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Urban land use/land cover changes in the Tema metropolitan area (1990–2010)

Simon Mariwah · **Kingsley Nana Osei** ·
Mark Seyram Amenyo-Xa

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Abstract Land use and land cover changes are local and place specific, occurring incrementally in ways that often escape our attention. This study sought to detect changes in land cover in the Tema Metropolis of Ghana from 1990 to 2010. Multispectral Landsat Thematic Mapper data sets of 1990, 2000 and 2007 were acquired, pre-processed and enhanced. Unsupervised classification of the images was performed and six land cover classes (water, wetlands, closed vegetation, open vegetation, cropped lands, and built-up) were derived. The post-classification change detection technique was performed to derive the changes in land cover and their corresponding change matrices. Between 1990 and 2010, built-up areas expanded steadily to become the most prevalent land cover type in the metropolis, reducing vegetation cover dramatically. High population growth with its attendant rise in the demand for housing, and increasing commercial activities, were found to have influenced land cover changes over the period.

Keywords Land use · Land cover changes · Change detection · Population · Tema · Ghana

S. Mariwah (✉) · K. N. Osei · M. S. Amenyo-Xa
Department of Geography and Regional Planning,
University of Cape Coast, Cape Coast, Central Region,
Ghana
e-mail: simonmariwah@gmail.com

Introduction

The earth's surface, throughout its history and existence, has undergone changes and modifications at varying space and time scales—some over short time spans and others over many years; some reversible and others irreversible (Erle 2010). The pace, magnitude and spatial reach of direct and indirect alterations of the earth's land surface by humans in recent decades according to Lambin et al. (2001) are unprecedented. Lambin et al. (2001) also posit that land use and land cover change are the most important effectors and outcomes respectively, of human induced earth surface alteration. Furthermore, when aggregated globally, both changes are so insidious that they considerably affect key aspects of earth system functioning.

Land cover designates the visible evidence of land use, to include both vegetative and non-vegetative features whiles Land use on the other hand, may be defined as the use of land by people usually with emphasis upon the functional role of land in economic activities (Campbell 1987). Land cover is easily recognised on the field than land use which is usually inferred from the cover. These two words are closely related that in mapping they are used together to avoid ambiguity (Lillesand et al. 2004).

The land use and land cover pattern of a region is largely considered to be an outcome of natural and socio-economic factors and their utilization by man in time and space (Fuller and Gaston 2009). Changes in

both phenomena directly impact biotic diversity worldwide (Sala et al. 2000), contribute to local and regional climate change as well as to global climate warming (Chase et al. 2000; Houghton et al. 1999), are the primary source of soil degradation and, by altering ecosystem services affect the ability of biological systems to support human needs. Such changes also determine, in part, the vulnerability of places and people to climatic, economic or socio-political perturbations (Kasperson et al. 1995).

Nevertheless, at national, regional and local levels, land use—land cover change outcomes are critical information (inputs) in the formulation of policies regarding economic, demographic and environmental issues; decision making, monitoring and management practices as in water—resource inventory, flood control, water-supply planning and waste-water treatment (Anderson et al. 1976; Campbell 1987).

According to the Intergovernmental Panel on Climate Change (IPCC 2000), despite improvements in land cover characterization made achievable by earth observing satellites, global and regional land covers and, in particular, land uses are poorly enumerated. Urban landscapes are proportionally the fastest emerging land cover type resulting from the fact that 50 % of the world's population, for the first time in human history, now live in towns and cities (UN Habitat 2009). Urban expansion has increased the exploitation of natural resources and has changed land use and land cover patterns. Yuan et al. (2005), for instance, have linked regional economic vitality with urban growth or expansion, particularly the movement of residential and commercial land use to rural areas at the periphery of metropolitan centres.

Recently, UN Habitat (2009) reported that nearly half of the world's population and three quarters of all westerners live in cities. World population, according to DESA (2009, 2010), is expected to increase by 2.3 billion, passing from the 2009 estimate of 6.8 billion to 9.1 billion by 2050. In that time, the report (DESA 2010) projects the population living in urban areas to gain some 2.9 billion, passing the 2009 figure of 3.4 billion to 6.3 billion by 2050. Urban areas of the world are expected to absorb all population growth projected over the next four decades, drawing in concurrently, some of the rural population (DESA 2010).

Furthermore, it is indicated that, the expected population growth in urban areas will be concentrated in the cities and towns of less developed countries,

with 66 % of the 2050 population projection for less developed countries being urban, and 86 % of the same projection for more developed countries being urban. Overall, the world population is expected to be 69 % urban in 2050. As an inevitable process which results from economic development and rapid population growth (Rimal 2011), urbanisation, especially for developing countries, places much pressure on existing urban structures such as housing and transportation. Problems emanate from the spatial distribution of the increasing urban population on the land that serves consequently as a fundamental determinant of land use/land cover changes (Small 2004). The increasing need for land and land resources forces urban dwellers to acquire and develop land at the fringes of urban centres.

Substantial amounts of data about the Earth's surface are required for effective monitoring and analysis of land use/land cover changes. Previously, throughout the world, such information on land use/land cover change were generated primarily through conventional ground survey methods which were not only time consuming, costly, tedious and demanding lots of manpower, but also somewhat impractical for monitoring dynamic changes over shorter periods (Chaudhary et al. 2008). Recent advances in geographic information system (GIS) and remote sensing (RS) tools and techniques enable researchers to model urban growth effectively. Through remote sensing satellite images provide excellent sources of data from which updated land use/land cover information and changes can be extracted, analysed, and simulated efficiently. Satellite remote sensing, for instance, as depicted in the works of Alberti et al. (2004), Goetz et al. (2004), and Yang (2002), has the potential of providing accurate and timely geospatial information that describe changes in land use/land cover of metropolitan areas.

In Ghana, Songsore (2003) suggests that the population, consistent with observed trends in most parts of Africa, is becoming largely urbanised. Indeed, data published by the Ghana Statistical Service (GSS 2002) indicated that the urban population increased from 23 % in 1960 to 44 % in 2000. Furthermore, the urban settlements—settlements with population of 5000 or more—increased from 98 to 364, accounting for 8.3 million people. This rapid urbanisation is largely driven by demographic factors such as rural urban migration and improved natural growth rate in

cities (GSS 2002; Songsore 2003). Like the nine other largest urban areas in Ghana—Accra, Kumasi, Sekondi-Takoradi, Tamale, Ashaiman, Obuasi, Koforidua, Cape Coast, and Wa—the statistics provided by the GSS indicate a consistent rise in population figures of the Tema metropolis in the 1970, 1984 and 2000 Population and Housing Censuses.

The Tema metropolis, however, is poorly enumerated with regards to spatio-temporal land use/land cover information which is essential for the planning, implementation and monitoring of development schemes to meet the increasing demands for basic human needs and welfare while at the same time preserving biodiversity. This study, therefore, seeks to provide spatio-temporal information on land cover changes in the Tema metropolis that are necessary for zoning and planning using GIS and RS tools. Specifically, the study seeks to generate a land cover classification maps for the Tema metropolis; establish land cover changes of the metropolis from the period 1990 to 2010 and the rate of transition of the changes; and identify the driving factors that have contributed to these changes.

Study area

The Tema Metropolitan Area is a coastal metropolis located in the Greater Accra Region of Ghana. Its capital—Tema, is located 25 km east of the country's capital, Accra. Located between latitudes 5° 35″N–5° 50″N and longitudes 0° 10″W–0° 05″E, the region covers an area of approximately 365.78 km^2 (See Fig. 1). The metropolitan area is bounded to the West by the Adenta and Leedzokuku Krowor municipalities, to the North by the Ga East and Akuapim South municipalities, to the East by the Dangbe West district, and to the South by the Gulf of Guinea. Situated at the centre of the area is the newly created Ashaiman municipality.

The Tema Metropolis lies within the coastal savannah vegetation zone with low annual rainfall averaging 800 mm distributed over <80 days. The rainfall pattern of the area is bimodal with the major season falling between the months of April and mid-July, and a minor rainy season around the month of October. The mean monthly temperature ranges from 24.7 to 28 °C with an annual average of 26.8 °C. The nearness of the region to the equator makes daylight hours practically uniform during the year. Relative humidity is generally high, varying from 65 % in the mid-afternoons to 95 % at night. The vegetation cover of the metropolis is primarily shrub and grassland with isolated trees that are only denser towards the northern fringes of the metropolis—the foothills of the Akuapem-Togo mountain range.

Materials and methods

Primary and secondary data sets were employed in the study. Primary data was derived from Landsat satellite imagery. Landsat TM and ETM+ satellite image data sets of 1990, 2000, and 2007 were used (See Table 1). All images were captured at approximately the same period during the dry seasons of the respective years. During that period, all land surface features exhibit consistent reflectance properties irrespective of the year of acquisition (Eastman 2006). Spectral bands 1, 2, 3 and 4 of each image set were stacked in ArcGIS.

Image processing

The Landsat image scenes for the study were radiometrically corrected to remove haze and noises from the image. They were then projected from WGS 84 (a geographical coordinate system of latitudes and longitudes) unto the Universal Transverse Mercator (UTM) Zone 30 North, (a projected coordinate system of Eastings and Northings). The images were then subsetted to the study area.

Linear contrast stretching was applied to the 2000 and 2007 Landsat images because of the general low level of contrast. This enhanced the contrast in the images thereby improving on the visual appearance of the images.

Unsupervised classification was carried out on the images in ERDAS Imagine 9.3 suite into 100 classes using the ISODATA (Iterative Self-Organising Data Analysis) algorithm. The outputs were further recoded into six (6) classes of water, wetlands, closed vegetation, open vegetation, cropped lands and built-up using spectral and auxiliary information (historical records) from temporal digital dataset including vector map, aerial photographs and satellites of Google Earth platform. Table 2 below presents a description of each land cover class.

Fig. 1 Map of study area
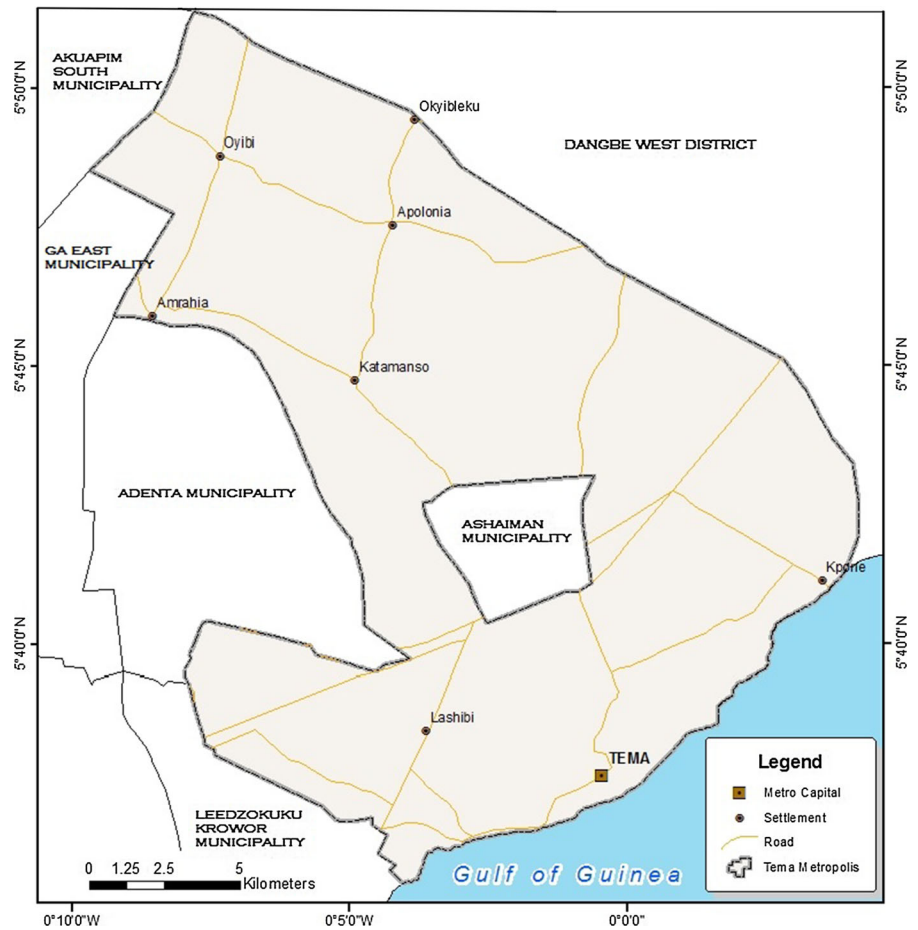
Table 1 Satellite images

Satellite	Image number	No. of bands	Pixel spacing metres (m)
Landsat TM	p193r056	7	30 × 30
Landsat TM	p193r056	7	30 × 30
Landsat ETM+	p193r056	7	30 × 30

Source: ftp://ftp.glcf.umd.edu/glcf/Landsat/WRS2/p193/r056/

Population and biophysical data and population interview

Population data from the Ghana Statistical Service were collected and examined. The objective was to draw on some relationship between the increase in population of the metropolis, and the changes that have occurred in land cover with particular interest in built-up. The figures derived from the National Population and Housing Censuses of 1970, 1984 and 2000 indicate a population growth rate of 0.044 per annum. Using this rate and the population of 1984 and 2000 as base years, the estimated population of Tema Metropolis for years 1990 and 2007 are 126,466 and 185,055 respectively.

Secondary data were also collected from the Tema Development Corporation (TDC) and the Tema Metropolitan Assembly (TMA) on land ownership

Table 2 Description of land cover classes (Level I)

Land cover	General description
Water	All areas characterised by still, open waters such as ponds or lakes. Also included in this class are channels of moving water including canals, streams and lagoons
Wetlands	Areas where the water table is at, near or above the land surface for prolonged periods of the year. Fresh water marshes with their associated vegetation are classified under this category
Closed vegetation	Areas dominated by closely knit trees and dense vegetative cover (canopy cover >70 %)
Open vegetation	This class describes all areas that depict sparsely located trees, shrubs and patches of bare soil. Areas of extensive grass cover and isolated thickets are classified under this category
Cropped lands	Lands under annual tillage and lands that have been cleared in preparation for crop cultivation, and lands left untilled such as fallow lands are identified as cropped lands
Built-up	Community service areas (parks, playing grounds, lorry parks), residential areas, commercial and industrial areas are classified as built-up areas. Lands that have been cleared in readiness for building construction are also classified as built-up

and administration in the metropolis. In-depth interview guides were used to gather information from some chiefs and traditional leaders regarding human activities on land, land tenure, ownership and administration. The chiefs and traditional leaders were purposively selected, because they are the custodians of the land and are directly in charge of the issue or sale of land for any developmental endeavour outside the Tema Acquisition Area. Their responses were considered against the results derived from the processed satellite images in an attempt to understand emergent trends in changes with respect to land use and land cover in the metropolis.

Rainfall data, which is also considered as a predisposing environmental factor that causes land cover changes by Geist and Lambin (2002), were collected from the Ghana Meteorological Service Agency and examined. Average annual rainfall figures for the period for the metropolis were computed from the data. This was done with a view to examine the influence of rainfall in the fluctuations in coverage areas of closed and open vegetation which was emergent in the land cover change maps.

Data analysis, land use: land cover change detection

Change detection studies based on remote sensing and GIS, according to Bektas and Goksel (2005), have generally focused on obtaining the information of how much, where and what type of land cover change occurred between different time intervals. It involves determining and/or describing changes in land cover properties based on co-registered multi-temporal remote sensing data. Post-classification change detection was employed to highlight changes in land cover. It is a quantitative method of change detection that is sensitive to spectral variations, provides a "from-to" change information, and results in a change map and change matrix. Change maps and matrices were developed for the period 1990–2000, 2000–2007, and 1990–2007.

Results

State of land cover in 1990, 2000 and 2007

In 1990, open vegetation occupied about 43 % of the study area (See Table 3; Fig. 2). It was mainly across the middle sectors of the metropolis and permeated down through the eastern and south eastern corridors. Built-up areas were spread and concentrated mostly in the bottom half of the metropolis to the coast and occupied approximately 30 % of land cover. Closed vegetation was located primarily in the northern fringes of the metropolis with small patches in the southern parts and occupied about 12 % of the study area. Almost 8 % of the study area was covered by wetlands which were dotted all over the metropolis, occurring in all other land cover types. Approximately 7 % of the area was detected as cropped lands and they

Table 3 Area of the land cover of Tema Metropolis (1990, 2000, 2007)

Years	1990		2000		2007	
Land cover	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Water	2.12	0.57	2.13	0.58	3.25	0.89
Wetland	27.96	7.65	21.83	5.97	22.13	6.05
Closed veg.	42.45	11.61	95.44	26.09	50.23	13.73
Open veg.	158.1	43.22	115.58	31.59	135.08	36.93
Cropped land	24.16	6.61	3.24	0.89	5.44	1.49
Built-up	110.98	30.34	127.56	34.88	149.65	40.91
Total	365.78	100	365.78	100	365.78	100

occurred in similar places as built-up. Water was found to be the smallest land cover type and it took up barely 0.6 % of total land cover.

In 2000, built-up areas increased distinctly in coverage to become the most prevalent land cover in the metropolis, increasing from a little over 30 % in 1990 to almost 35 % of total land cover. Open vegetation reduced in coverage area from about 43 % in 1990 to about 31 %. Closed vegetation increased noticeably from about 12 % in 1990 to 26 % of total land cover. Wetlands covered an area of about 6 %—a fall from the 1990 figure of 8 %. Cropped lands covered about 1 % from an average area of about 7 % in 1990. Water coverage in the metropolis appreciated marginally but the covered area was <1 % of total land cover.

In 2007, built-up further increased in coverage area to about 41 % with the land cover spreading into the middle sectors of the metropolis with small isolated patches occurring in the northern fringes. About 37 % of the metropolis was now covered by open vegetation indicating an increase of about 5 % from the area covered in 2000. Closed vegetation decreased from 26 % in 2000 to a total area of about 14 %. Cropped lands with an area cover of less than 1 % in 2000, increased in cover to more than 1 %. Water, although exhibiting an increase in coverage area relative to the area covered in 1990 and 2000, still covered less than 1 % of total land cover.

Land cover conversion 1990–2000, 2000–2007, 1990–2007

Whereas about 14 % of wetlands remained unchanged, about 54 % of the land cover transitioned from wetlands in 1990 to open vegetation in 2000, while almost 29 % of wetlands were also converted to built-up in the same period (See Table 4; Fig. 3) and

about 4 % of wetlands also transitioned into closed vegetation. In that time, about 6 % of open vegetation and approximately 1 % of closed vegetation transitioned into wetlands. Furthermore, as 90 % of closed vegetation remained unchanged, about 8 % of this land cover transitioned into open vegetation and about 1 % was converted to built-up areas. An estimated 51 % of open vegetation remained consistent, whereas about 35 % of the land cover transitioned into closed vegetation and approximately 7 % was converted into built-up areas. Also, about 94 % of cropped lands were converted into built-up areas whiles an estimated 5 % remained unchanged.

Between 2000 and 2007, wetlands of about 8 % remained unchanged. In the same period, 5 % of wetlands were converted to cropped lands, 45 % transitioned into open vegetation, and about 2 and 40 % of wetlands transitioned into closed vegetation and built-up areas respectively. About 47 % of closed vegetation remained unchanged. On the other hand, 51 % transitioned into open vegetation, whiles approximately 1 % transitioned into wetlands. Built-up areas also expanded to claim an estimated 1 % of close vegetated areas whiles Open vegetation remained unchanged during the period. About 4 % of the land cover, however, transitioned to closed vegetation with a further 11 % transitioning into wetlands. In addition, 18 % of open vegetation was converted to built-up and almost 1 % was also converted to cropped lands. Almost all cropped lands were converted to built-up areas within this period.

In the entire period, 44 % of wetlands remained unchanged. A total of 13 % of wetlands transitioned into open vegetation within the period. Also, about 33 % of the land cover was converted to built-up areas and an additional 10 % converted to cropped lands. Closed vegetation remained unchanged for a total of
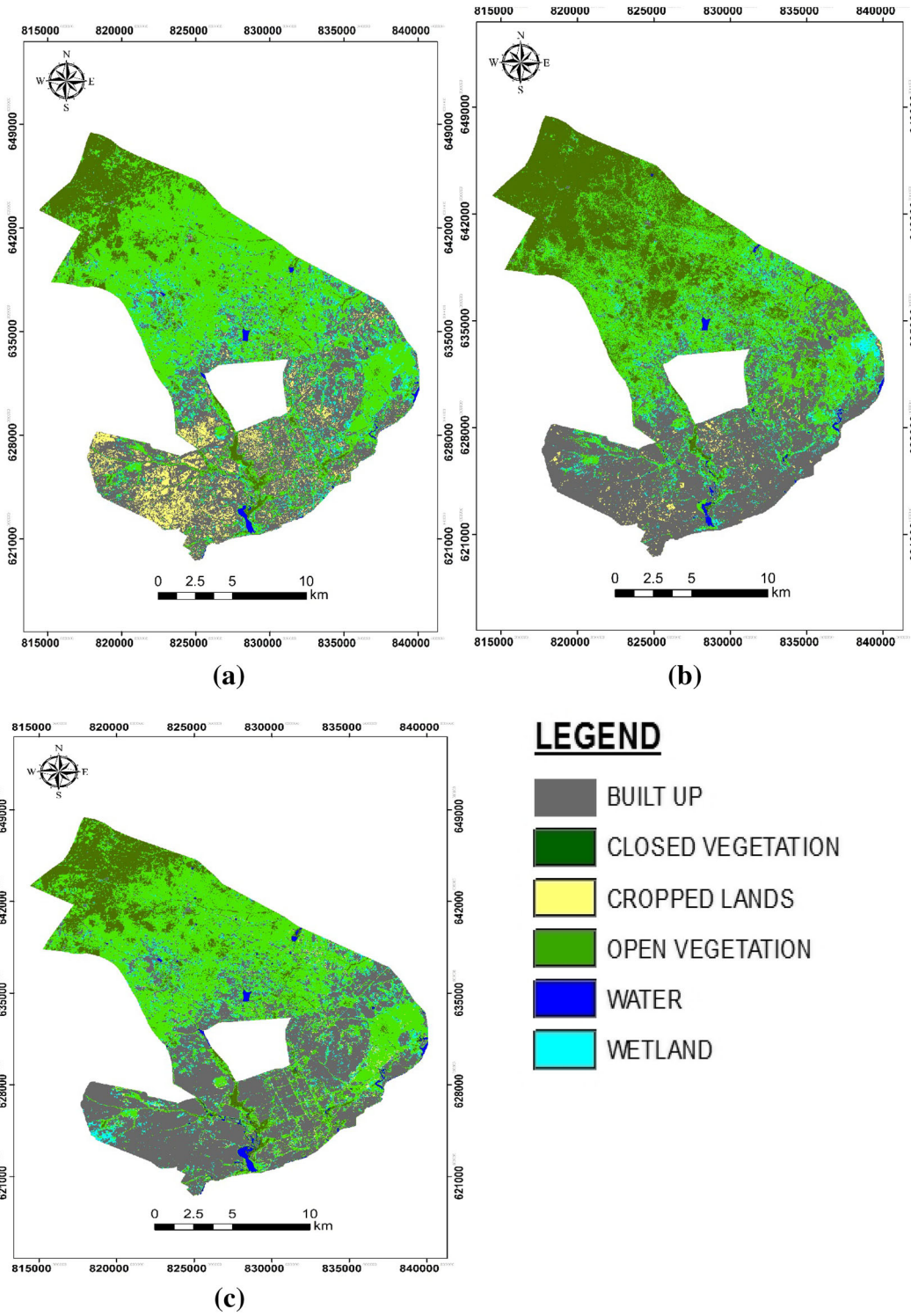
Fig. 2 Land cover maps of 1990, 2000 and 2007 labelled as (**a**), (**b**) and (**c**)

Table 4 Rate of land cover increase/decrease (1990–2000, 2000–2007)

Years	1990–2000		2000–2007	
Land cover	Increase (%/annum)	Decrease (%/annum)	Increase (%/annum)	Decrease (%/annum)
Water	0.001	–	0.04	–
Wetland	–	0.17	0.011	–
Closed veg.	1.45	–	–	1.77
Open veg.	–	1.16	0.76	–
Cropped lands	–	0.57	0.09	–
Built-up	0.45	–	0.86	–

89 %, whiles 11 % of it transitioned into open vegetation throughout the period. Conversion of closed vegetation to built-up for the entire period took up a total area of approximately 2 %. A total of approximately 86 % of open vegetation remained unchanged between 1990 and 2007. The area of open vegetation that transitioned into wetlands was about 4 %, whereas the transition to closed vegetation took up about 8 %. Additionally, 1 % was converted to cropped lands and built-up took up <1 % of open vegetation. Water remained unchanged throughout the period although its coverage area increased. Built up also underwent no conversion, but expanded to claim other land cover types.

Population data

Data available from the Ghana Statistical Service depict a growing trend in the population of Tema since 1970 (See Table 5). The figures show that the population of the Tema metropolis barely doubled from 1970 to 1984, and this trend was nearly the same in the period 1984 to 2000. The figures derived from the National Population and Housing Censuses of 1970, 1984 and 2000 indicate a population growth rate of 0.044 per annum. Using this growth rate and the population of 1984 and 2000 as base years, the estimated population of Tema Metropolis for years 1990 and 2007 are 126,466 and 185,055 respectively.

Discussion

Factors influencing land cover changes 1990–2007

Although changes as caused by predisposing environmental factors are not easily detectable by studying satellite imagery, infrastructure extension—herein categorised under built-up—and agricultural expansion can be visually interpreted and inferred from land cover classification and land cover change maps. Analysis of the generated land cover classification maps of the Tema metropolitan area and the consequent change maps for the years (1990, 2000 and 2007) indicate a consistent trend in the expansion of built-up areas. The expansion of built-up was most prevalent in the areas previously covered by cropped lands in the southern and middle parts of the metropolis. Secondary data from the TDC indicates that these areas lay in what is known as the Tema Acquisition Area (TAA)—an area of approximately 163.17 km^2 that was given to the TDC to manage for a 125 year lease term. Parts of this area that lay undeveloped were leased out to farmers whiles others farmed on them without permit. However, with the rise in demand for housing and serviced plots from the TDC, and with the corporation's quest to fulfil its mandate, these plots under tillage in the TAA were gradually taken from the farmers for development into residential quarters.

Interviews with some chiefs in the area revealed that, in 1994/95 officials of the Greater Accra Regional Agroforestry Unit initiated an agroforestry project in the metropolis which involved the participation of the chiefs in the area. The project assisted the chiefs in the cultivation of a variety of trees and fruit trees on selected sites. Fruit tree species such as mangoes and non-fruit ones like teak were planted. This project contributed to the significant increase in closed vegetation between 1990 and 2000. Rainfall data available from the Meteorological Service Agency for the metropolis depicted a significant increase in amount of annual rainfall beginning in 1995 (See Fig. 4) which would also have contributed
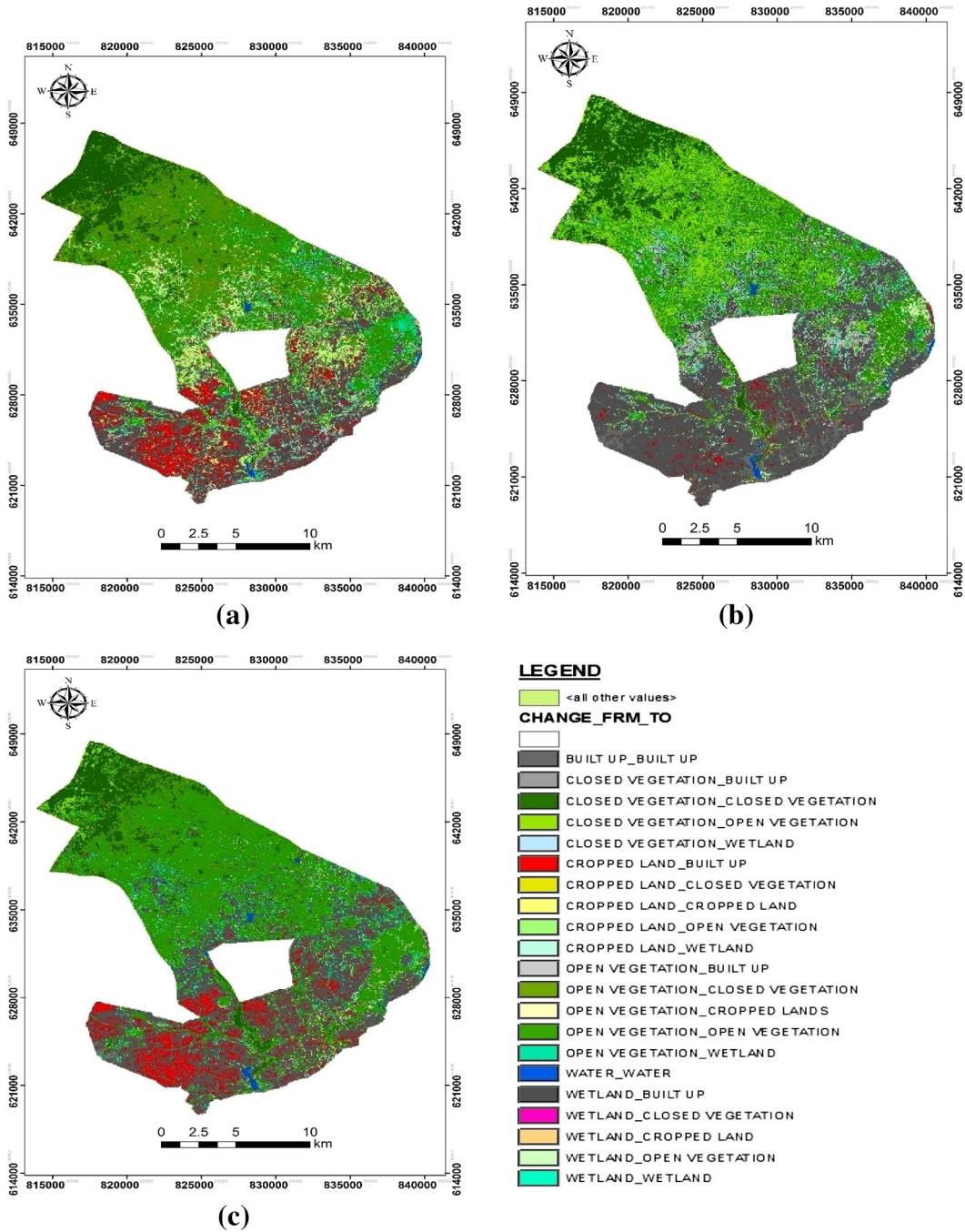
LEGEND

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CHANGE_FRM_TO

BUILT UP_BUILT UP
CLOSED VEGETATION_BUILT UP
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Fig. 3 Land cover conversion maps for (1990–2000), (2000–2007) and (1990–2007), labelled as (**a**), (**b**) and (**c**)

to extensive vegetative growth. This trend supports Geist and Lambin (2002) assertion that predisposing environmental factors such as rainfall also contribute to land cover changes. The land cover classification map for 2000 shows that, this increase in closed

vegetation occurred mainly in the middle sectors of the metropolis.

However, the interviews with the chiefs also revealed that, in 2005/06 tree species such as teak that had been planted during the agroforestry project

Table 5 Census figures for Tema Metropolitan Area

Date	03/1970	03/1984	03/2000
Tema	60, 767	100, 052	141, 479

Source: Ghana Statistical Service 2002

of the mid 1990s had been harvested for sale as electricity transmission poles. The trees, according to them, have since not been replanted and the lands have thus been outgrown with grass. Some of the trees are also cut by the local people for use as fuel wood even though the practice is forbidden by the chiefs. "We remind the people continually that cutting of trees for fuel wood is not allowed, but the practice continues even though we seize the fuel wood of those we occasionally apprehend," intimated a land sales person from one of the traditional divisions in the metropolis. These activities contributed to the fluctuation in the coverage area of closed vegetation over the period.

Furthermore, the interviews revealed a shift from farming or crop cultivation to real estate development or complete cessation of farming activities. According to the chiefs, in times past, plots of land were leased to farmers—most often without fixed terms. As the rise in demand for plots of land for housing surged, these lands were taken back and sold out. Some farmers are said to have purchased the plots of land leased to them and have now ventured into real estate development. Indeed, the chiefs further alluded that several real estate developers have also favoured their lands primarily due to the relatively flat topography of the area and the close proximity to the metropolitan capital—Tema. In their bid to meet the large undeveloped tracts of land required by these real estate firms, they have been pushed to sell lands previously untouched. Parts of these lands, field visits revealed, have already been fully developed into residential quarters whiles a greater part remains under various stages of development.

Southworth and Tucker (2001) have suggested that population growth—natural increment or in/out migration—is a major driving force of land cover changes in the cities of developing countries, particularly due to the relatively higher direct dependence on their surrounding natural environment to meet the numerous and diverse survival and developmental needs (Ingram and Dawson 2005). The population of the Tema metropolis has increased consistently since 1970. With such rise in the number of people, come an increasing need for land and land resources principally for the development of residential quarters and their concomitant social amenities. Correspondingly, the study revealed a consistent increase in the area covered by built-up in the respective years under study. Built-up areas in the metropolitan capital grew denser whiles its fringes in the south-western, middle and eastern corridors experienced conversion from mainly cropped lands, open vegetation, and wetlands to built-up.

These phenomena, as the land cover maps show, have led to a substantial decrease in urban tree cover in

Fig. 4 Annual rainfall data for the Tema metropolis 1990–1999. *Source*: Meteorological Service Agency, 2011
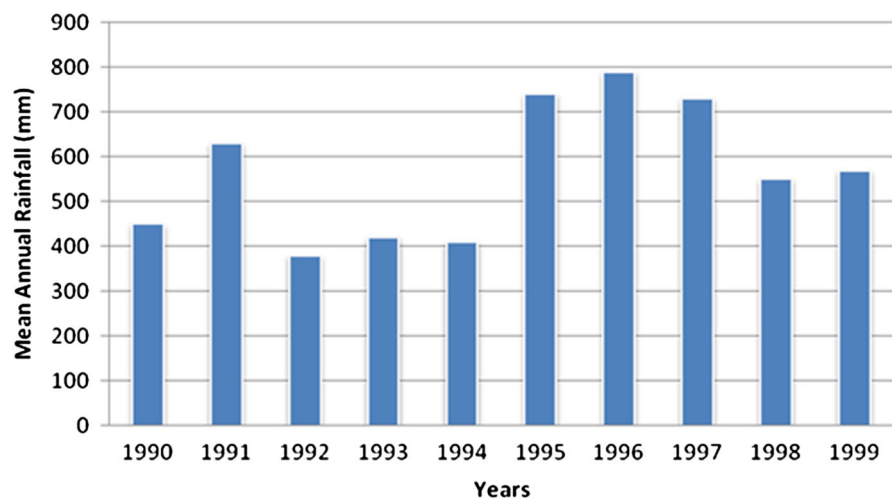
the metropolitan capital. As a city with light and heavy industrial, commercial, and transport activities, Tema is constantly fraught with the fumes and gaseous emissions emanating from these activities. A depleting tree cover, therefore, only means less carbon sequestration and little air purification which only leads to poorer air quality. The implication is that, vital ecosystem services such as air purification, necessary for human wellbeing in the metropolis and general earth system functioning are hindered each passing moment.

Conclusion

This study provides empirical evidence of rapid urbanisation or growth of built-up areas in the Tema metropolitan area between 1990 and 2007. The expansion in built-up areas was predominantly in the areas immediately surrounding the metropolitan capital—Tema. They constitute the areas in the western, eastern and middle sectors of the metropolis. This expansion of built-up areas involved a rapid loss of, particularly, cropped lands and substantial areas of open vegetation. While open and closed vegetation fluctuated in coverage within the period, built-up areas increased steadily and water covered areas remained fairly constant.

The drivers of these changes are associated principally with the population growth of the Tema metropolis with the 1970 population and housing census as bench mark. The results obtained from the 1984 and 2000 population and housing censuses indicate consistent increase in the population of the area. With increasing population also comes an increasing need for land resources with particular regards to the location of residential complexes. Land tenure or ownership schemes, land policy and institutional arrangements also account for other drivers of land cover changes in the metropolis.

Squires (2002) has argued that the benefits of regional economic vitality, and by implication urban growth, notwithstanding, these benefits are increasingly balanced against ecosystem impacts including the degradation of air and water quality, loss of farmlands or cropped lands, and infrastructure costs. As it stands in the Tema metropolitan area, as at 2007, water, wetlands, closed and open vegetation together comprised 57.60 % (approximately 210.69 km^2) of total land cover. This implies that a greater part of the metropolis still remained under land cover types that supported vital ecosystem services. The growing population of the area and its attendant increase in built-up areas, increase in pressure on existing infrastructure, and loss of ecosystem service-supporting land cover types, nevertheless, remains a threat to human wellbeing, optimal ecosystem functioning, and ultimately to global earth system functioning.

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