Urban sprawl and land use/land-cover transition probabilities in peri-urban Kumasi, Ghana

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Abstract

This paper examines Land Use and Land Cover (LULC) transition probabilities and its implications for Kumasi Metropolis using remote sensing image analysis technique. Methods used for the study include sub-setting of satellite images for the metropolis using the metropolitan shapefile boundary and classification of the images using maximum likelihood image classification algorithm. A Markov Model was applied to predict probabilities of LULC changes in 15 years (2016 - 2031). Study results show the probability of urban lands changing to agricultural land as low and so is the probability of farmland transitioning to urban land use. Vegetation however shows a high probability of change to built-up area while the likelihood of change from water to other land cover types is not a possibility. The study recommends enforcement of relevant land use policies backed by vigorous public education to make sustainable urban land use in the Metropolis a reality. Also, vertical rather than horizontal construction of buildings could stem the sprawling city.

Introduction

Spatial expansion of cities in developing countries such as Ghana is occurring at a rapid rate, but accurate information on the extent of urban sprawl and projections for future urban land use changes is difficult to come by. Characterising urban growth processes and investigating future scenarios are necessary for decision making to deal with urban sprawl (Mahmoud and Divigaipitiya, 2016).

The global view of settlement habitation in 1950 was that rural settlements accommodated more than 70% of people with less than 30% living in urban settlements. The proportion of people living in urban areas increased to 54% in 2014 while the proportion of rural dwellers reduced to 46%. In Asia and Africa, the proportion of urban dwellers increased at rates of 1.5 % and 1.1% per annum respectively. Projections show that the level of urbanisation will increase in all regions in the coming decades, but at a faster rate in Africa and Asia (United Nations Population Division, 2015). Unplanned urbanisation in the midst of increased economic activities could destroy large tracts of natural landscapes (Walker, 2001). While urbanisation may unleash positive results, its impact has been devastating in the African cities including rapid urban sprawl, deteriorating physical environment and squalid living conditions (Chirisa, 2010). Unplanned urbanisation in the midst of increased economic activities could destroy large tracts of natural landscapes (Walker, 2001) and most cities in sub-Saharan Africa have suffered and still suffer from this negative circumstance.

In Ghana, about 51% of the population live in towns and cities, as such the country is said to have crossed the urban divide (Ghana Statistical Service, 2014; GOG, 2012). Over the years however, Ghanaian towns and cities comprising Accra, Kumasi, Tamale and Secondi-Takoradi have expanded in size and numbers with no national urban policy to guide the urban expansion (GOG, 2012). The growth and development of these cities, therefore, have taken place largely in an uncontrolled and unplanned manner. The increase in the number of city dwellers has resulted in land scarcity which then pushes land value up beyond the reach of the majority of urbanites (Afriyie et al., 2014). Since land is relatively affordable in the peri-urban areas, and often not shrouded in litigation, land requirement needs of developers are met at the peri-urban areas. The peri-urban zone becomes a place for brisk business where parcels of land are sold in an uncoordinated manner. Agricultural and non-urban land use sites are converted to urban land uses in the form of housing and infrastructure development for industrial and commercial activities (Afrane and Amoako, 2011; Afriyie et al., 2014). Consequently, rural land prices escalate (Gantsho, 2008), creating opportunities and challenges for peri-urban dwellers. Urban expansion has thus led to changing land use from non-urban to residential accommodation and other urban land use forms (Abass et al., 2013; Abass et al., 2018; Naab et al., 2013; Afriyie et al., 2014; Cobbinah et al., 2015).

Inadequate housing remains a major challenge facing rapidly growing cities in Ghana. While the state is unable to meet the huge demands due to resource constraints, majority of the working population find it difficult to build houses of their own due to generally low income levels, the complex system of land tenure and escalating cost of building materials. Private Estate Developers have attempted to address the challenges but are faced by high bank interest rates on borrowings that contribute to high mortgaging costs. As a result, private-sector housing tends to be out of reach of the poor. A window of opportunity according to Obeng-Odoom (2009) is to own houses through self-help initiatives. Owning houses through self-help starts with acquisition of land mostly within the peri-urban interface which are subsequently developed on incremental basis (Gambrah, 2002; Oppong and Yeboah, 2013). This mode of housing contributes to rapid natural landscape depletion (Farooq and Ahmad, 2008).

Land use land cover conversion probability analysis, therefore, serve as a useful way of assessing changes in ecosystems and the implications for the environment at various temporal and spatial scales (Lambin, 1997; López et al., 2001). For monitoring and planning purposes, knowledge of the likelihood of one form of land use changing to another form is crucial particularly in a rapidly sprawling city like Kumasi.

Study context

Kumasi Metropolis is one of the thirty (30) political and administrative districts in the Ashanti Region of Ghana. It lies between latitude $6^{0}35'$ and $6^{0}40'$N and longitude $1^{0}30'$ and $1^{0}35'$W and approximately 270 kilometers north of Accra, the national capital. The Metropolis shares its northern border with Afigya-Kwabre District and Kwabre East District while the eastern border is shared with Ejisu-Juabeng Municipality and Bosomtwe District. In the western section, it shares boundary with Atwima Nwabiagya District while Atwima Kwanwoma District forms its southern boundary (Fig. 1). The Metropolis has the wet sub-equatorial climatic type with double maxima rainfall regime and a moderate temperature and humidity that support the growth of different plants and animals.

Kumasi has seen tremendous growth in terms of population and infrastructural expansion.

It grew at 5.2% annually between the 1984 and 2000 inter-censal years but grew at an unprecedented growth rate of 5.4% from 2000 to 2010, which is about twice the national annual growth rates of 2.7% and 2.4% for the periods 1984 - 2000 and 2000 - 2010 respectively (Afrane and Amoako, 2011). This is attributed to Kumasi being the Asante State capital and currently Ashanti regional capital. Its strategic location as a nodal city and its rich and varied natural resource endowments make it a transit location and an important commercial hub for a large number of migrants from different parts of the country and beyond. Since 1960, migrants from other parts of the country to Kumasi and foreigners accounted for 63% and 13% respectively of the total population (Korboe, 2001). The rapid growth of population has implications for housing delivery. In effect, the housing growth rate per annum was 8.6% from 1984 to 2000 (Afrane and Amoako, 2011). This percentage increase had negative effect on the physical structure of the Kumasi Metropolis such that the city expanded at the fringes of the metropolis. The population of KMA according to the 2010 census is 1,730,249 and represents 36.2% of the total population of the Ashanti Region which is 4,780,380. The Kumasi Metropolis is the most populous and indeed the fastest growing urban centre in the country (GSS 2014). For effective administration, the Metropolis is sub-divided into nine sub-metropolitan areas. These sub-metropolitan areas are *Asokwa, Nhyiaeso, Tafo, Manhyia, Bantama, Suame, Kwadaso, Subin* and *Oforikrom* (GSS, 2014).

Expansion of the city fringes absorbs peri-urban lands and many other villages which hitherto were in rural locations. The rural characteristics of these settlements are gradually changing due to the urban way of life (Busck et al., 2006). As urbanisation intensifies, land within urban centres becomes relatively scarce. Consequently, the value of parcels of land rises beyond the reach of the average Ghanaian. Land values decrease however, with distance from the city centre. Kumasi peri-urban areas become tenure hot spots where there is rapid conversion of agricultural and prime lands to housing and small-scale industries, a development that undermines the traditional crop production in these areas (Aberra and King, 2005).

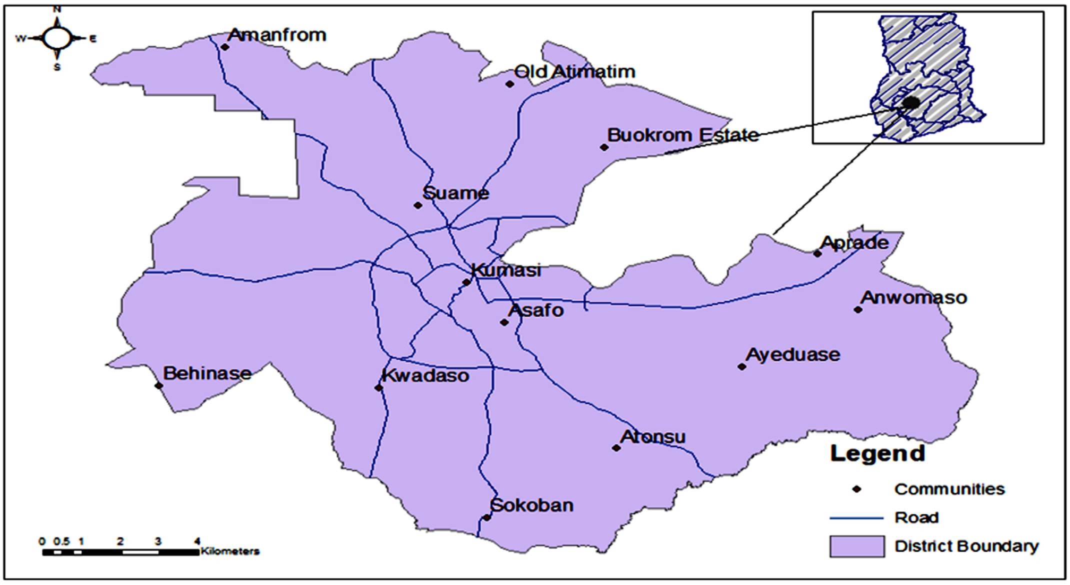

Figure 1. Map of Kumasi Metropolis
Source: Centre for Remote Sensing and Geographic Information Services, UG, Legon

Materials and Methods

Data used for the land use and cover (LULC) change analysis were ortho-rectified Landsat Thematic Mapper (TM) 1986, Enhanced Thematic Mapper Plus (ETM+) 2004 and Landsat 8 operationalised Landsat imager/ thermal infrared sensor (OLIS/TIRS) 2016 images. These were downloaded from the United States Geological Survey (USGS) global visualisation viewer website (https://glovis.usgs.gov) using path 194 and row 055. Landsat TM 1986, Landsat ETM+2004 and OLIS/TIRS 2016 images were used because the image sensors have seven spectral bands at a medium resolution of 30m which is adequate for the analysis. These multispectral bands sufficiently captured data on other vegetation, built-up/bare areas, farmlands and water bodies which are target objects for analysis. The images were clear and nearly free of clouds. These image scenes were sub-setted using the district boundary shape file in ArcGIS 10.2 software. The characteristics of the satellite images used are shown in Table 1. The subset images were loaded into ERDAS imagine 2013 software for image pre-processing using bands 4, 3, 2 and 5, 4, 3 in false-colour composite, for the TM/ETM+ and the OLIS/TIRS images respectively. These bands were chosen because of the spectral properties which show high reflectance of green vegetation as they are chlorophyll absorbing bands (Lu et al., 2015).

Specifically, bands 2 and 3 were used because they produced distinct spectral signatures for vegetation which is needed for analysis. Band 4 is a near infra-red band which shows contrast between vegetation and soil and band 5 which is a mid-infrared band helped to differentiate between vegetation and built up/bare areas for easy image classification.

Land cover categories or classes were built-up/ bare land, farmland, vegetation (which consist of a mixture of light forests groves, grasslands and other green spaces) and water bodies using onscreen digitising method by drawing polygons around identified land cover classes. Maximum Likelihood supervised image classification algorithm was used to classify the three images because of a priori knowledge of the area (Abass et al., 2018). The supervised classification algorithm ensured that all pixels that belong to the same class comprising urban/ built-up area, farmland, vegetation and water were grouped into probability thresholds of the highest frequency. Maximum Likelihood method was used because of the advantage of providing an index of certainty linked to the choice of each pixel to the given class.

Accuracy assessment of land use and land cover classifications obtained from remote sensing data is a useful tool for judging how fit data is for particular application (Janssen and Vanderwel, 1994). For the 2016 image,

TABLE 1
Satellite images characteristics

Image Year	Landsat Sensor	Bands used	Date acquired	Spatial resolution
1986	Thematic Mapper (TM)	1, 2, 3, 4, 5, & 7	21st April	30m × 30m
2004	Enhanced Thematic Mapper plus (ETM+)	1, 2, 3, 4, 5, & 7	6th February	30m × 30m
2016	Operationalise Landsat Imager/ Thermal Infrared Sensor (OLI/TIRS)	1, 2, 3, 4, 5, & 7	7th February	30m × 30m

Etrex garmin GPS was used to collect point data in geographic coordinates from visited sites along with samples extracted from google earth and loaded onto the classified imagery for accuracy assessment. For each land use and cover class, 8 sample points were picked with GPS giving a total sample size of 32. Accuracy assessment of classified imagery was done by comparing identified point locations such as urban/built-up areas, farmlands, vegetation and water bodies on the classified imageries with the referenced coordinate samples for built-up areas, water, vegetation and farmlands. A confusion matrix was obtained from which the overall accuracy was calculated for each classification.

To project change in the land use and land-cover from time t to t_{+1}, the Markov Model equation $x(t_{+1}) = Px(t)$ was used. When the state of a system (land-cover class) denoted by the vector x is known, the future state of the system (land-cover change) can be projected as: $x_t + 1 = x_{tP}$ that is, the state vector x multiplied by the transition matrix. The projection for time t_{+2} can be stated as $x_{t+2} = x_t +_1 P = x_{tP}, P = x_{tP2}$. Details of the Markov transition matrix model projection are as follows:

$$P = \begin{array}{c} \\ \text{From} \end{array} \begin{array}{c} \text{To} \\ \begin{array}{c|ccc} & S_1 & S_2 & S_3 \\ \hline S_1 & p_{11} & p_{12} & p_{13} \\ S_2 & p_{21} & p_{22} & p_{23} \\ S_3 & p_{31} & p_{32} & p_{33} \end{array} \end{array}$$

subject to:

$$\sum_{j=1}^{m} p_{ij} = 1 \qquad i = 1, 2, \ldots m$$

Transition probability (p_{ij}) shows the probability that class *x* would be in state *j* at time *t+1* given that class *x* was in state *i* at time *t*.

$$P_{ij}^{t+1} = Pr [x_{t+1} = j \mid x_t = i]$$

A first step to projecting land use and land cover change in Kumasi Metropolis was to do a change detection statistics report from 2004 to 2016 by subtracting pixel values of the 2004 image from the 2016 image. A basic rule for calculating Kappa index is that, each of the values in the row of the probability matrix has to be ≤ 1.0 (Landis and Koch, 1977). The diagonals of the probability matrix table show pixels or areas that have not changed while the off diagonal figures indicate the probability of change from one class to the other. The results have been classified into ranges of Kappa index prediction reliabilities. Values between 0.81 – 1 represent almost perfect reliability, 0.61 – 0.80 represent substantial reliability, 0.41 – 0.60 show moderate reliability, 0.21 – 0.40 is a fair prediction and 0.00 – 0.20 is slightly reliable and values <0.00 are poorly reliable predictions (Cohen, 1960).

Results

Land use/land cover change in Kumasi Metropolis

Supervised classification method was used to classify the area into four classes namely: built up/bare land, farmland, other vegetation types and water bodies. Results show urban land use as the dominant land use type in the Kumasi Metropolis (see Figs. 2a, 2b, 2c and Table 2). In 1986, urban land use covered approximately 58.64 km^2 of the total land area of KMA. This increased to171.33 km^2 in 2016. The area covered by farmlands, however, fell from 7.84 km^2 in 1986 to 4.64 km^2 in 2004 but increased to 6.2 km^2 in 2016. In effect, farmland or area under cultivation declined by 20.8% between

1986 and 2016. Satellite image analysis shows an inverse relationship between urban expansion and 'other vegetation' cover. 'Other vegetation' in this contest refers to green belts, parks, play grounds/playfields, forest, sacred groves and other shade trees. While the urban proportion of the total land use increased by 52.2 % between 1986 and 2016, other vegetation decreased by 51.5 % within the same period (see Table 2).

Although the Metropolis is drained by streams and rivers, the proportion of the total area covered is small. The satellite image analysis shows that water bodies cover about 0.02% of the total area of the Metropolis in 1986 but shows 0.05% in 2016.

TABLE 2
Land use/Land change in the Kumasi Metropolis

Land use/Land cover Type	Area (Sq. Km)			Percentage change		
	1986	2004	2016	1986-2004	2004-2016	1986-2016
Urban/Built-up/bare soil	58.64 (27.2 %)	127.85 (59.2%)	171.33 (79.4 %)	118.0	34.0	192.2
Farmland	7.84 (3.6 %)	4.64 (2.1%)	6.21 (2.9 %)	- 40.8	33.8	-20.8
Vegetation	149.37 (69.2%)	83.33 (38.6 %	38.28 (17.7 %)	- 44.2	-54.1	-74.4
Water	0.02 (0.01%)	0.05 (0.02 %)	0.05 (0.02 %)	150.0	0.0	150.0
Total	**215.87**	**215.87**	**215.87**	-	-	-

Source: Computed from the satellite image analysis

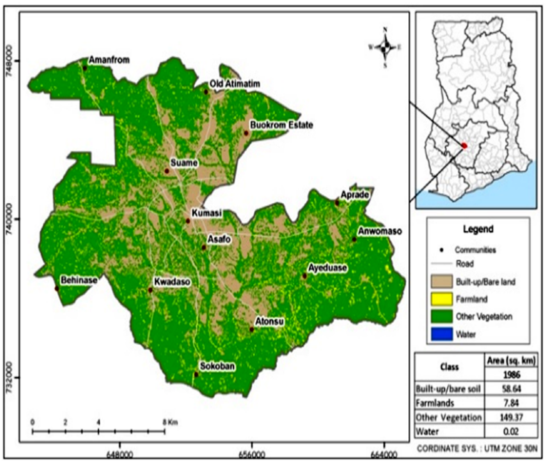

Figure 2a: Classified Land Cover of 1986 TM Image

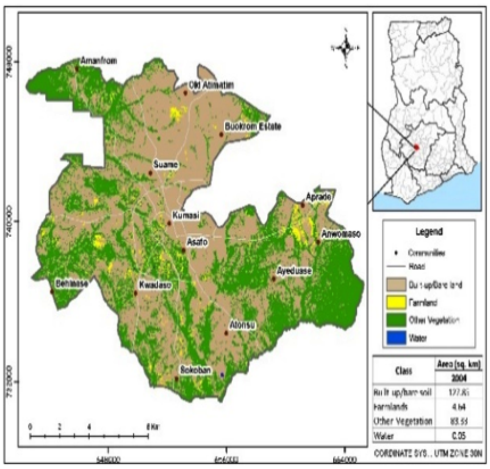

Figure 2b: Classified Land Cover of the 2004 ETM+ Image

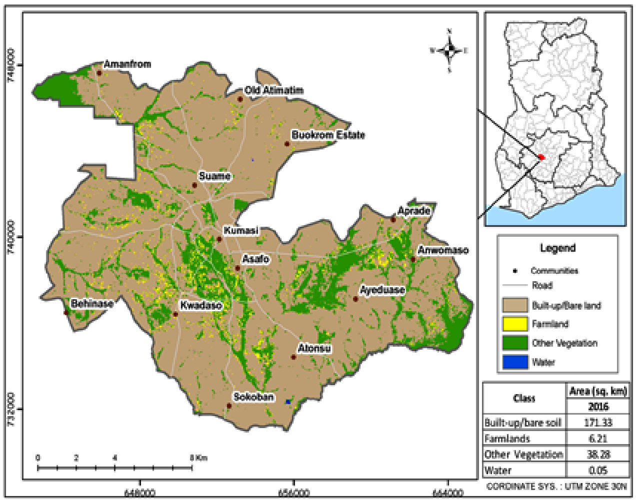

Figure 2c: Classified Land Cover of the 2016 ETM+ Image

Land Use and Cover Projection for 2031 using Markov Model

Four discrete states of land cover class transitions are being predicted (Built/Bare area, Farmland, Other Vegetation and Water). Table 3 shows change detection statistics report from 2004 to 2016.

Determination of Kappa value was done by dividing the row class values of each land cover class by the row totals in each of the rows in Table 2. For example, Built/Bare area class value of 118.158 Sq. km was divided by Built/Bare area row total value of 127.85 to arrive at a Kappa transition index of 0.92. Calculation of probability of change in Square Kilometers was computed by multiplying the row class values of each land cover class by the row total and then divided the results of the multiplication by the grand total of the row total value. For example, row class value 3.36 × (row total) 4.644 = 15.60384 ÷ (row total) 215.872 = 0.07 Square Kilometers.

From Table 4, Built/ Bare area has 0.01 (1.37 Sq. km) Kappa transition probability

TABLE 3
Change Detection Statistics Report in Square Kilometers (2004 – 2016)

Land cover classes	Built/Bare area Sq. km	Farmland Sq. km	Other Vegetation Sq. km	Water Sq. km	Row Total
Built/Bare area	118.158	2.321	7.371	0	127.85
Farmland	3.36	0.492	0.792	0	4.644
Other Vegetation	49.814	3.398	30.116	0	83.328
Water	0	0	0	0.05	0.05

TABLE 4
Kappa index conditional transition probability matrices

Land cover classes	Built/Bare area		Farmland		Other Vegetation		Water	
	Square km	Kappa Index	Sq. Km	Kappa Index	Sq. Km	Kappa Index	Sq. Km	Kappa Index
Built/Bare area	69.9	0.92	1.37	0.01	4.36	0.05	0	0
Farmland	0.07	0.72	0.01	0.1	0.01	0.17	0	0
Other Vegetation	19.22	0.59	1.31	0.04	11.62	0.36	0	0
Water	0	0	0	0	0	0	1.15	1

of change to farmland is a slightly reliable prediction of loss by 2031 as it is very unlikely that built up or bare surfaces will be converted to farms. There is also 0.07 (0.72 Sq. km) Kappa transition probability of change from farmland to built-up area which is also a slight reliability of change as there is already limited farm space available in the metropolis. In terms of converting vegetation lands such as gardens, trees between residential areas to built-up areas, there is 0.59 (19.22 Sq. km) probability of change from other vegetation to built-up area which is the most competitive land use in the metropolis due to the increased urbanisation of the area. In terms of reliability of prediction, there is substantial reliability of change prediction given the extent of change from 2004 to 2016 which is the base data for prediction. Prediction of change from water to other cover types is not a likely possibility given the zero (0) value of prediction for this cover type, hence a poor reliability of prediction according to Cohen (1960). What is most possible is water remaining as water given the Kappa index of 1 (1.15 Sq. km) which is a perfect reliability of projection.

Discussion

Kumasi Metropolis is urbanising at a fast rate. Considering the fact that the metropolis is spreading more horizontally than vertically (Quagraine, 2011), pressure has been brought to bear on urban and peri-urban lands, resulting in changes on land use and land-cover from 1986 to 2016. Urban sprawl has affected land use patterns with much of the natural physical environment of the urban and peri-urban areas of the Metropolis undergoing rapid conversions to various urban land uses (Afriyie et al. 2014; Cobbinah and Amoako, 2012; Quagraine, 2011) including among other things residential facilities, roads, industries and public structures (Corubolo and Mattinglz, 1999; Quagraine 2011). Systemic laxity in controls by the district and metropolitan assemblies on land use plans of the urban and peri-urban areas has invariably engendered chaotic physical development ahead of land use (Larbi, 1996). This has led to land use abuses, with water bodies, green spaces and other ecologically sensitive areas not spared in the process.

Urban land use is generally considered by city authorities to be more rewarding compared to agricultural land use. This thinking has accelerated the process of land conversion from arable, green and open spaces to urban land (Skinner et al., 2001; Tan et al., 2005; Zhang, 2000) since these land use forms bring little by way of economic returns. Within the Kumasi Metropolis, Chiefs are more willing to release or sell lands for projects that bring them the highest economic returns. There is abundant evidence to show how the landscape in the Mtropolis has been abused through unregulated and uncontrolled conversions. The Adehyeman Gardens, for instance has been transformed from its recreational nature to a hotspot of commercial centre in Kumasi Metropolis. The original trees, grass and beautiful flowers are all gone (Asare, 2013). The Asafo Tennis Court, close to the Kumasi Polytechnic, has also been converted to a lorry terminal while Abbey, Jackson, Kotoko, Rivoli, Addo and Dogo Moro parks which were constructed purposely to offer an opportunity to the youth to develop and nurture their potentials in soccer have been changed from their original functions to different uses (Quagraine 2011; Adjei Mensah, 2014). The sacred grove at Atasemanso and other forest reserves have been encroached by urban development.

The current findings are consistent with those of Zhou and Wang (2011) in their study of Kunming city (China), where rapid urban expansion has been blamed for huge natural landscape losses. As a result of farmland encroachment due primarily to urban expansion, an estimated number of 1.5 million farmers lost their arable lands annually in China since the last ten years (Lu et al., 2003). Similarly, temporal land cover analysis by Ramachandra et al. (2015) of Delhi (India) shows a decline in vegetation by 75.03%, while the area under non vegetation increased by 121%. Land use analysis on the other hand shows an increase in built-up area from 3.6% in 1977 to 25% in 2010 with the past four decades seeing built-up areas increasing by more than 638% due to conversion of non-urban land to urban. Between 1982 and 1997, urban and built-up areas expanded by 34% in the United States and this occurred at the expense of croplands and forestland (Alig et al., 2004). Thus, uncontrolled growth of cities affects the surrounding landscape as it leads to excessive use of green spaces and prime agricultural lands (Brueckner, 2001; Travisi and Camagni, 2005).

Urban sprawl and the depletion of natural landscape in the Metropolis must be taking place within the context of weak legal and institutional regime. The legal framework that regulated planning practices and functions within the country for years were contained in various legislations, the concurrent operation of which was cumbersome and confusing because of different procedures and mechanisms for plan preparation, approval and implementation (Kyei, 2016; MESTI, 2015). Besides, there was duplication of functions by the institutions established under the various enactments to undertake land use planning and management. Some of the planning standards adopted by the Town and Country Department under the Town and Country Planning Ordinance, 1945 (CAP 84), and the Town and Country Planning (Amendment) Act, 1960 (Act 33) have for long been outdated and out of tune with current international standards (MESTI, 2015). These and the apparent lax in the enforcement of relevant legislations pertaining to land use in Ghana in general and Kumasi in particular provides the grounds for all forms of land use abuses by nonchalant citizens. The passage of Ghana's Land Use and Spatial Planning Bill by parliament into a law (Act 925) and given Presidential Assent in 2016 is a laudable move. This bill provides among other things a comprehensive legal framework for sustainable development of land and human settlements through a decentralised planning system (Kyei, 2016; MESTI, 2015). The problem in Ghana however, is with the enforcement of the laws and not necessarily an issue of laws. We can only hope that this Land Use Act will not end up like its precursors which faced enforcement challenges.

For the purpose of land use planning and monitoring, land use and land-cover transition probability study is important. As the findings show, the probability of urban lands being converted to agricultural land use is low. This suggests that it is unlikely that any land that has been converted to urban use will revert to its original cover. The probability of change from farmland to built-up area on the other hand is low as there is already a limited farm space available in the metropolis. Thus, continuous conversion of arable lands in peri-urban Kumasi to urban use would not only create livelihood challenges for peri-urban farmers but could potentially cause food security challenges. Data from the Ministry of Food and Agriculture (MoFA, 2017) show consistent decline in the output of major crops in Kumasi Metropolis in a period of 17 years (2001-2017) due partly to loss of arable lands to urban land use forms as a result of urban expansion. In 2001, cropped areas for maize, cassava, yam and cocoyam were 3626, 4865, 439 and 254 hectares respectively. These fell to 228, 407, 7 and 8 respectively in 2017. Correspondingly, output of maize, cassava, yam and cocoyam which were respectively 5036, 51142, 3406 and 2390 metric tonnes in 2001 fell to 408, 6980, 95 and 34 respectively in 2017 (MoFA, 2017). As a consequence of the loss of large areas of cropland due to their conversion to urban uses, many countries have transitioned from being predominantly self-sufficient in food production to net grain importers of food. In a period of 44 years (1950–1994) Japan lost more than half of its cropland which contributed to greater dependence on grain imports (70% in 1985, 25% in 1950). This pattern of increased dependence on imports has also occurred in South Korea and Taiwan (Brown, 1995). These are useful lessons for Ghana.

Vegetation on the other hand shows a high probability of change to built-up area. The likelihood of change from water to other cover types shows an impossibility because this covers already a negligible proportion of the total urban space. The challenge in the metropolis is how to regulate the fast growing and expanding city from taking over parks, gardens, sacred groves, forest reserves and other open spaces. There is abundant literature to show that such green and open spaces provide a lot of benefits to both people and wildlife as illustrated by Escobedo et al. (2011). They help to shape the character of cities and their neighbourhoods (Pauleit 2003) and engender a sense of place for city inhabitants (Frumkin, 2003). Trees provide aesthetic, social and environmental functions that are important in urban areas (Pauleit, 2003). Not only do these spaces make urban and suburban places appealing and pleasant to city dwellers (Nassauer, 1997), they also make them more sustainable (Dumreicher et al., 2000). They also provide critical ecosystem services (Sadler et al. 2010), ensure ecological integrity of cities and offer public health protection to urban populations (Wolch, et al. 2014). While green spaces may filter air, remove pollution (Nowak et al. 2006), they also cool temperatures, replenish groundwater and provide food (Escobedo et al. 2011). They are thus the lungs of human settlements (Jim and Chen, 2006; Scheer, 2001). These and many other benefits provide the overarching reason for a new policy direction in order to sanitise land use activities in the Metropolis.

Conclusion and policy recommendations

The study analysed the probabilities of one land use form being converted to another in Metropolitan Kumasi. Urban land expansion has occurred at the expense of non-urban land use, a process that has been influenced by rapid population growth and continuous urbanisation of the Metropolis. The results show that agricultural or non-urban land use areas have reduced due to conversions to urban land uses. Built/bare areas have a relatively low probability of change to farmland which is a slightly reliable prediction of loss by 2031 as it is very unlikely that built up or bare surfaces will be converted to farms. Also, the probability of farmlands being converted to built-up area in the Metropolis is low as there is already a limited farm space available in the metropolis. In terms of converting other vegetation lands to built-up area, there is a high probability of change due to competitive urban land use in the metropolis. Prediction of change from water to other land cover types is not a likely possibility.

Its role as a nodal city means that Kumasi would continue to attract large migrants from within and outside the country. The implication is that LULC conversions from non-urban to urban will continue to rise. This trend is however unsustainable, and therefore requires policy intervention to avoid adverse socio-economic and ecological consequences. For the new Land use and Spatial Planning Act (Act 925) to address the challenges of land use and misuse, its strict enforcement is critical. In a country where development goes ahead of planning, it would be interesting to see how the changes in the structure of the planning system through this Act will enhance planning standards and improve the delivery of planning decisions. The paper makes the following recommendations:

To check the sprawling city from consuming non-urban land, emphasis should be placed on a compact city model (vertical construction). The initiative to protect open spaces, green belts, water bodies, forest reserves, wetlands, water catchment and other ecologically sensitive areas from urban encroachment as captured in the 2012 National Urban Policy should be pursued. This will help control abuses as well as irregularities in the system and check the rapid pace at which non-urban land use is being turned into various urban land use forms. As a requirement, all key actors in land and land use administration, planning, zoning, allocation and utilisation must come onboard. Zoning regulations must be enforced to avert further chaotic land use patterns. The Metropolitan Assembly, Department of Town and Country Planning, traditional rulers, Lands Commission and other key stakeholders should be up and doing. The mammoth challenges that face the Metropolitan, Municipal and District assemblies in executing this mandate are not in doubt. Undue political interference, human and financial resources inadequacy, weak institutional structure, chieftaincy and land disputes among other challenges are inevitable but at all material times the law must work.

Given the magnitude and alarming nature of the problem, placing the responsibility solely on the city authorities may not achieve the desired result. A new generation of citizens, ready to support the city authorities to ensure a more sustainable use of the urban environment is needed. A vigorous public education and enforcement of relevant laws against objectionable and reprehensive public attitudes and conduct that are inimical to the environment must be pursued. To succeed, a dynamic management process that should involve city authorities, traditional authorities and urban residents is necessary.

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