

## Remote Sensing for Mapping Land-Use/Cover Changes and Urban Sprawl in Sekondi-Takoradi, Western Region of Ghana

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### ABSTRACT

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Land use/land cover influences a variety of processes on the Earth surface which also generate feedback effects on the natural environment, economic and social systems. Poorly managed changes in urban areas have resulted in many catastrophic consequences such as floods, landslides, droughts etc. The Landsat satellite system has long term data archives and can be used to assess the land cover changes in the landscape to provide information to support future urban planning. In this paper Landsat images were used to map the land use/land cover changes in the city of Sekondi-Takoradi in the Western region of Ghana from 1988 to 2011 through a change detection process. The post-classification method of change detection was used and the accuracies achieved were high. The analysis showed that a large portion of the city and its surrounding areas has been converted from natural surfaces to impervious surfaces. Also it was observed that precipitation has reduced considerably during the period and high temperatures have been observed. A model developed between land use change and time have showed that in the next 50 years if the trend of land use change continues, there will be complete removal of natural surfaces. These could lead to increased incidence and severity of flash floods and droughts. Therefore the data produced in this study can be used to guide effective urban planning to mitigate the combined effects of land use changes due to urbanisation and climate change. This study demonstrates the critical role remote sensing can play in the developing world in terms of providing data for planning since many countries do not have the resources to map their territories regularly through conventional means.

**Key words:** change detection, land use/land cover, Landsat, remote sensing, Sekondi-Takoradi

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### I. INTRODUCTION

Land use/land cover (LULC) influences a variety of processes on the Earth surface. These processes also generate feedback effects on the natural environment, economic and social systems. LULC is pervasive in urbanised environments worldwide and reflects a society's interactions with the physical environment (Campbell, 2002). Hence poorly managed changes in urban areas have the potential to result in many social, economic and environmental catastrophes such as floods, landslides, droughts, lack of safe drinking water and loss of crop productivity etc. It is imperative therefore that urban land use is planned properly to ensure that sustainable social, economic and environmental goals are achieved. To achieve these objectives it is important to map the existing LULC of the urban areas. It is only then that it will be possible to analyse which land use best suits a particular land cover considering all necessary variables. For example, it will not make economic sense to build low cost estates on rich agricultural lands and it will not make environmental sense to construct certain industries in riparian habitats. The overall objective of ensuring that the urban land use is not mixed is to ensure sustainable utilization of the natural resources.

Urban LULC occurs mostly by the removal of vegetation through anthropogenic activities such as construction of housing estates, road construction, agriculture and livestock raising, forest harvesting and mining etc. These causes are influenced by population increase, government policy and economic development. In some places the occurrence of major floods can also alter the land cover though the floods are also influenced by LULC. Other causes of LULC changes include bushfires and climatic changes (Aduah *et al.*, 2012). LULC changes in urban areas create impervious and non-evaporative surfaces. The consequences include increases in storm run-off, river discharge rates and floods in low lying areas. Others include increased soil erosion and alteration of the surface energy balance resulting in increased land surface temperatures and urban heat islands (Aduah *et al.*, 2012). These changes also cause high evaporation rates and decreased productivity of soils and crops. Over long period of time urban land cover turning into impervious area will reduce the ground water recharge and pollution of water bodies due to non-point source pollution and sedimentation. Pollution and sedimentation of water bodies will reduce wetland habitats and affect the flora and fauna hence reducing biodiversity. Consequently water treatment for the urban areas would be expensive and supplies would be limited.

LULC and its changes have been mapped extensively in the past five decades through multiple techniques. These include ground surveys, aerial photogrammetry and satellite remote sensing. However, the use of ground surveys and aerial photogrammetry is expensive and time consuming and therefore normally limited to small areas and low temporal domains. Satellite remote sensing with its long term data, wide spatial and synoptic coverage and high temporal resolution has become the most important technology for mapping LULC and its changes for the past three decades after the launch of the Landsat group of satellites. Today LULC is one key area where satellite images are routinely used. This is mainly because satellite images provide synoptic and spatial coverage over large areas for a long period of time and repeated views of the same location can be obtained. The basis of remote sensing is that changes occurring in the land cover alter the reflected radiation which is recorded in the images. Also the development of high spatial and spectral resolution sensor technology (e.g. Ikonos, Orbview, GeoEye, QuickBird etc) has provided the opportunity to conduct detailed inventory of LULC. Consequently, it is now possible to generate detailed and timely LULC inventories for many Countries using a variety of optical and microwave satellite images. Until recently this was only possible with aerial photography interpretation and ground surveys.

Change detection is the process of categorizing differences in the state of an object or phenomenon by observing it at different times (Abiy, 2010). Remote sensing methods of mapping LULC change include multi-date composites, change vector, image algebra (image differencing, image ratio), on-screen digitization, GIS overlay and post-classification comparison (Zubair, 2006; Coppin *et al.*, 2004; Lu *et al.*, 2004, Lunetta and Elvidge, 1999 and Campbell, 2000). These methods have been used extensively over the past four decades. For examples of studies see Manonmani *et al.*, 2010 for multi-date composites and Aduah and Aebayir, 2012; Prabaharan *et al.*, 2010; Boakye *et al.*, 2008 for post classification comparison techniques.

The post classification method is the most widely used change detection algorithm. The approach classifies and labels two images from different dates. The area of change is then calculated through direct comparison of the classification results. Main advantages of post classification include: detailed “from – to” information. Also the spectral complexities associated with the analysing images acquired at different times of year or with different sensors is avoided. However, the accuracy of the analysis depends on the accuracy of the image registration and classification of the individual images. This implies that the individual classification be executed carefully so as to achieve the best accuracy as possible (Abiy, 2010). The extensive application of these methods in the remote sensing community has ensured that LULC inventories are available for many Countries.

The availability of LULC inventories serves as the baseline upon which effective monitoring and management of the urban environment can be carried out. This enhances the ability to combat or adapt to the negative effects LULC change and global climate change at the local scale. To be able to ascertain how the LULC has changed and how it has affected many environmental parameters it is imperative to conduct effective LULC inventory over a period of time. Since the LULC changes are speculated to affect the magnitudes of the predicted effects of climate change, it is also relevant to predict the status of the LULC in the future. This study is therefore conducted in the Sekondi-Takoradi Metropolitan area of Ghana to map LULC and its change using the post classification comparison method. This is to provide data suitable for monitoring and managing the local environment.

## **Materials and Methods**

The material and methods used in this research are elaborated in the sections below.

### **Study Area**

Sekondi-Takoradi metropolis (Figure 1) comprises of the cities of Sekondi and Takoradi. The metropolis is located within latitude  $05^{\circ} 55'$  North and longitude  $01^{\circ} 46'$  West with a land area of about 49.78 km<sup>2</sup>. It is the capital of the Western Region of Ghana and it is Ghana's fourth largest city. It also serves as an industrial and commercial center. The major industries are timber, plywood, shipbuilding and railroad repair and recently, oil. The Metropolis is characterized by faulted shales and sandstone resting on a hard basement of granite, gneiss and schist (Anon., 2011b). The faulting system has influenced the land form along the coastline. It clearly follows the main fault direction of North East (Anon., 2011b).

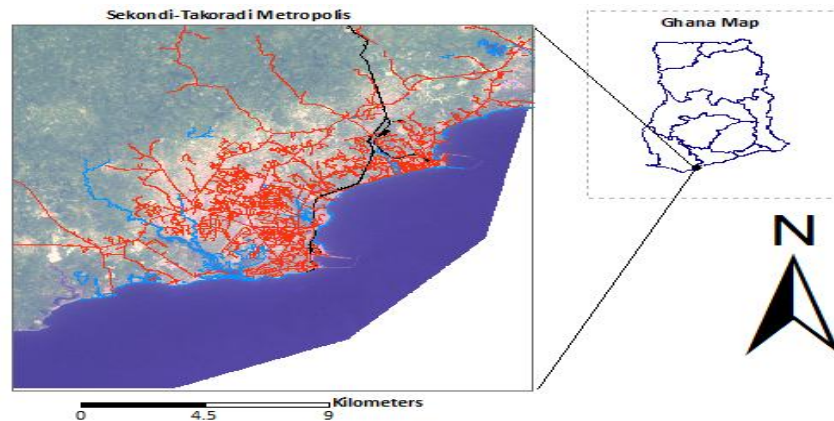


Figure 1: Map showing the location of the Study Area in Ghana

Generally, the Metropolis does not experience severe weather conditions. The climate of the metropolis is equatorial, with an average annual temperature of about 22 °c. Rainfall is bi-modal, with the major season occurring between March and July and the minor season occurring between August and November. The mean annual rainfall is about 1,380 mm, covering an average of 122 rainy days (Anon., 2011b). The natural vegetation has largely been degraded due to slash and burn farming practices and other human activities. The existing vegetation in the north and central portions of the Metropolis is mainly woodland. However, along the coastal areas there are thickets interspersed with tall grass species (Anon., 2011b). The Metropolis is of varied landscape; the coast line has capes and bays, which have been largely eroded. The central portion of the metropolis is low lying while the rest of the area is undulating with ridges and hills. The metropolis is drained by two main rivers; the Whin and the Kansawora Rivers, while the lagoons are the Essei and the Butre (Anon., 2011b). Major crops cultivated in the metropolis are cassava, maize, plantain, cocoyam, yam, sugarcane, oil palm, citrus, sweet potato, vegetables and coconut. Livestock reared include sheep, goats, local and commercial poultry, and to a lesser extent, cattle. Non-traditional commodities include grasscutter, beekeeping, mushroom, snail and agro-forestry/woodlots. In the fisheries sub-sector, marine fishing and aquaculture are the major areas.

#### Data acquisition

The data used for the study included subset of two Landsat images of 30 meter spatial resolution captured in 1988 and 2008. One image was obtained from the enhanced thematic mapper plus satellite (ETM+) and the other was from the thematic mapper (TM). The images were ordered and downloaded from the United States Geological Survey (USGS) website. Landsat images were chosen because they covered the period of the intended study and they have high spatial resolution suitable for the USGS Land cover classification system level 1 (Campbell, 2002; Jensen, 2000). The selection of the images was restricted to similar season to avoid seasonal differences in reflected radiation due to vegetation senescence. In addition, sample land cover information was collected with reference to the 2008 ETM+ image during field work in January 2012. Therefore the land cover map accuracy assessment was executed for only this image. The field work was also used to measure coordinates of known ground points for geo-referencing of the two images. The geo-referencing was executed with the ArcGIS software from Environmental Systems Research Institute (ESRI). Also digital line maps were obtained from the Survey Division of the Lands Commission, Ghana. In order to draw inferences with relevant environmental variables, precipitation and temperature data was obtained from the Metrological Agency of Ghana. Also discharges of two rivers (Whin and Kansawora) were obtained from the Hydrological Service Department of Ghana's Ministry of Water Resources Works and Housing. In figures ... and ...precipitation and temperature measured at the Takoradi Airport from 2001 to 2011 is displayed.

#### Image Registration

Image registration is executed to assign real world coordinates to images. This is to correct for geometric errors associated with the satellite images due a variety of reasons. These include instrumental errors, attitude of the sensors with respect to the rotation of the Earth and swath width of the sensor etc. Also image registration is executed to assign coordinates systems and projections to images. Image registration ensures that the features and process found on the satellite image are allocated their correct dimensions and positions. This is very important for change detection since we only compare the same geographic location at different times. The image registration in this study was executed with the ArcGIS software from ESRI. The images were registered to the 1984 World Geodetic System Universal Transverse Mercator (WGS '84 UTM) Zone 30 North Projection. Although the images were already geo-referenced to the UTM '84 zone 30 N, they were re-projected to ensure that they are allocated their correct ground coordinates. This is normally referred to as geometric correction.

**Land Cover Classification**

Image classification is performed to identify and assign real world thematic classes to the image pixels. In this study image classification was done in two stages, first by performing an unsupervised classification to assist in collecting additional training samples for the supervised classification. The maximum likelihood classification algorithm was selected because it has the ability to incorporate the statistics of the training samples before assigning the land covers to each pixel. The training samples obtained during fieldwork in January 2012 were used together with those collected after unsupervised classification. The landsat image bands used for the classification were the visible, near-infrared, middle and far-infrared. After image classification the land cover maps generated were filtered with the majority filter to remove the “salt-and-pepper appearance” (Lillesand and Kiefer, 2000) and to enhance the cartographic presentation. The landcover classes generated were built-up, grassland/shrubs, forest/farm lands, rivers/lakes/lagoons and sea. See Table 1 for the display of the nomenclature used for the land covers.

**Table1: Land cover classes nomenclature**

| Code | LULC Classes       | Description derived from USGS Level I                                  |
|------|--------------------|--|
| 1    | Built-up land      | Urban residential, commercial, industrial, transportation and services |
| 2    | Grassland/shrubs   | Grasses, shrubs,bushes   |
| 3    | Forests/farm lands | Forests, palm, rubber plantations,coacoa farms                         |
| 4    | Water              | Rivers, streams, lagoons, bays, estuaries, wetlands, lakes, dams       |
| 5    | Sea                | Sea water in the Atlantic Ocean  |

**Urban LULC Change detection**

Change detection is a process to record the changes that have occurred in the LULC over a period of time. The change detection process to use depends on the phenomena or feature under investigation. If the change being studied has high temporal resolution, the images and procedures must account for the time. The change detection process adopted for this study is the post classification comparison. This is because the method is simple to execute and it provides detailed “from to” statistics suitable for decision making. The method was executed by using the two land cover maps generated for 1988 and 2008 in a raster GIS analysis. The 1988 land cover map was reclassified and combined with that of 2008 using map algebra functions within the spatial analyst of the ArcGIS software. The result was a land cover change map from 1988 to 2008. Also, the statistics of the change was extracted and analyzed using tables and graphs.

**Urban sprawl measurement and Analysis using Shannon’s Entropy**

Urban sprawl is the ‘scatteredness’ of an urban area (Quezada *et al.*, 2009). Urban sprawl has been measured in a variety of ways (Tewolde and Cabral, 2011; Besussi *et al.*, 2006 ). However, the most common form of measurement and analysis has been the use of the Shannon’s entropy index (Tewolde and Cabral, 2011). It is computed by defining zones along major roads or by using buffers from the city centre(s) and calculating the density of built-up areas in each zone. This means the “scatterednes” of development is measured along major roads or from the city centre. The index ranges from 0 to 1. An index of 0 means there is compactness in the urban development and efficient utilization of land is implied while an index of 1 means there is scattered development. In this paper the Shannon’s entropy,  $E_n$ , was calculated for the 1988 and 2008 land cover maps using the formula in equation (1).

$$E_n = \sum_i^n p_i \log\left(\frac{1}{p_i}\right) / \log(n) \tag{1}$$

Where,  $p_i = x_i / \sum_i^n x_i$  and  $x_i$  is the density of land development, equal to area of built-up divided by total land area in  $i^{th}$  of  $n$  total zones,  $n$  is the number of zones from city centre.

**Results and Discussion**

**Urban Land cover/Land use**

Results of the study are shown in the figures and tables below. In Figure 2, land cover maps of 1988 and 2008 are displayed. Five land cover classes: built-up areas, grasslands, forest, rivers/lakes and sea were identified in the study area. The classification accuracy estimate was executed for the 2008 image since ground truth data was captured with respect to that image. The overall accuracy of the classification generated from the confusion matrix was 88.88%.



It can be observed from Figure 2 and Table 3 that in 1988 the built-up area was 14.14 km<sup>2</sup> only 3% of the study area while the forests covered 332.66 km<sup>2</sup>, 70% of the study area. The land cover map of 2008 however shows that the built-up area was now 51.31 km<sup>2</sup>, 11% of the study area, an increase of 263 % (Table 4). In addition, the forested areas had reduced to 293.56 km<sup>2</sup>, a reduction of 12% (Table 4). In Figure 3 and Table 5 the LULC change map and statistics are also displayed. It can be observed from figure 4 that built-up areas in 2008 have mainly been taken from grasslands and forests. Also a substantial part of the forested areas have been converted to grassland or shrubs. In addition, some grasslands in 1988 have been reforested by 2008. This is possible because there are commercial rubber and palm plantation farms in the northern sections of the study area. The built-up areas have increased about 263% in the twenty year period while forested areas have reduced by more than 11% and grasslands by almost 2%. The reduction of the forest and grasslands and increase of urban built-up areas indicates a substantial increase in impervious surface areas. It is well noted that impervious surface areas are a major contributing factor to urban floods and urban heat island effects (Aduah et al., 2011). Therefore it is necessary that plans are made to convey run-off in the Takoradi-Sekondi Metropolis with a variety of objects. These could include well designed drains, ponds and wetlands. In Table 5 it is also interesting to note that some of the urban areas (rivers to urban: 0.68 km<sup>2</sup>) have encroached on the river banks most of which are wetlands. It is not surprising that many of the residences in these areas experience floods the most.

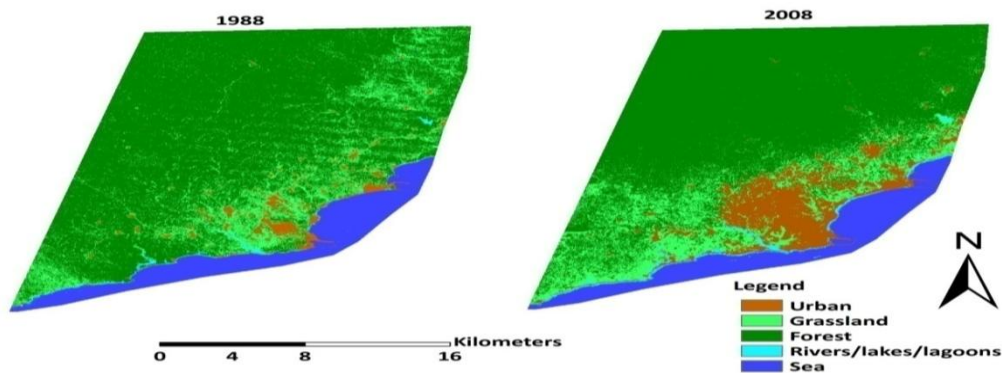


Figure 2: A map showing land cover/land use for 1988 and 2008

Table 3: land cover statistics

| Class     | 1988                   |           | 2008                   |           |
|-----------|------------------------|-----------|------------------------|-----------|
|           | Area(km <sup>2</sup> ) | % of Area | Area(km <sup>2</sup> ) | % of Area |
| Built-up  | 14.148                 | 2.98      | 51.314                 | 10.82     |
| Grassland | 72.958                 | 15.39     | 74.304                 | 15.67     |
| Forest    | 332.658                | 70.15     | 293.561                | 61.91     |
| Water     | 2.957                  | 0.62      | 5.986                  | 1.26      |
| Sea       | 51.472                 | 10.86     | 49.028                 | 10.34     |
| Total     | 474.193                | 100.00    | 474.193                | 100.00    |

Table 4: Land cover change statistics from 1988 to 2008

| Land cover | Area (Km <sup>2</sup> ) |         |         |          |
|------------|-------------------------|---------|---------|----------|
|            | 1988                    | 2008    | change  | % change |
| Built-up   | 14.148                  | 51.314  | 37.166  | 262.691  |
| Grasslands | 72.958                  | 74.304  | 1.346   | 1.845    |
| Forest     | 332.658                 | 293.561 | -39.097 | -11.753  |
| Water      | 2.957                   | 5.986   | 3.029   | 102.404  |
| Sea        | 51.472                  | 49.028  | -2.444  | -4.747   |
| Total      | 474.193                 | 474.193 |         |          |

The urban land cover change detected in Sekondi-Takoradi Metropolis shows that the city have experienced massive growth in the urban space and therefore problems associated with such changes are expected. These include high urban temperatures, high vulnerability to floods and reduction in rich agricultural areas. Some of the causes of these massive urban changes in the study area include high growth rate of population (Ghana statistical Service, 2000) and high population density. Also an increase in the Gross Domestic Product (GDP) of the city accounts partly for the high rate of urbanization. Many people are able to buy land and construct their own homes. Also many firms have established their regional or sub-regional offices and factories in the city within the period and many of them have constructed staff accommodation. The high rate of urbanization could also be negative for the communities living at the city fringes. This is because many of the peasant farmers have lost their lands to real estate developers, individuals and companies over the years. For many of these farmers they have no other source of income and therefore could become poorer as a result of losing their farm lands.

The urban change therefore has both negative and positive effects on the community. However, until detailed and timely inventory is done, it is not possible to make any assessment. Land cover land use map is therefore one of the first statistic required to manage the urban space efficiently to generate opportunities for all sectors of the economy. Without these maps it will be difficult to assess the success of any urban planning strategy.

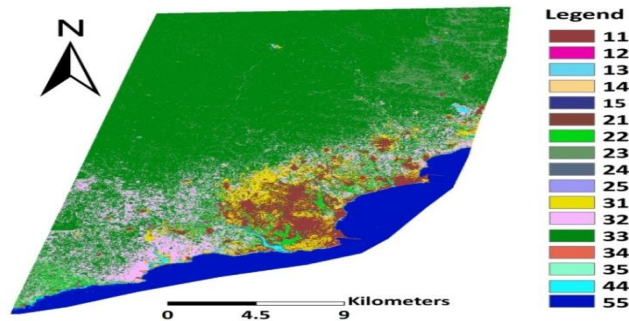


Figure 3: Land cover changed map from 1988 to 2008

Classes: 11-urban unchanged, 12: urban to grassland, 13: urban to forest, 14: urban to water bodies, 15: urban to sea, 21: grassland to urban, 22: grassland unchanged, 23: grassland to forest,

Table 5: Land cover changed statistics

| Land cover          | Area(Km <sup>2</sup> ) |
|---------------------|------------------------|
| Urban unchanged     | 12.196                 |
| Urban to Grassland  | 0.655                  |
| Urban to Forest     | 0.743                  |
| Urban to Rivers     | 0.333                  |
| Urban to Sea        | 0.221                  |
| Grassland to Urban  | 19.997                 |
| Grassland unchanged | 20.005                 |
| Grassland to Forest | 32.103                 |
| Grassland to Rivers | 0.850                  |
| Grassland to Sea    | 0.003                  |
| Forest to Urban     | 17.842                 |
| Forest to Grassland | 53.473                 |
| Forest unchanged    | 260.677                |
| Forest to rivers    | 0.666                  |
| Forest to Sea       | 0.001                  |
| Rivers to urban     | 0.683                  |
| Rivers to Grassland | 0.168                  |
| Rivers to Forest    | 0.003                  |
| Rivers unchanged    | 1.953                  |
| Rivers to sea       | 0.150                  |
| Sea to Urban        | 0.596                  |
| Sea to grassland    | 0.003                  |
| Sea to Forest       | 0.035                  |
| Sea to Rivers       | 2.184                  |
| Sea unchanged       | 48.654                 |
| Total               | 474.193                |

24: grassland to water, 25: grassland to sea, 31: forest to urban, 32: forest to grassland, 33: forest unchanged, 34: forest to water, 35: forest to sea, 44: water, 55: sea unchanged

### Urban Sprawl Analysis

To evaluate the level of dispersion of the urban development in the study area, the Shannon entropy index was calculated for the two dates studied. The study area is a coastal city hence the area of the sea was removed from the land cover maps before the sprawl analysis was done. The land cover maps of the two dates (1988 and 2008) were reclassified into built-up and non-built-up and crossed with 2 km buffer zones (Figure 4a) whose centre start from the city centre. Figure 4b show the built-up and non-built-up lands in 1988 and 2008 respectively. The area of built-up in each zone was calculated and the Shannon entropy was determined for each zone as well as the entire study area. The Shannon entropy for the study area ranged from 0.59 to 0.62 in 1988 and 2008 respectively. This is an indication that sprawling in the study area has not increased substantially between the two dates despite a massive (more than 263%) increase in built-up areas (Table 4).

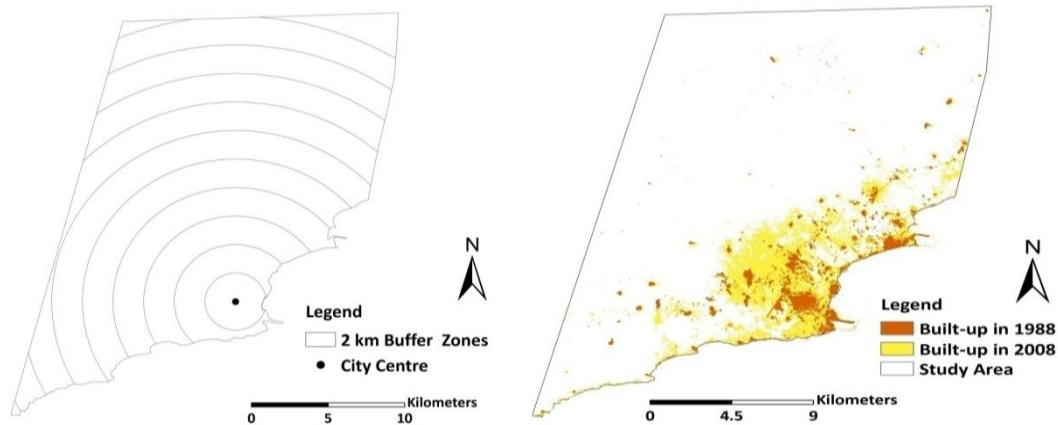


Figure 4: a) Buffer zones in Sekondi-Takoradi and b) Built-up areas in 1988 and 2008

The fact that the city is less scattered therefore makes provision of services and infrastructure such as electricity, water, schools, hospitals and roads less complicated in terms of their spatial distribution. However, by inspecting the entropies for each zone it is revealed that the values for zones 6 km to 10 km from the city centre had the highest values for both the 1988 and 2008 land cover maps. This together with field evidence shows that some of the sections of the study area are more fragmented than others. For example new neighborhoods in the north eastern part of the study area, behind Kansaworodo, Anaji Namibia and Ntankoful communities are scattered. There are many uncompleted buildings within a few completed residential ones. It is therefore imperative that urban planning methods that suit all these sections of the city be adopted for a sustainable utilization of the limited land resources in the study area. It is also important that plans are made to safeguard the agricultural lands in the outskirts of the city. The result of the study indicates that this can be done since the city has only few isolated settlements.

### Conclusions

Land cover and its changes in the Sekondi-Takoradi Metropolis have been successfully mapped using satellite remote sensing techniques. The techniques adopted generated acceptable accuracies. The land cover changes in the study area have changed drastically since 1988. The urban area has more than doubled, while the forest areas have decreased by more than 10%. Also the areas covered by grasslands have increased. This means the percentage of impervious surface areas have increased tremendously raising the vulnerability of sections of the community living near rivers. Furthermore, urban sprawl analysis showed that Sekondi-Takoradi has not witnessed substantial sprawling between 1988 and 2008. However, sections of the city especially between 6 km and 10 km from the centre have high sprawling. The results of this study further indicate the importance of remote sensing to urban environmental monitoring and management especially in Africa. The city authorities in Sekondi-Takoradi can use the data generated to aid their future development plans that also protects agricultural lands in the outskirts. Also since land cover affects the climate, it is important that the land cover in the city is managed so as to protect the citizens from phenomenon such as urban heat island effects and floods.

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