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MONITORING OF DEFORESTATION IN KUMASI AREA (GHANA) BY SATELLITE BASED MULTI-TEMPORAL LAND USE ANALYSIS

MONITORING WYLESIEŃ W REJONIE KUMASI (GHANA) NA PODSTAWIE WIELOCZASOWEJ ANALIZY UŻYTKOWANIA ZIEMI

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Introduction

Deforestation in tropical Africa is driven by a variety of socio-economic and environmental factors, and has resulted in land cover changes that threaten biodiversity, water and energy resources, and contributes to trace-gas emissions. Several conservation and development studies have concluded that the deforestation in Africa is closely tied to demographic conditions such that the greatest loss of rain forests has occurred in the countries with high population growth. However, lack of reliable data and survey information in some countries, has made the estimation of areas of intact forest and/or under land use change and their relation to economic indicators surprisingly difficult to establish. Consequently, the extent and rate of deforestation in Africa are less known than in other regions of the world.

The studies by the Food and Agriculture Organization (FAO, 1997; 2007) reported that the world's tropical forests are reduced by an average of 15.4 million hectares per year (0.8% annual rate of deforestation). The phenomenon of deforestation is occurring globally, in different types of forests, and for different reasons. At the end of 2005, Africa had estimated 635.4 million hectares, or ca 30% of the world's tropical forests. In several Sub-Saharan African countries, the rate of deforestation exceeded the global annual average of 0.8%.

In West Africa, in 2005 some 74.3 million ha of forest was registered. This means about 1.17% annual decrese since 2000 when annual deforestation rate for 1990–2000 was estimated at 1.17%. Ghana contributes to deforestation as well. Since 1990 the annual deforestation rate is some 2% (FAO, 2007). The rate of forest area decline in Ghana is higher than average values for Africa (which is 0.62% annually) and West Africa (1.17%).

The largest proportion of Africa's tropical moist and rainforests exist in their West and Central parts. These are rapidly vanishing. Africa lost the highest percentage of rainforests during the 1980s and this trend has continued. Around the turn of the century, West Africa had some 500,000 km^2 of coastal rainforest. However, the tropical forests of West Africa, mostly lowland formations easily accessible from the coast, have been largely depleted by commercial exploitation, namely logging, and conversion for agriculture. Only 22.8% of West Africa's moist forests remain, much of them degraded (FAO, 1997).

Biodiversity conservation and the judicious use of natural resources engaged the attention of scientists, politicians and other active players in world affairs and culminated in the 1992 Earth Summit in Rio de Janeiro, Brazil where issues of environmental conservation received major boost. Other conventions have taken place to set the political framework to do away with the negative utilisation practices, which destroy conservation and management of biodiversity (Klein et al., 2001)

Trees appear to receive more attention, probably because of the popular axiom, which says that, when the last tree dies the last man will also die (Osei-Adu, 2002). This axiom illustrates the importance of trees to human beings as a source of oxygen, food and shelter.

In Ghana laws protect forest reserves. The ministry and commission at both the central and local government levels protect these forests reserves. However trees outside of the forest, which obviously in the majority play significant roles in the national development are unregulated and left to the mercies of landowners (Boffa, 2001).

Land use and land cover change have become central components in the current strategies for managing natural resources and monitoring environmental change. Since late 1960's, rapid development of the concept of vegetation mapping has led to increase in the number of studies of land use and land cover change worldwide. Providing an accurate assessment of the extent and health of the world's forest, grassland, and agricultural resources has become an important priority.

Viewing the Earth from space since 1970s has become essential to comprehend the cumulative influence of human activities on natural resource base. In the times of rapid, and often unrecorded, land use change, observations from space provide objective information about human utilization of the landscape. Over the past three decades, data from satellites has become important in mapping the Earth's features and infrastructure, managing natural resources, and studying environmental change.

Geographic information system (GIS) and remote sensing technologies have greatly increased the capability to study different parts of the environment in an amazing fashion. This technology has provided resource managers and researchers a tool to analyze data and address specific problems at a variety of spatial scales, in less time, and in a more cost-effective manner (Sample, 1994). One major focus of using GIS techniques as a management tool is to quantify, qualify, analyze, and evaluate wildlife species habitats and their distributions. Due to of coverage, high spatial resolution and exact allocation in time, remote sensing data is a vital source of information for mapping and modelling for various applications in landscape ecology. Although recent and future sensors offer better spatial resolution (0.5 m), satellite data with mid-resolution (i.e. 15-30 m resolution, e.g. Landsat ETM+, SPOT, ASTER) still play a major role for areas under investigation on a contry or continental scale.

This study employs remote sensing and geographic information system to make effective analysis of the land use/cover change in the Kumasi metropolis and its environs within the Ashanti Region of Ghana. It intends to address three distinct and interrelated scientific goals:

1. To estimate the land cover and land use change in the Kumasi metropolis and its environs for the period between 1986 and 2003 using Landsat images.
2. To classify and map the designated area with regard to land use/cover.
3. To integrate the resulting land cover map and classification in a socio-economic comparative study in order to draw conclusions on the general patterns and causes of land use/cover in this part of Ghana.

Ghana and Ashanti region

Ghana is situated on the West coast of Africa with a total area of 238540 km^2. It has a North-South extent of about 670 km and a maximum East-West extent of about 560 km. It shares borders with Côte d'Ivoire to the West, Burkina Faso to the North and Togo to the East. The South is the Gulf of Guinea, which is a part of the Atlantic Ocean. The topography is predominantly undulating and has low relief with slopes of less than 1 percent. Despite the gentle slopes, about 70% of the country is subject to moderate to severe sheet and gully erosion. The highest elevation in Ghana, Mount Afadjato in the Akwapim-Togo Ranges, rises 880 m above sea level (www.ghanaweb.com).

Ghana's Gross Domestic Product (GDP) in 2003 was USD 7.7 billion. Agriculture contributed 35.2% of the GDP in 2003, while about 56% of the economically active population was employed in the sector in the same year. The annual per capita income in Ghana was USD 390 in 2001. The services sector and the industrial sector, including mining and construction, are also important in terms of contribution to the GDP. The country continues to be an exporter of primary products (cocoa, timber, gold) and an importer of manufactured goods and fuels, making its economy vulnerable to external shocks (Asenso-Okyere, 2001).

Ghana is one of the most populous countries in Western Africa. The population of 12 million in 1984 had increased to over 21 million in 2005 (Table 1). The past rapid growth of Ghana's population is the outcome of high fertility, which until recently remained fairly constant, and declining mortality. This combi nation of high fertility and declining mortality is also the cause for the young age structure of the Ghanaian population with 43 percent under 15 years of age (GSS, 2005).

Table 1. Regional population of Ghana in 1984 and 2005

Region	Population 1984	Population 2005	Population increase in %
Ashanti	2 090 100	3 533 227	70
Brong Ahafo	1 211 907	2 412 859	99
Central	1 142 335	1 667 082	45
Eastern	1 680 890	2 782 426	65
Greater Accra	1 431 099	2 861 777	100
Northern	1 164 583	2 378 246	104
Upper East	772 744	1 334 186	73
Upper West	438 008	709 979	62
Volta	1 211 907	1 768 612	46
Western	1 157 807	2 173 911	88
Total	12 301 380	21 622 305	76

The country is divided into 10 administrative regions (Tab. 1 and Fig. 1). The highest concentration of habitation continued to be within the Ashanti, Greater Accra and Western regions triangle, largely because of the economic productivity. In fact, all of the country's mining centres, timber-producing deciduous forests, and

cocoa-growing lands lie in Ashanti, Brong Ahafo, in Eastern and Western parts of the Central regions. It also is conveniently linked to the coast by rail and road systems – making this area an important magnet for investment and labour. The rate of urbanization varied from one administrative region to another. However, the Greater Accra and Ashanti showed a high percentage of urban residencies. Urban areas in Ghana have customarily been supplied with more amenities than rural locations. Consequently, Accra, Kumasi, and many towns within the Southern economic belt attracted more people than the savannah regions of the North (GSS, 2005).

The prevalent agricultural system in the Southern Ghana is land rotation. This system almost always is preceded by slash and burn. This has been a powerful tool of transformation of land cover types giving rise to new land cover types after the farming season. It was estimated that as much as USD 50 million of wood is illegally exported from Ghana annually (Aiken, 1995). Due to the fast declining timber resources, 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 foreing exchange earner for Ghana after cocoa, but it has now slipped to third place behind cocoa and gold (TEDD, 2002). The land use activity like logging has been observed to have the potential of reducing trees out of protected areas (IDRC, 1999).

Tropical rain forests cleared for colonization, conversion into agricultural fields, and the use of wood for fuel is important for assessing the net release of carbon into the atmosphere. The forest conversion affects the biogeochemical cycle and global atmospheric concentration of carbon dioxide in two phases: the initial clearing of forests (burning and logging) releases significant amount of carbon; and the type and intensity of subsequent agricultural use determines the long-term carbon cycling. The conversion/intensification sequence influences other important processes such as biotic control of water and energy exchange between the land surface and atmosphere (Houghton, 1991).

The agents of deforestation are those individuals, corporations, government agencies, or development projects that clear the forests as opposed to the forces that motivate them. The direct causes are most visible, easily identified and readily associated with the agents of deforestation. The main causes are: slash-and-burn farming, commercial agriculture, mining and petroleum exploration, infrastructure development, fuel-wood collection and charcoal making, logging.

Ashanti region, with Kumasi as its capital, lies approximately in the centre of the country (Figure 2). It covers an area of 24,390 square kilometres representing 10.2% of the land area of Ghana (www.ghanaweb.com).

Ashanti region is the most populous in Ghana. According to the 2000 Population and Housing Census Report called the Ghana Living Standards Survey for the year 2000 (GSS, 2005) by the Ghana Statistical Service, the region recorded a total of 3,612,950 persons representing 19.1% of national total of 18,912,079 persons. Males constitute 50.2%. Out of the 364 settlements described as urban in Ghana that is with a population of 5000 and above, 58 are in Ashanti. Some 51.3% of people live in urban settlements. The region has 18 administrative districts, the highest in the country. It is made up of 1 Metropolitan Assembly (Kumasi metropolitan Assembly) and 17 other District Assemblies (www.ghanaweb.com).

Materials and methodology

This research addresses land use and land cover changes over a 17-year period of study, 1986 to 2003 in the Ashanti Region. The dynamics of forest conversion to agricultural land and expanding human settlements were visualised. The spatial distribution and patterns are the primary focus of this study.

The following materials were used for the study:

1. A digital map of Ghana in vector shapefile format containing districts, regions, forest reserves, roads and water bodies (obtained from the Forest Commission of Ghana in Kumasi).
2. Landsat images acquired on 11th January 1986 (TM) and 19th February 2003 (ETM+) obtained from University of Maryland.
3. ERDAS Imagine, ArcGIS and ArcView softwares.

Maps and site visitations were undertaken (ground truthing or ground verification) to ascertain the extent of environmental and anthropological activities on the area of interest. Moreover, one of the authors is a native of the region and familiar with environmental, climatic and anthropogenic happenings of this region. The forest commission of Ghana also offered insight into the land use/cover, especially concerning forests reserves located in the region.

Within the scope of this project, the concept behind the process of mapping land use and land cover change over time was to begin with mapping the present (2003 satellite imagery), then looking back to map the past (1986 satellite imagery) to assess for changes.

Landsat 1986 image is partly covered with clouds at the South-Western part. Forest reserves here are relatively undisturbed; the city of Kumasi is relatively small as compared to other elements in this image. The lake Bosumtwi is clear and surrounded by its satellite towns and communities. Northern part of the image shows the savannah of the Brong Ahafo region of Ghana. At this resolution of the image of 25.8 metre, smaller water bodies and roads can not be clearly seen.

Landsat ETM+ 2003 image shows extensive cloud formation at the Southern part. The lake, Bosumtwi and its satellite towns are heavily covered. The cloud also covers the part of the city of Kumasi at the lower image. However, the savannah of the Brong Ahafo region is clear. Disturbances in the forest are quite extensive in this image. Similar to TM image from 1986, smaller water bodies cannot be visualised because of the resolution (25,8 metre) of the Landsat ETM+ satellite image.

Both Landsat TM 1986 and Landsat ETM+ 2003 images were geo-referenced to vector shape format map of Ghana containing regions, districts, roads, forests reserves, towns and water bodies. Verified accuracy of georeferencing was 1 pixel. There were some difficulties in referencing to forest reserves which boundaries obviously were not very precisely digitised. All other elements of vector map fit to the images well.

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, January 11, 1986 and February 19, 2003. A hierarchical level II land use and land cover classification comprised of 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% was deemed satisfactory.

Results

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 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, transportation and other social amenities.

Table 2. Acreages of land use classes

Categories	Lan use class areas in km^2 (and %)	
	1986	2003
Forest	528.35 (71.22)	246.96 (33.24)
Agriculture	169.13 (22.77)	358.68 (48.28)
Stable Water	1.89 (0.25)	2.15 (0.30)
Housing & Utilities	43.49 (5.85)	135.07 (18.18)
Total	742.86 (100.00)	742.86 (100.00)

The land use/cover map for 1986 (Figure 3) showed the Kumasi metropolis very green. Some 71% of the land cover is forest (Table 2). The agriculture is next in rank with 23%. Most of the population are subsistent farmers. This explains why the agricultural lands are in clusters, where they appear as a big mass, subdivided into small farms. Water and housing takes the last 6%. The Barekese and Owabi head works are the only visible water bodies in the image. This does not mean that there are no rivers and lakes. The non-appearance of smaller water bodies is due to the fact that, the images were taken in January, at the peak of dry season. Moreover, the resolution of the Landsat TM is unable to show all the terrestrial features.

The land use/cover map for 2003 (Figure 4) shows that the Kumasi metropolis lost almost 38% of its forest cover. Housing and social amenities have expanded in all directions. Agriculture has also increased and has taken much of the forest. Water share of the land cover remains somehow constant. However, serious encroachment is seen in the forests surrounding the two water bodies in view. The expansion of the city is getting closer to the water bodies.

Table 3 and Figure 5 show extensive changes that have occurred between 1986 and 2003 on the almost 50% of AOI. The biggest change was recorded as forested land gave way to agriculture (some 35% of AOI). Housing also took another slice of the forest cover (5%). A marginal gain for the forest cover was probably the result of teak plantation, which is becoming popular in Ghana due to their fast growth and market value in electrification projects (2%). Agriculture lands were also converted into places for housing (8%).

Table 3. Change in land use 1986–2003 for Kumasi and it environs

Changes in land use	Area of change		
	km^2	%	% of AOI (742.86 km^2=100%)
Forest → Agriculture	256.50	69.40	34.51
Forest → Housing	39.71	10.70	5.35
Agriculture → Forest	15.52	4.20	2.10
Agriculture → Housing	58.00	15.70	7.81
Total	369.73	100.00	49.77

Figure 5 shows that, expanding human settlements were along the road networks. The city expansion from 1986 to 2003 was in all direction.

Discussion

The use of remote sensing and geographic information system provided a very useful means of studying land use/cover. The results (Tables 2 and 3, and Figures 3, 4 and 5) of this study indicate that, the land cover of Kumasi and it environs have undergone serious and very profound changes. Overall analysis indicates that, there was net expansion in agriculture, housing and utilities at the expense of the forest cover between the 1986 and 2003.

It looks like the 1992 Earth Summit in Rio de Janeiro (Brazil) where issues of environmental conservation received major boost and other international conventions which have taken place to look at the management of biodiversity (Klein, 2001), mean nothing to the people of Kumasi and its environs. This could be a misconception as the causes of deforestation and other environmental degradation issues are steeped in the struggle for survival and economic freedom in this part of the world. Ghanaians have long cherished tradition of managing their environment. For example it is a taboo to farm along rivers and other water bodies. The traditional laws sought to protect rivers, lakes and their catchments from drying (Akuoko, 2001). However, these traditions are threatened and eroding as a result of civilisation and proliferation of religious beliefs.

The modern Ghanaian society and for that matter its environments are governed by proper laws. For example, laws and statutory bodies protect trees in forest reserves. The real problem of deforestation is the management of trees outside of the forest, which are unregulated and left to the mercies of landowners (Boffa, 2001).

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

The results obtained from the land use/cover classification clearly indicate that, the change in land use/cover from 1986 to 2003 (seventeen year interval) was clearly driven by anthropogenic forces as Hens and Boon in 1999 stated: *A major characteristic of land use/ cover in Ghana is competition among the three main economic sectors namely agriculture, mining and logging*.

Within a period of seventeen year (1986-2003), 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 factors:

1. Rapid population growth: increase in the population has contributed significantly to deforestation. The population growth rate of 3% per year is relatively high. Increasing population require more land to put to agricultural use to provide food for the growing population. More lands have to be cleared or give way to provide places for settlements and other social amenities for the increasing population.

2. The timber industry: it is estimated that as much as US$50 million of wood is illegally exported from Ghana annually (Aiken, 1995). 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 foreign exchange earner for Ghana after cocoa, and 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 can occur 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 the forest as the chainsaws are to individual trees. Land use activities like logging have been observed to have the potential of reducing trees out of protected areas (IDRC, 1999).

3. Agriculture: most of the clearing is done for agricultural purposes — grazing cattle, planting crops. Poor farmers chop down a small area (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 grow beef for the world market. The agricultural system in the area of interest is land rotation. This system, almost always preceded by slash and burn, has been a powerful tool of transformation of 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 the basic way of life for a large part of the population. In Brazil, for example, the average annual earnings per capita is USD 5,400, compared to USD 26,980 per capita in the United States (World Bank, 1998).

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.

Conclusions

The main thrust of this study involves the classification of Landsat TM and ETM+ satellite imagery to study land use/cover changes between 1986 and 2003, in the Kumasi metropolis and its environs in the Ashanti Region in the Republic of Ghana. The main aim of this study was to produce land use/cover map for Kumasi and its environs from satellite imagery spanning the period of study. In addition, the aim was to assign reasons for the changes in land use/cover between 1986 and 2003.

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 ever 100% correct, when it is produced by a computer (Robinove, 1981). 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 seventeen-year time span, 1986–2003, considered in this study is a relatively 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 in other parts of the world. These changes result from mainly anthropogenic forces such as rapid population growth, agriculture, timber exploitation and other economic ventures.

The patterns of land use/cover are changing rapidly in Kumasi and its environs as more houses continue to be built, small-scale and commercial farmers clear more land in an attempt to increase their production to meet the needs of increasing population and to ensure their economic well-being. Thus, the deforestation, which has occurred in the Kumasi metropolis and its environs in the past 17 years, 1986–2003, appears to be linked to increased housing and utilities provisions and agricultural production.

The assessment of the land use/cover change has been compiled with remote sensing and GIS analysis. However, the resulting spatial data yielded from this study offers prospects for further analysis. As satellite technology continues to advance, satellites with increased resolution characteristics will be utilized in future studies. Presently, commercialized satellite corporations such as the QuickBird satellite system offer satellite imagery characterized by spatial resolution of 0,5 m in panchromatic and 2 m in multispectral mode. In addition, hyperspectral sensors characterized by very large spectral ranges will also improve future mapping projects on smaller scale. However, the high cost and tremendous data storage requirements currently limit the use of such data for larger scale mapping projects. Nonetheless, future utilization of such satellite imagery will allow for finer levels of detail, for more accurate classifications and analysis of more subtle changes in land use and land cover.

This study considered mainly the anthropogenic factors as the main forces of land use/cover changes in the Kumasi metropolis and its environs. However, it will be very expedient to examine the influence of climatic factors such as rainfall and temperature on the land use/cover as well. It was not possible under this study but in the future, with improved data collection, this part could be added.

Aldo Leopold argued that land ethics must become instilled as a primary component of global society. In other words, land ethics changes the role of Homo sapiens from the conqueror of the land to a member and citizen of it. It reflects the existence of ecological consciousness, and this in turn reflects the conviction of individual responsibility for the health of the land. It also implies respect for 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 (Leopold, 1949).

Although this was written six-eight years ago, the words of Aldo Leopold speak louder than ever and hold more truth as mankind continues to modify the 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).

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Streszczenie

Wylesienia lasów tropikalnych powodowane są przez różne czynniki społeczne, gospodarcze i środowiskowe. Wiele studiów pokazuje, że zmiany w użytkowaniu ziemi i pokryciu terenu Afryki są związane ze zwiększaniem zaludnienia. W samej tylko Ghanie w latach 1984–2003 zaludnienie zwiększyło się o 76%, a w niektórych prowincjach nawet ponad 100%. Powoduje to wylesienia i degradację lasów. Szacuje się, że wskutek antropopresji utracono juz około 80% wilgotnych lasów w Afryce Zachodniej. Artykuł przedstawia analizę zmian użytkowania ziemi w rejonie Kumasi w Ghanie. Miała ona na celu:
1) określenie zasięgu i rodzaju zmian w użytkowaniu ziemi w rejonie Kumasi w okresie ostatnich lat,
2) wykonanie analiz dostępnych zobrazowań satelitarnych badanego obszaru z punktu widzenia klasyfikacji użytkowania ziemi,
3) analizę wyników klasyfikacji w odniesieniu do danych społeczno-gospodarczych.

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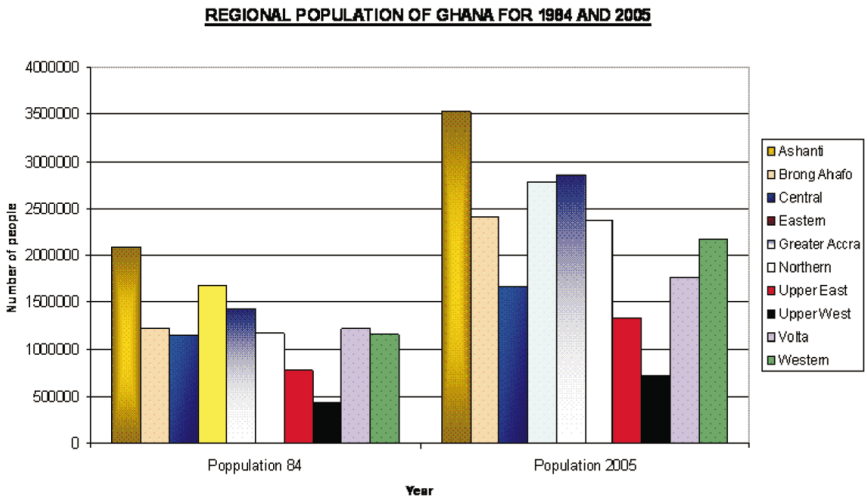

Figure 1. Regional population of Ghana in 1984 and 2005

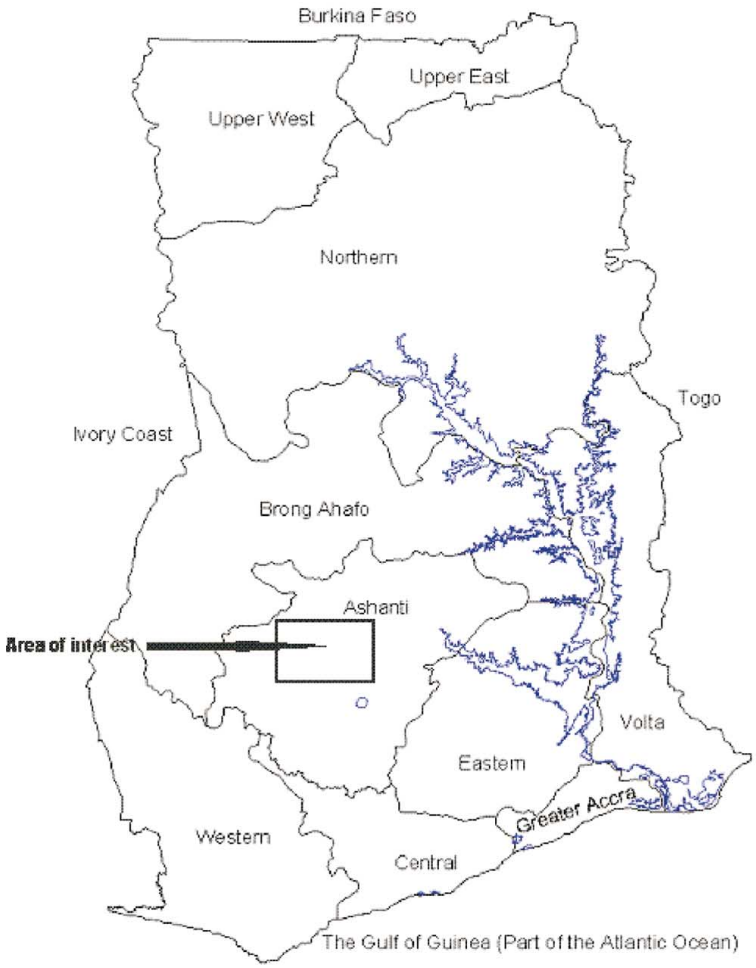

Figure 2. Regions of Ghana and area under study

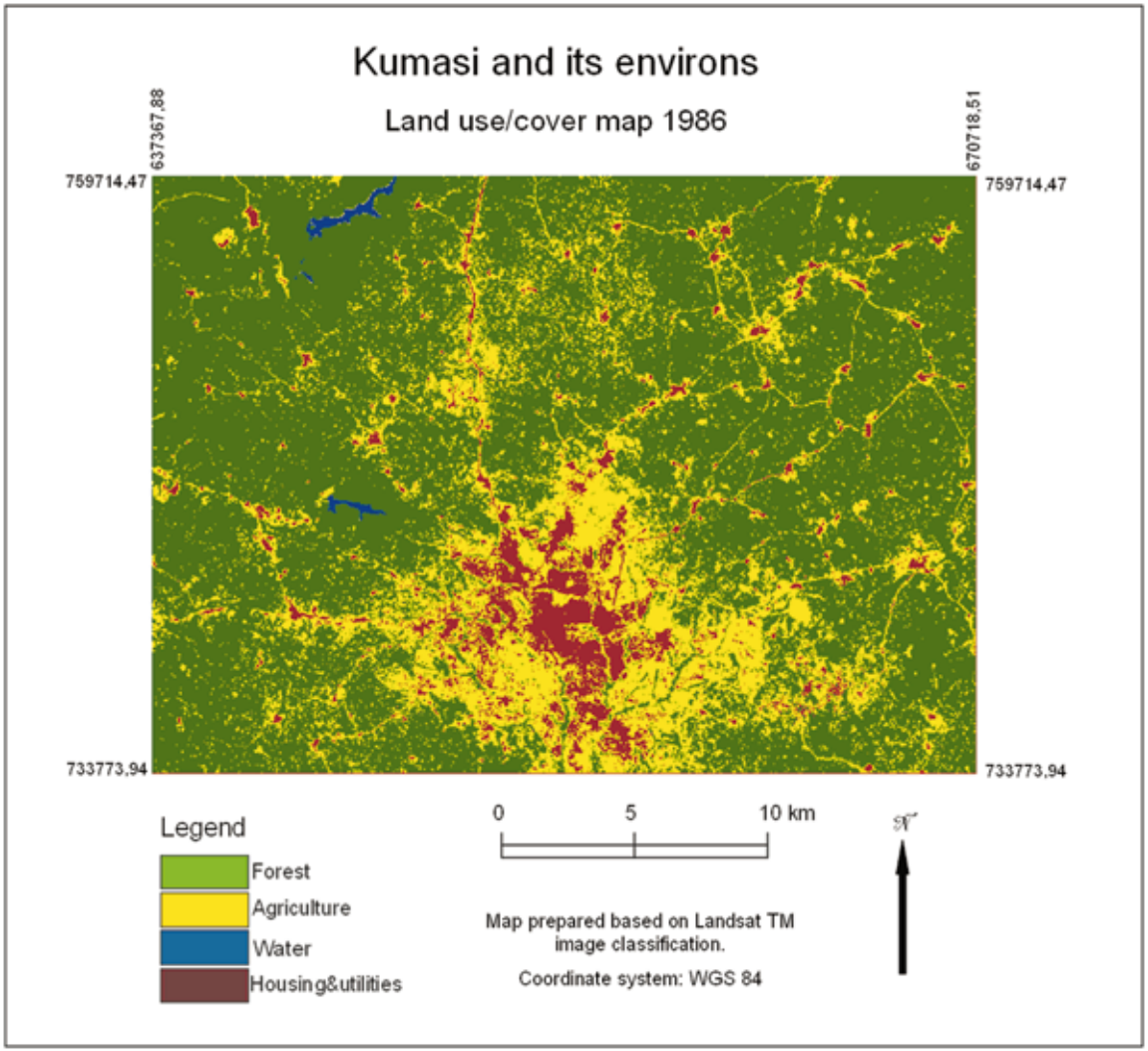

Figure 3. Map of land use/cover in 1986

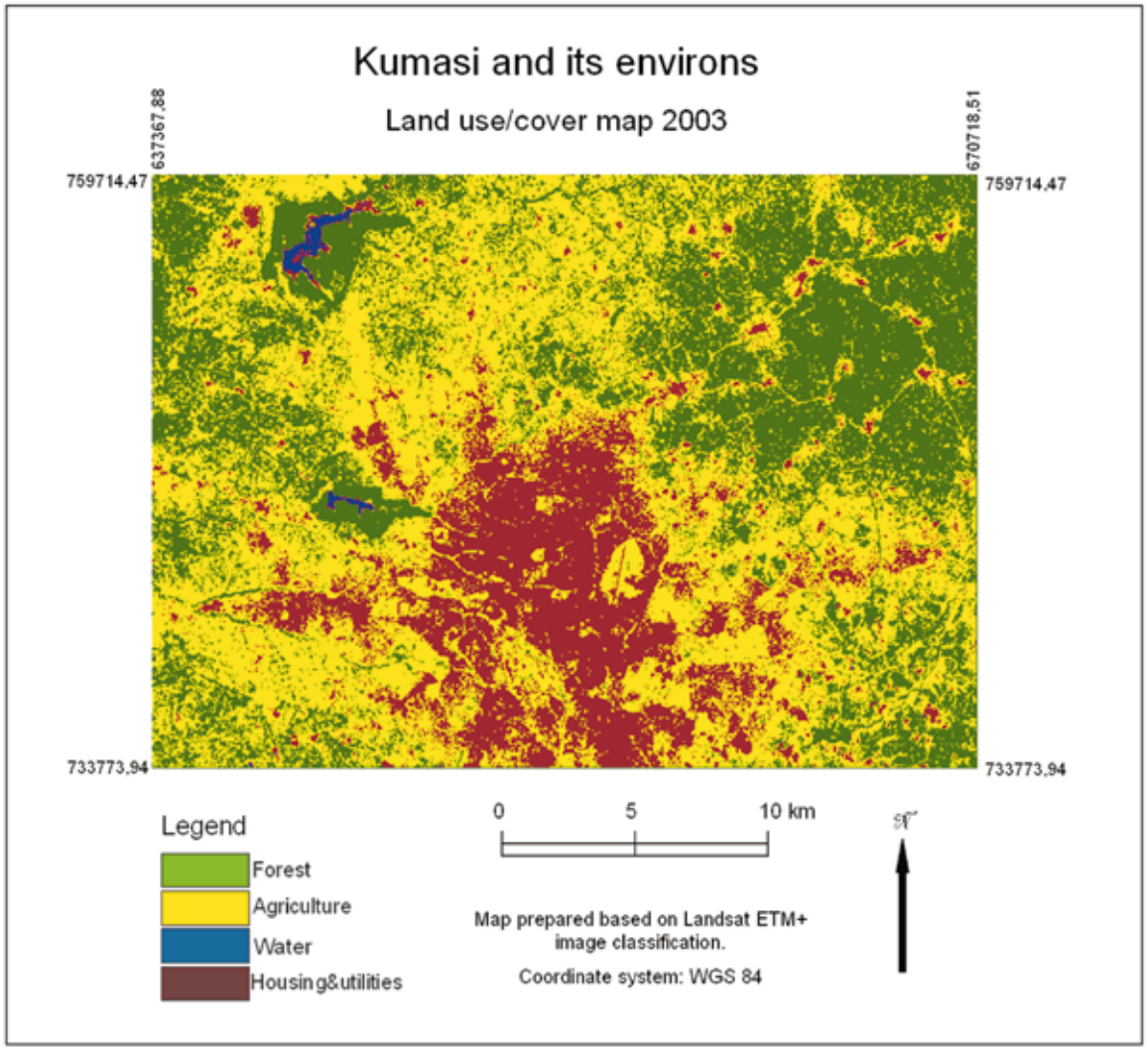

Figure 4. Map of land use/cover in 2003

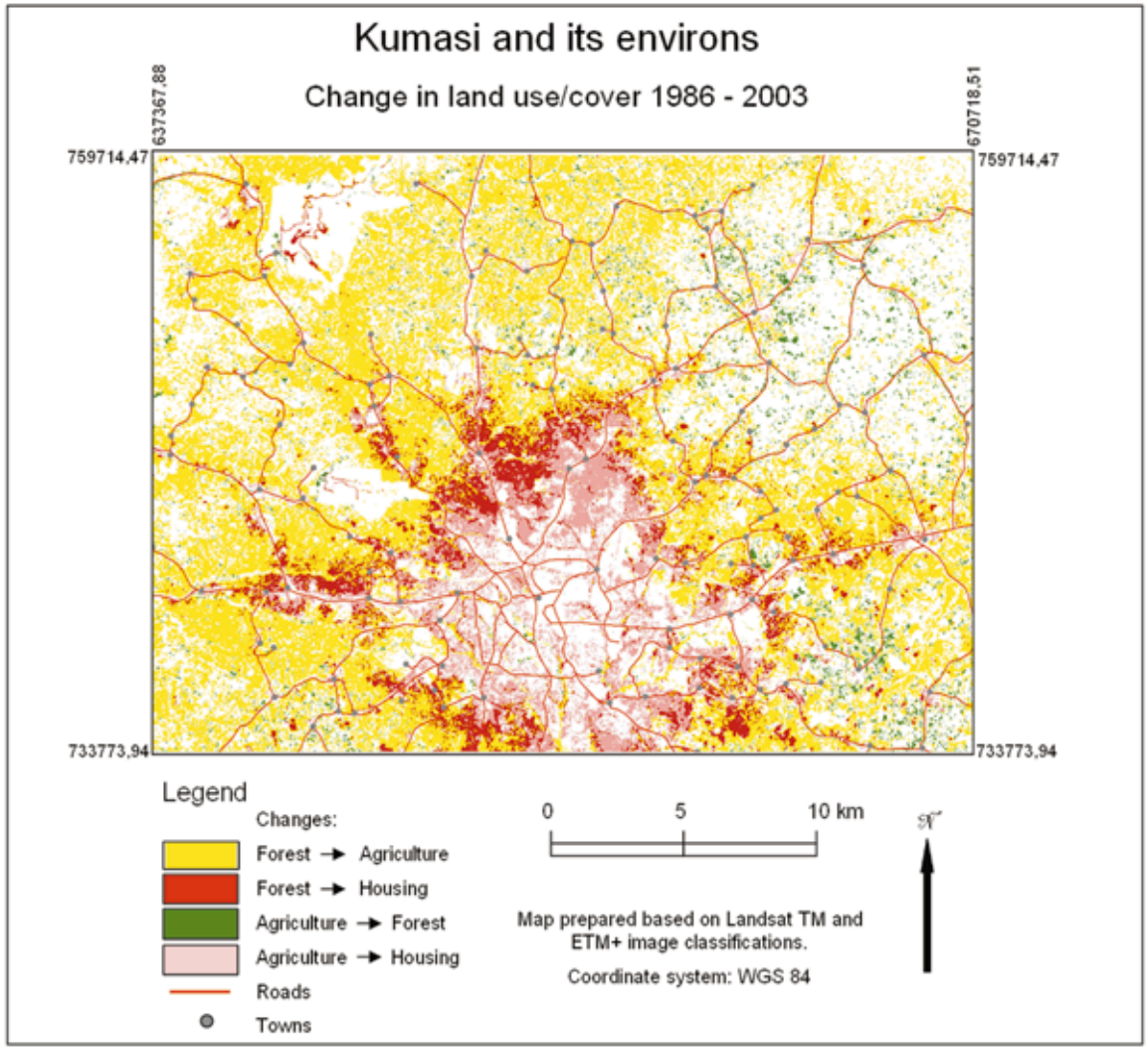

Figure 5. Map of land use change 1986-2003 for Kumasi and its environs