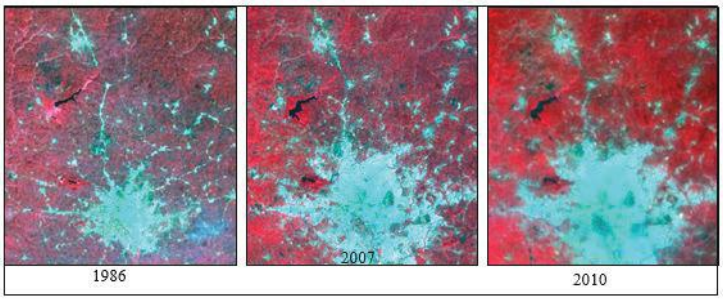

Figure 3: Extracted Area of interest (AOI) for Landsat TM 1986, ETM 2007 and ETM 2010

Table I: Land use/cover Classification for Kumasi and its environs

Classification Class	Classified Area / km^2			% Classified Area		
	1986	2007	2011	1986	2007	2011
Forest	964.26	372.26	227.27	68.70	26.52	16.19
Farmland	290.82	618.62	782.07	20.72	44.07	55.72
Settlement	145.38	401.32	369.38	10.36	28.59	26.31
Water	3.20	11.45	24.93	0.23	0.82	1.78
Total	1403.66	1403.65	1403.65	100.00	100.00	100.00

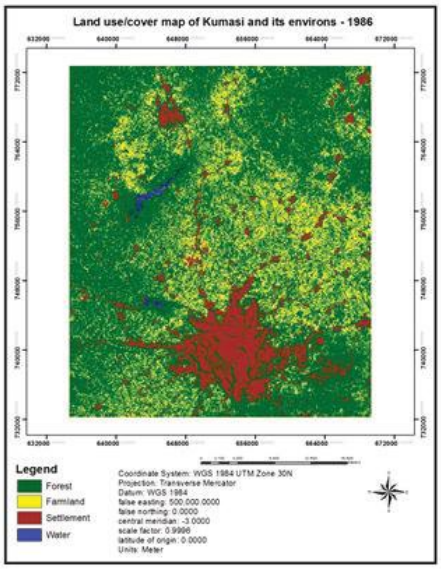

Figure 4:1986 Land use/cover map

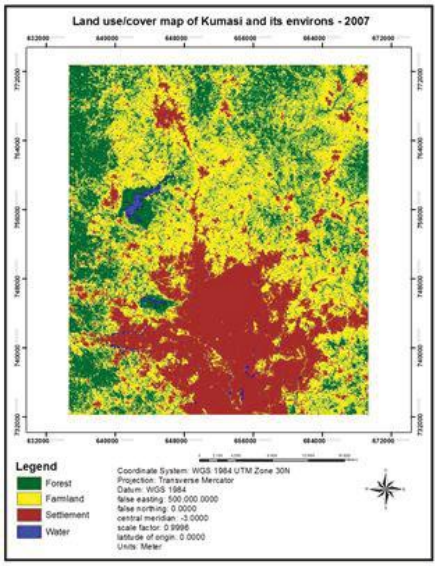

Figure 5:2007 Land use/cover map

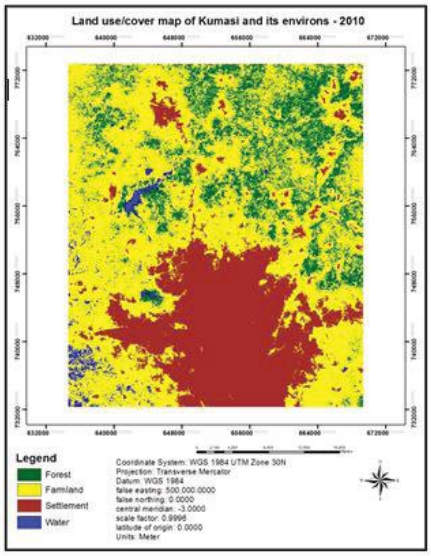

Figure 6: 2010 Land use/cover map

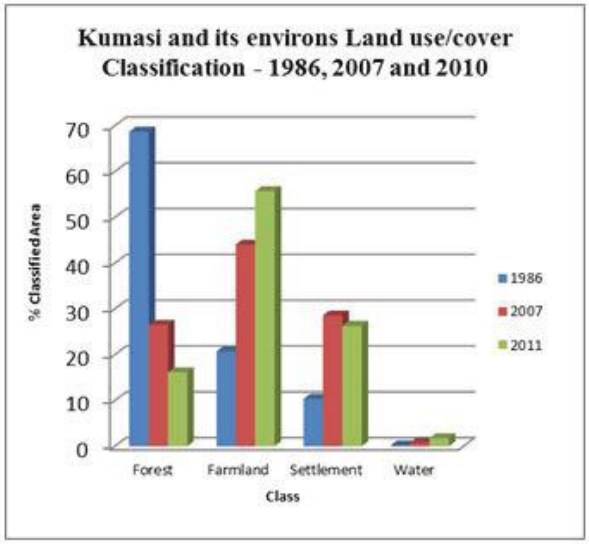

Figure 7:1986, 2007 and 2010 Land use/cover

Table 2: Change detection 1986-2007 and 2007-2010 for Kumasi and it environs

Categories	Classified Area / Km²		% Classified Area	
	1986-2007	2007-2010	1986-2007	2007-2010
Forest - Agriculture	435.70	258.41	55.75	52.10
Forest - Settlement	205.32	1.11	26.27	0.22
Agriculture - Forest	55.12	126.78	7.05	25.56
Agriculture - Settlement	68.21	37.51	8.73	7.56
Settlement-Forest	1.43	1.36	0.18	0.27
Settlement - Agriculture	15.72	70.81	2.02	14.28
Sum	781.50	495.98	100.00	100.00

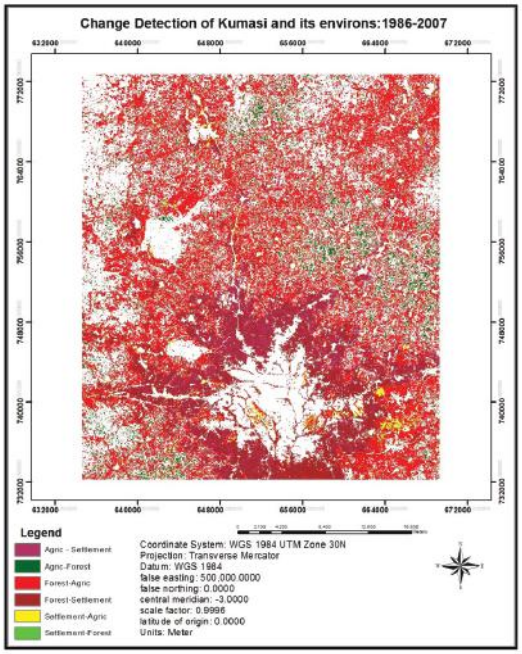

Figure 8: Change Detection 1986-2007

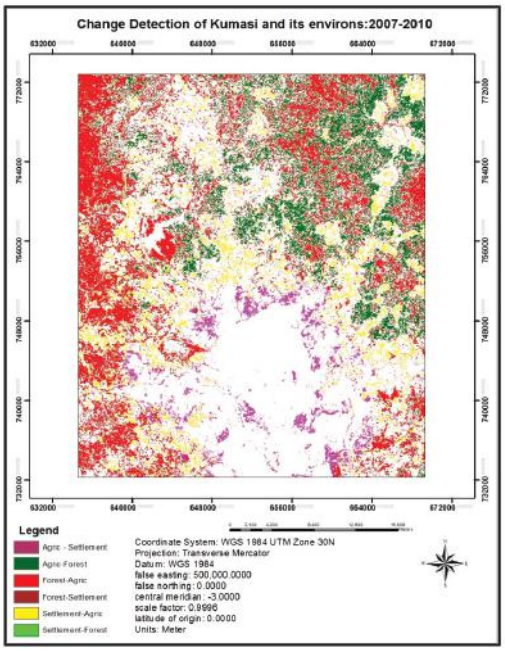

Figure 9: Change Detection 2007-2010

Table 3: Ghana's Population and Ashanti Regional Share 1960, 1970, 1984, 2000 and 2010

Period	Ghana Population	Ashanti Region share	% Ashanti Share of Ghana's Population
1960	6,726,815	1,109,133	16.3
1970	8,559,313	1,481,698	17.3
1984	12,296,081	2,090,100	17.0
2000	18,912,079	3,612,950	19.1
2010	24,658,823	4,780,380	19.4

Source: Ghana Statistical Service, 2013

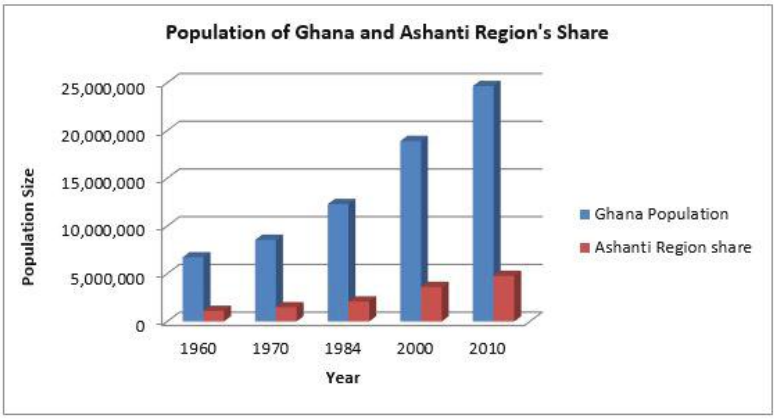

Figure 10: Ghana Population Census

Discussion

The use of remote sensing and geographic information system has provided a very useful means of studying land use/cover. The results indicate that, the land cover of Kumasi and its environs have undergone serious and very profound changes. Overall analysis indicates that, there was net expansion in agriculture and settlement at the expense of the forest cover. The causes of deforestation and other forms of environmental degradation are issues that are linked to the struggle for survival and economic freedom in this part of the world. This pattern of development is not peculiar to Africa and other areas of extensive deforestation. Develop economies and places where forests are well protected now have all gone through such developmental stages before. Europe especially, treated its forests in a very similar way in times past (European Forest Institute, 1996).

Deforestation is a real problem in Ghana. It is intensifying alarmingly as the years go by. It is estimated that, Ghana loses 22,000 hectares of forest every year (Aiken, 1995). This rapid deforestation could be attributed to the forest policies for the period 1954 – 1990, where forestry policies were tailored towards the establishment of forest reserves with an avid goal of the maximization of timber production. The main thrusts of these policies were economics and not the maintenance of ecological systems and other environmental conservation outside the forest reserves.

The results obtained from the land use/cover classification clearly indicate that, the change in land use/cover from 1986 to 2010 (twenty-four year interval) was clearly driven by anthropogenic forces. This agrees with the study conducted by Hens and Boon in 1999 which stated that, "A major characteristic of land use/cover in Ghana is the competition among the three main economic sectors namely agriculture, mining and logging". Within an analysed period of twenty-four years (1986-2010), the land cover had been altered so much mainly by the expanding human settlements and agriculture.

The land use/cover change in Kumasi and its environs is attributed to the following:

1. Rapid population growth: Increase in the population has contributed significantly to deforestation. The population growth rate of three percent per year is relatively high. Increasing population require more land to put to agricultural use in order to provide food for them. More lands have to be cleared or give way to provide places for settlements and other social amenities for the increasing population.

2. Logging: It is estimated that as much as US$50 million of wood is illegally exported from Ghana annually (Aiken, 1995). Due to the fast declining timber, the government of Ghana has currently embarked on an incentive package for tree farmers to keep timber shade trees as opposed to non-timber shade tree (IUCN, 1995). This is an indication of the importance of timber to the economy of Ghana. Timber used to be the second largest forest exchange earner for Ghana after cocoa, but has now slipped to third place behind cocoa and gold (TEDD, 2002). Commercial logging is another common form of deforestation, cutting trees for sale as timber or pulp. Logging occurs selectively –where only the economically valuable species are cut – or by clear cutting, where all the trees are cut. Commercial logging uses heavy machinery, such as bulldozers, road graders, and log skidders, to remove cut trees and build roads, which is just as damaging to a forest overall as the chainsaws are to the individual trees. Land use activities like logging has been observed to have the potential of reducing trees out of protected areas (IDRC, 1999).

3. Agriculture. Most of the clearing of forest is done for agricultural purposes such as livestock rearing and crop production. Poor farmers chop down trees (typically a few acres) and burn the tree trunks — a process called slash and burn agriculture. Intensive, or modern, agriculture occurs on a much larger scale, sometimes deforesting several square miles at a time. Large cattle pastures often replace rain forest to produce beef for the world market. Agricultural system in the area of study is the land rotation. This system almost always preceded by slash and burn has been a powerful tool of transformation land cover types giving rise to new land cover types after the farming season. Deforestation by a peasant farmer is often done to raise crops for self-subsistence, and is driven by the basic human need for food. Most tropical countries are very poor by U.S. standards, and farming is a basic way of life for a large part of the population.

4. Fuel: Developing countries rely heavily on wood fuel, the major energy source for cooking and heating. In Africa, the statistics are striking: an estimated 90 percent of the entire continent's population uses fuel wood for cooking, and in Sub-Saharan Africa, firewood and brush supply approximately 52 percent of all energy sources (Cleaver and Schreiber, 1994).

The Barekese and Owabi headworks have been degraded through anthropogenic activities along its catchment area contributing to deteriorating water quality. The water level has been gradually reducing foreshadowing a looming water crisis in Kumasi in the coming years. The degradation of the reservoirs is attributed to clearing of land for farming and illegal sawn lumber of the forest reserve that is responsible for protecting the catchments of the Rivers Offin and Owabi. This deforestation has resulted in reduced inflow and increased evaporation of the reservoir. The Kumasi metropolitan area is also responsible for dumping tonnes of solid waste into the surrounding areas adding to the deteriorating quality of the reservoir.

Overall, Ghana's population and characteristics pose serious challenges for her development and not until Ghana achieve considerable fertility decline within the next few years, the nation's development efforts will be frustrated. Her annual population growth rate is among the highest in the world. It has hovered around and 3.1 percent since 1984 compared with the average rate of less than one percent (0.6%) for the developed world. For the foregoing, the following problems may be identified among others:

- High population growth rate induced by sustained high fertility and declining mortality rate arising from increased access to health delivery system.
- High pressure on land arising from increasing population growth rate and increasing competing demand for land for economic and residential purposes.
- High age and economic dependency and rising level of unemployment.

Population-Environment linkages: The impact of population on the environment has often been mathematically given as I=P * A * T ((Ehrlich and Ehrlich, 1990; Zaba and Clarke, 1994):

Where I = environmental impact,

P = population size,

A = affluence (which is measured by the average person's consumption of resources) and

T = technologies (which disrupt the environment to provide goods consumed).

For example, an increase or decrease in P, A, or T will correspondingly raise or lower the environmental impact although equal change in either P, A, or T with the other factors remaining constant may not have the same effect in all regions of the world. At the Rio conference in 1991 countries of the South felt that those in the North, through their excessive consumption and advanced technologies, have more adverse effects on the environment than them. Developing countries also with their large populations but limited economic advancement can generate a vast impact on the environment if only the P multiplier on the A and T factors is so large. (Ehrlich and Ehrlich, 1990). Thus, population pressure due to high growth rates is one of the main proximate causes of environmental degradation in the South.

Since, he United Nations Conference on Environment and Development at Rio de Janeiro in June 1991, there has been increased awareness that problems of the environment cannot be fully addressed without first considering population–environment linkages. It was clearly stressed in the final document of the United Nations International Conference on Population and Development (ICPD) held in Cairo in September 1994. "Pressure on the environment may result from rapid population growth, distribution and migration especially in ecologically vulnerable ecosystems. Urbanization and policies that do not recognize the need for rural development also create environmental problems" (UNICPD, 1994). The major objective of ICPD was to integrate both the environment and population in development planning and activities.

Conclusion

The creation of land use/cover map for the study area was derived utilizing standardized digital remote sensing classification techniques. The classification employed Landsat scenes dated 1986, 2007 and 2010. A hierarchical level II land use and land cover classification comprised forest, agriculture, water and housing and utilities. The final classification accuracy was determined to be satisfactory or 'good' by means of employing standardized accuracy assessment measures. An overall accuracy assessment of 80 percent was deemed satisfactory.

The Landsat TM and ETM+ mapping of the land associated with digital remote sensing techniques is characterized by, but not restricted to, inherent limitations. No map produced by digital manipulation of multispectral data is 100 percent correct when it is produced by a computer (Robinove, 1986). By nature, the process of classifying such a broad range of the Earth's features into specific and often simplified land use and land cover classes introduces error by drawing boundaries around geographically located classes that are 'homogeneous' or acceptably heterogeneous. However, these limitations can often be overcome by sound statistical analysis to produce acceptably accurate land use and land cover maps as derived from Landsat TM and ETM+ satellite data.

The resolution of the Landsat TM and ETM+ was relatively low, thus classification was inhibited. The classification into four categories inhibited a very detailed classification. The forest category included the different forest types such as deciduous, semi-deciduous and other forest types; the agriculture category included different forms of agricultural lands from bare farm lands, grass fields, dry and drying crop fields and fresh farm lands; the housing and utilities was a hybrid of urban housing, industries, transportations and other social amenities.

The patterns of land use/cover are changing rapidly in Kumasi and its environs as more houses continued to be built, small-scale and commercial farmers clear more land in an attempt to increase their production to meet the needs of the increasing population and to ensure their economic well-being. Thus, the deforestation which has occurred in the Kumasi metropolis

and its environs the past 24 years (1986 – 2010), appears to be linked to increasing agricultural activities and provision of housing and utilities.

Aldo Leopold (1949) reasoned that a land ethic must become instilled as a primary component of global society. In other words, a land ethic changes the role of Homo sapiens from conqueror of the land community to member and citizen of it. It reflects the existence of an ecological conscience, and this in turn reflects a conviction of individual responsibility for the health of the land. It also implies respect for his fellow members and respect for the community as a whole. Conservation is a state of harmony between men and land. Mankind must take on a new role in conservation as husbandry of the land. Although this was written sixty-five years ago, the words of Aldo Leopold speak louder than ever and hold more truth as mankind continues to modify his environment to suit its needs. On the Earth at this moment, estimates suggest that an acre of forest disappears every second of every day. There are only so many acres on the planet (Sagan, 1990).

The year time span, 1986 – 2007 - 2010, considered in this study is relatively a short increment of time in a long history of land use dynamics, but even then the changes were tremendous. This means that changes in the tropics are much faster than other parts of the world. These changes results from mainly anthropogenic forces such as rapid population growth, agriculture, timber exploitation and other economic ventures.

The Barekese and Owabi catchment area have endured tremendous changes from 1986- 2007 -2010 as a result of anthropogenic activities and this has unfavorably impacted the quality and quantity of the raw water and the feeder streams. The forecast of the catchment areas predicts that vegetation cover will continue to experience a decline in forest cover in the year 2043 resulting in feedbacks in regional climate and weather. The four most highly ranked causes of land cover change in the Barekese catchment are poverty-driven agriculture, lack of alternative rural wage employment other than farming, household population levels, and conflict in traditional land practices. If this rate of deforestation remains as it is now, then water supply from these two Headworks would be under enormous pressure and would be on the verge of destruction in the very foreseeable future.

References

Journal

Aiken, R., (1995), Deforestation Pressures and Impacts in Ghana. URL: World Wide Web. UL:http://www.openmediagroup.com/jane/deforestation. 11/01/07.

Anderson, J.R., Hardy, E.E., Roach, J.T., and Witmer, R.E.,1976. A land use and land cover classification system for use with remote sensor data. U.S. Geological Survey Professional Paper 964. Cihlar, J 2000. Land cover mapping of large areas from satellites: Status and research priorities, International Journal of Remote Sensing 21, pp. 1093–1114.

European Forest Institute, 1996. History of forests in Finland. URL: World Wide Web. UL:http://www.efi.fi/five/fine/finland/history.htm. 13/06/07.

Foody, G., 2002. Status of land cover classification accuracy assessment. Remote Sensing of Environment. Vol. 80. p. 185-201.

Lambin, E. F., Geist, H. J., & Lepers, E. (2003). Dynamics of l and -u se and l and -c over change in tropical regions. Annual Review of Environment and Resources, 28(1), 205–241. doi:10.1146/annurev.energy.28.050302.105459

Mas, J. F. 1999, Monitoring Land-Cover Changes: A Comparison of Change Detection Techniques. International Journal of Remote Sensing, 20(1), , pp. 139 - 152.

Miller, A. B.; Bryant, E. S., and Birnie, R. W. 1998, An Analysis of Land Cover Changes in the Northern Forest of New England Using Multi-temporal LANDSAT MSS Data. International Journal Remote Sensing, Vol. 19, No. 2, , pp. 215-265.

Sagan, C., 1990. Croesus and Cassandra: Policy Response to Global Warming. Carl Sagan's Acceptance Speech for the 1990 Oersted Medal Presented by the American Association of Physics Teachers. January 23, 1990. American Journal of Physics. Vol. 58: 8. pp. 720 – 730.

Singh, A., 1989. Digital Change Detection Techniques Using Remotely Sensed Data. International Journal of Remote Sensing. Vol. 10, No. 6, pp. 989-1003

Yang, X.; Lo, C. P2002. Using a Time Series of Satellite Imagery to Detect Land Use and Land CoverChanges in the Atlanta, Georgia Metropolitan Area. International Journal of Remote Sensing, Vol.23, , pp.1775–1798.

Report

Cleaver, K.M. and Schreiber G.A., 1994. Reversing the Spiral: The population, Agriculture, and Environment Nexus in Sub-Saharan Africa, The World Bank, Washington, D.C.

Ghana Statistical Service (GSS), 2013. 2010 Population and Housing census National analytical report . Accra, Ghana. pp 1-430

Giri, C., Pengra, B., Zhu, Z., Singh, A. & Tieszen, L. (2007) Monitoring mangrove forest dynamics of the Sundarbans in Bangladesh and India using multi-temporal satellite data from 1973–2000. Estuarine, Coastal and Shelf Science, 73, 91–100.

Houghton, R.A., 1994.Tropical deforestation and atmospheric carbon dioxide, Climatic Change , pp19, 99-118.

TEDD, (2002, Ghana's Current Export Species. World Wide Web UL: www.ghanatimber.org/ghanatimber/timber.html.

Online Documents

Forestry Commission of Ghana. Owabi Wildlife Sanctuary, Kumasi, Ghana, 2006. Available at http://www.fcghana.org. Date Accessed: 10 February, 2011.

IDRC, 1999. Cut and Run –Illegal Logging and Timber Trade in the Tropics. URL: World Wide Web: http://www.drc.ca/acb/showdetl.cfm?&DID=6&Product DD=70&CATID=15. 05/05/07.

IUCN, 1995. Incentives for Cocoa Farmers in Ghana. URL: World Wide Web:www. biodiversityeconomics.org/incentives/topics-15-00.htm

Meyer, W.B., 1995. Past and Present Land-use and Land-cover in the U.S.A. Consequences Vol 1, No. 1:www. gcrio.org . p. 24-33..

Millennium Ecosystems Assessment, 2005 http://www.unep.org/maweb/documents/document.358.aspx.pdf

Overmars, K. P., & Verburg, P. H. 2006. Multilevel modelling of land use from field to village level in the Philippines. Agricultural Systems, 89(2-3), 435–456. doi:10.1016/j.agsy.2005.10.006

Robinove, C.J. (1986), Principles of Logic and the Use of Digital Geographic Information Systems. U.S. Geological Survey Professional Paper No. 977.U.S. Gov. Printing Office, Washington, D.C.

Sanderson, R. (2010), New Mexico State University http://www.irfanakar.com/turkish/pdf2/UA/Kitaplar/remote_sensing.pdf pp 1-38

Conference Proceedings

UNFPA (1994), Programme of Action - Adopted at the International Conference on Population and Development (ICPD), Cairo,-PoA_en.pdf.(n.d.).

United Nations 1993. Report of the United Nations Conference on Environment and Development (UNCED), Rio de Janeiro, 3-14 June 1992, vol. 1.

Teotia, H. and Santos, D. (2010), Remote sensing and GIS based land cover, soil & land capability information for resources management in semi-arid region of Paraiba, Brazil: ASPRS 2010 Annual conference, April 26-30 2010, San Diego, California.

Books

Ehrlich, P. and Ehrlich A. 1990. The Population Explosion. New York: Simon & Schuster.

Leopold, A., 1949. A Sand County Almanac. Oxford University Press. Ballantine Books. New York.

Zaba, B. and J. Clarke, eds. 1994. Environment and population change. Liege, Belgium: Ordina Editions.