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Identifying and Quantifying Urban Sprawl in the Greater Accra Region of Ghana from 1985 to 2014

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Abstract: ***Urban sprawl has become one of the major threats to sustainable development of our time. This not withstanding is not given the needed attention by authorities to curb this menace. It is against this backdrop that this study was carried out. Changes in the land cover between the period of 1985 and 2014 in the Greater Accra Region were considered and how the urban lands changed during that period, using geospatial techniques. The built–up areas were obtained from the Landsat classified images of two different years to monitor the dynamics of urban sprawl. Land use/cover change analysis coupled with Shannon's entropy index was employed to identify and quantify the changes in the urban growth pattern in the Greater Accra Region of Ghana. The results showed both the non-urban and water lands are decreasing at an annual rate of 0.38% and 0.23% respectively while the urban lands keep increasing annually at 7.8%. The Shannon's entropy values for the area ranged from 0.4019 to 0.9199 in 1985 and 0.8162 to 0.9923 in 2014. These figures showed that the rate of sprawl was more pronounced in 2014 than in 1985.***

Keywords: Urban sprawl, Sustainable development, Geospatial techniques, Shannon's entropy index

1. Introduction

Ghana's population is becoming increasingly urbanized. In Ghana, any settlement with a population of 5,000 or more persons forms an urban center[1]. Currently five out of every ten Ghanaians live in a city or town of more than 5,000 people [1]. The forecasts [2]that should current trends continue, by the year 2020 more than half of all Ghanaians will live in urban areas. In 1931, only 9.4% of the total population was urban dwellers. By 1948 this population had shifted to 13.9%, 23% in 1960, 28.9% in 1970, 31.3% in 1984 and 43.9% in 2000 [2]. Greater Accra region is where the capital city of the country is located and according to [3]the most urbanized with as much as 90.5% of its total population living in urban centers. The annual growth rate of Accra is 4.4% with the city predominantly growing towards the west and the far eastern suburbs. Most areas in the region, which were classified as rural in the 1984 census, have attained urban status in the 2000 census [4]. A study by [5]reveals that the built up area in the Accra Metropolitan area increased from 133 square kilometers in 1985 to 344 square kilometers in 2000. Unfortunately, this growth is not commensurate with its planning, and most of its spatial patterns can be interpreted as urban sprawl.

[6]posited that urban sprawl is a consequence of socioeconomic development under certain circumstances. Urban sprawl has been defined by a plethora of authors [7,8,9,10, 11], from different perspectives. [12]defined sprawl as the process in which the spread of development across the landscape far outpaces population growth. Thus it is the physical outward expansion of cities characterized by low densities, separated land uses and car dependent communities. Urban sprawl, according to [13, 14 and 15]is also referred to as urban decentralization. Usually, sprawls take place on the urban fringe, at the edge of an urban area or along the highways in most parts of the globe. The need for understanding urban sprawl is already stressed [16].

Urban sprawl has both environmental and social impacts on a society. Unplanned urbanization leading to increased economic activities complicates efforts to improve solid wastes management, [17] and destroys large tracts of natural areas [18].

As pointed out by [5], the built up area in the Accra Metropolitan area increased from 133 square kilometers in 1985 to 344 square kilometers in 2000 implies that other land use had to make way for such expansion with most serious impact on farmlands [19]. Another consequence of urban sprawl in the Greater Accra region is the over dependence on car to commute long distances within the region [20and 21]. This has led to increased air pollution and excessive traffic congestion. Wildlife has not been spared in the attack of urban sprawl on their habitat [22]as most wildlife is endangered or close to extinction in the region[22]. Because development is haphazard in the fringes of the region culminating in sprawl, structures have been put up on waterways resulting in increased flooding and no wonder cases of floods is on the increase in the region as indicated by [23].

The traditional techniques of surveying have proved inefficient in management strategies of natural resources resulting in high consequences for man and environment. However, the physical expressions and patterns of sprawl on landscapes can be precisely detected, mapped, and analyzed using geospatial techniques [24, 7]. Therefore, this study will adopt remote sensing and geographical information system as tools for identifying and quantifying urban sprawl in the Greater Accra Region of Ghana.

2. Literature Survey

Although the Greater Accra Region is the capital region and a very old and important urban area of Ghana, analysis of urban growth and sprawl for this Region was not found in the existing literature when this research was initiated.

Greater Accra Region urban agglomeration is the largest urban agglomeration in Ghana, with a population of 4.01 million as per 2010 census and not until recently (2010) had six districts, namely Accra, Tema, Ga East, Ga West, Dangbe East, and Dangbe West. For this work, these six administrative boundaries would be used to assess the sprawl in the region. Greater Accra Region is the most urbanized region of Ghana and therefore, while initiating this research, the region has been considered as a study area to understand the pattern and process of urban growth and sprawl.

It has been reported [11]that unlike in the other developing country where urban sprawl is triggered by a combination of peri-urbanized economic and residential activities, in the case of Greater Accra Metropolitan Area (GAMA), peri-urbanization is mainly for residential development characterized by low-density development. The conclusion was that, the present size and scale of GAMA suggests the failure of the containment strategy, which was developed to limit the sprawl of GAMA, thereby leading to a sprawled GAMA. Thus the work of [11] only considered one out of the six districts while this work plans to reveal the sprawl pattern in the whole of the region.

3. Materials and Method

3.1 Study Area

The Greater Accra region is one of the ten administrative regions of Ghana. It lies in the South East of the country along the Gulf of Guinea and has coastal savannah, a little forest area inland towards the Eastern region in the Ga district, and miles of beautiful coastline especially in the rural parts of the region. There is wide variation in communities and living standards in the region, which ranges from reasonably high and middle-income urban communities to deprived urban slums and typical deprived rural farming.

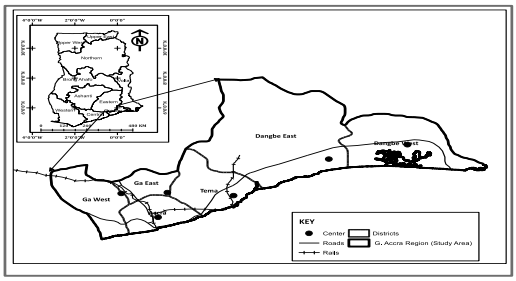

Figure 1: The study Area

3.2 Materials

Cloud Free Landsat images for the years 1985 and 2014 with path 193 and row 056 containing the study area were downloaded free from the USGS website. According to [25] and [26] Landsat images have high spatial resolution suitable for the USGS Land cover classification system level 1. The analytical tools used were ERDAS Imagine 9.2 and Envi 4.7 for digital image processing, while ArcGIS 10.1 was used for spatial analysis and to generate map layout.

3.3 Method

Bands 4, 3 and 2 for the TM images and bands 5, 4, 3 for the OLI images were combined to produce the standard "false color" composite [27]. This is a very popular band combination and is useful for vegetation studies, monitoring drainage and soil patterns and various stages of crop growth [27]. The images were geometrically corrected and re-projected into the Ghana Datum, War Office whose projection is based on the Transverse Mercator projection. However, this study did not do radiometric correction, because the datasets obtained were already corrected by the USGS to some extent necessary for this work [28].Enhance tool of Envi 4.7, the Image Equalization was performed in ENVI tool to make the image clearer for onward processing. Two subset images of the study area were created using the shape file for the area. To get an idea about the number of training sites to use in the supervised classification, the unsupervised classification was done using the ISODATA clustering algorithm in ENVI 4.7 to classify the images according to the number of classes required and the digital number of the pixels available in the unsupervised classification method. Ground-truth spatial and attribute data obtained during the visits to the area and the output of the unsupervised classification were used to perform a supervised classification on the images, using the maximum likelihood classification algorithm. The algorithm was used because it is able to incorporate the statistics of the training samples before assigning the land covers to each pixel. From the recommendation by [29], the land cover maps generated were filtered with the majority filter, a post-classification tool in Envi 4.7, to remove the "salt-and-pepper appearance" and to enhance the cartographic presentation after the image classification. The individual images were classified into three main distinct land cover classes based on the Anderson Classification System. The Shannon's Entropy Index, reputed as the commonest form of urban sprawl measurement and analysis [30] was used in this study. In this work zones were defined along the main road that cuts across the region as well as the city centers of the various districts in the region. The density of built-up areas in each zone was then calculated. 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. The Shannon's entropy (En) was calculated for the 1985 and 2014 land cover maps using the formula in the equation below.

$$En = \frac{\sum_i^n pi \log\left(\frac{1}{pi}\right)}{\log(n)} \quad (1)$$

Where, $pi = \frac{xi}{\sum_i^n xi}$ and xi is the density of land development, equal to area of built-up divided by total land area in ith of n total zones, n is the number of zones from city center.

Table 1: Description of the land cover classification system

Main Cover Class	*Sub-cover Class*	*Description*
URBAN	Urban/Built - up	This comprises of areas of intensive use with much of the land covered by structures. Included in this category are cities, towns, villages, highways and transportation, power, and communications facilities.

WATER	Water and Wetland	This consists of areas persistently covered with water; provided that if linear they are at least 200m wide. This category includes; streams and canals, lakes, reservoirs, bays and Estuaries
NON-URBAN	Barren land	Barren Land is land of limited ability to support life and in which less than one-third of the area has vegetation or other cover.
	Agricultural land	Agricultural Land may be defined broadly as land used primarily for production of food and fiber. This category includes; Cropland and Pasture, Ornamental Horticultural Areas.
	Forestland	Forest Lands have a tree-crown areal density (crown closure percentage) of 10% or more, are stocked with trees capable of producing timber or other wood products, and exert an influence on the climate or water regime. Forestlands include Deciduous, Evergreen and Mixed Forestlands.

(Source: [31])

4. Results and Discussion

4.1 Land Cover/Land Use Change

The three main land cover classes used in this study, based on the Anderson Classification System are shown in Table 1. The results of the supervised classification produced the thematic maps in Figures 2 and 3 with the accompanying statistics in Table 2. Table 2 showed that in 1985, urban area in the Greater Accra Region was only 163.7097 km^2 representing 4.43% of the total land cover in the Region while the non-urban covered 3094.1930 km^2, 83.77%. By 2014, the urban area had increased to 534.2279 km^2 (14%) while the non-urban further reduced to 2754.1254 km^2 (75%).

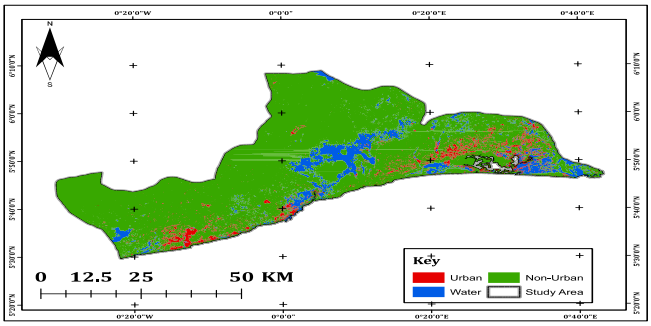

Figure 2: Classified Land Cover of the 1985 TM Image

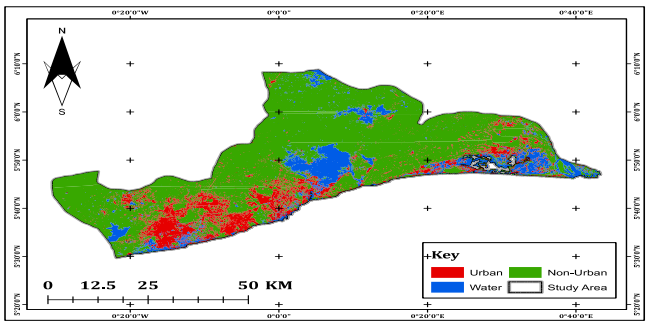

Figure 3: Classified Land Cover of the 2014 OLI Image

Table 2: Land cover statistics for the study period (1985-2014).

	1985		2014	
Feature	**Area (Km²)**	**Cover**	**Area (Km²)**	**Cover**
Non-Urban	3094.1930	83.77%	2754.1254	75%
Urban	163.7097	4.43%	534.2279	14%
Water	435.7903	11.80%	406.3510	11%
Total	**3693.6931**	**100.00%**	**3694.7043**	**100%**

It was observed that the increase in urban space was a direct consequence of the non-urban land cover, which recorded 2941.6578 km^2 (80%).

It can be observed from Table 2 that there have been changes in the land cover. While there was a 10.99% and 6.76% decrease in the percentage cover of the non-urban area and water respectively, the urban space more than quadrupled in the study period. Thus, there was an increase of 226.33% of the urban cover.

The results show that the land cover of Greater Accra has changed over the period studied. The non-urban lands which in this work was considered to include barren land, farmland and forestland has seen a seen a decrease from 3094.1930 km^2 in 1985 to 2754.1254 km^2 in 2014. This represents a total of about 11% decrease within the 29-year period of this study. This change therefore means that, the non-urban lands keeps reducing at an annual rate of 0.38%. In the same period, water (which includes wetlands and other water bodies) has also experienced a 6.67% reduction in land cover, 0.23% annually. However, the case of the urban land cover, which in this study was considered to include built-up and urban areas, has increase tremendously. There has been a 226.33% increase in this land cover. This means that the urban area of the region is growing at an annual rate of 7.8% since 1985.

This quadrupling of the urban area while the non-urban area has decreased means impervious surface areas has increased in the region and as [32] noted, impervious surface areas is a major contributing factor to urban floods and urban heat island effects.

4.2 Urban Expansion Analysis

To facilitate easy analysis of rate, nature, location and trend of urban expansion, a thematic class of urban land cover class was extracted from both classified images of 1985 and 2014.

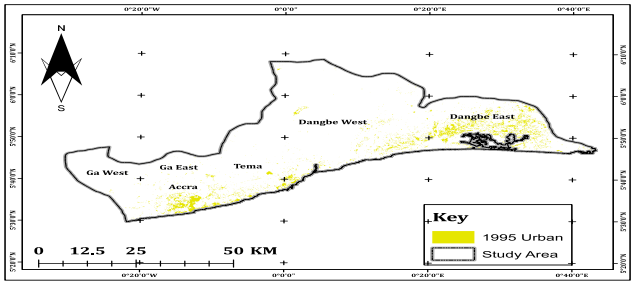

Figure 4: Urban Area in 1985

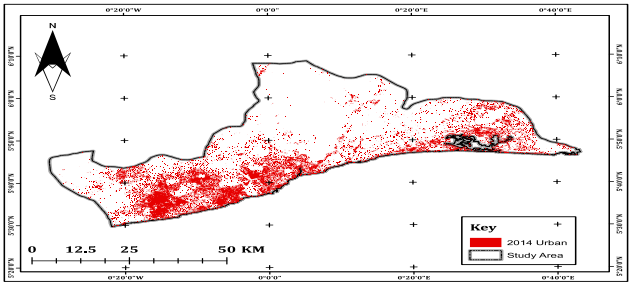

Figure 5: Urban Area in 2014

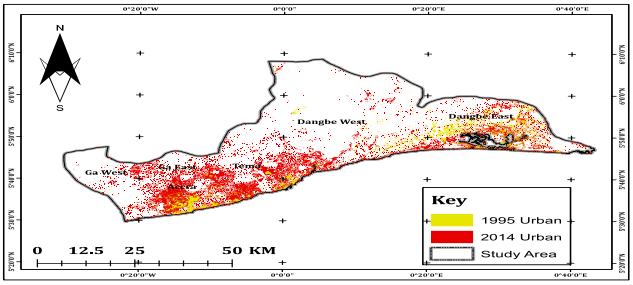

Figure 6: Urban Expansion from 1985 to 2014

Figure 4 and 5 show the thematic map of urban land cover class for 1985 and 2014 respectively. These two thematic maps show that there has been a considerable amount of change in urban land from 1985 to 2014. Most of the change is concentrated at the Accra and Tema metropolitan areas (south western part of the study area map). These two metropolitan areas are the industrial and commercial hubs of the Region and the country as a whole.

An overlay of the 1985 and 2014 (Figure 6) urban land images further indicates that there has been a considerable increased or expansion in urban land.

Figure 6 indicates the spatial occurrence and area extent of urban expansion that has occurred within the Greater Accra Region over the 29-year period.

Within the 29-year period, urban expansion was identified as one of the major forces responsible for the alteration of the land cover in the study area. The population of the region as at 1984 was 1,431,099 [33]; however, this population grew to 4,010,054 in 2010 [33]. It can therefore be deduced from the figures that between 1984 and 2010, the population of the region had more than quadrupled. It can only be inferred from these figures that the population will further increase in 2014.

4.3 Urban Sprawl Analysis

To understand the complexity of a dynamic phenomenon such as an urban sprawl, land use change analyses, urban sprawl pattern and computation of sprawl indicator indices were determined. To evaluate the level of dispersion of the urban development in the study area, there were two main features that were considered. The first was the main road that cuts across the region. Buffer zones ranging from one to fifteen kilometers from the road were created and the extracted urban area was overlayed on this as illustrated in Figure 7, and 8.

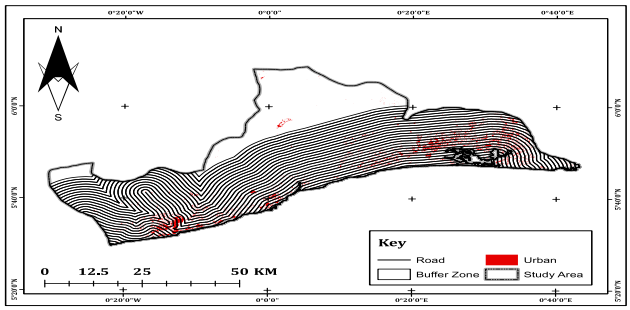

Figure 7: Sprawl across Greater Accra Region in1985

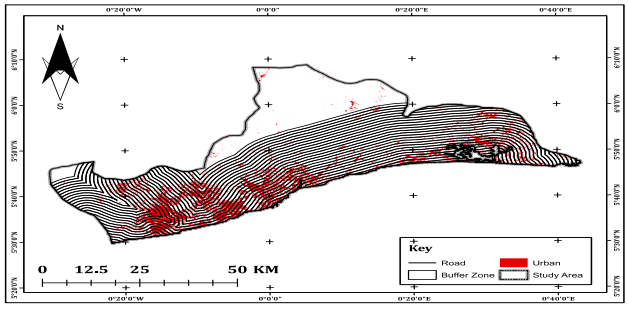

Figure 8: Sprawl across Greater Accra Region in2014

It is observed that the urban density decreases away from the main road, an indication of the road instigating urban development. Shannon entropy indices calculated for the study area were 0.7763, 0.8562 and 0.9321 respectively in 1985, 2002 and 2014. This shows a progressive increase in sprawl along the major road. Thus, the settlement along the road, though sprawled from 1985, the degree of sprawl is increasing as suggested by the sprawl indices. The second approach evaluated sprawl in the study area was using the city center approach. Each of six districts in the regions has a capital, which serves as the city center since most of the economic activities happen in these places. Buffer zones were created at one-kilometer intervals around the various capitals to fill the each whole district as depicted in Figure 9 and 10 for 1985 and 2014 respectively.

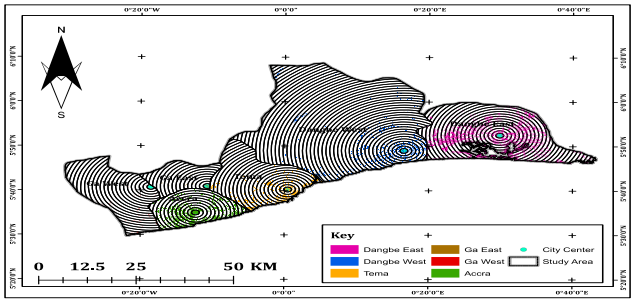

Figure 9: The sprawl from city centers of the various districts (1985)

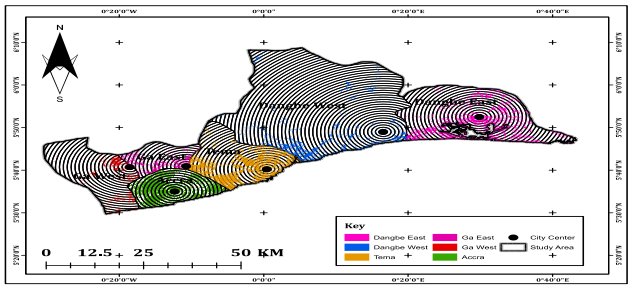

Figure 10: The sprawl from city centers of the various districts (2014).

The Shannon entropy calculated for the various districts has been summarized in Table 3below.

Table 3: Shannon Entropy for the districts in Greater Accra Region

	Shannon Entropy	
Districts	1985	2014
Ga East	0.4019	0.9158
Ga West	0.8990	0.8162
Accra	0.8453	0.9923
Tema	0.6623	0.9331
Dangbe West	0.7277	0.9024
Dangbe East	0.9199	0.9245

All figures as shown in Table 3 clearly show that sprawl in the study area is on the increase from 1985 up to now. The figures from the table indicate that sprawl has been the case even in 1985. Since this has not been controlled over the period, it continues to grow. In 1985, the Ga East part of the study area was quite compact in the sense that it has a lower index. This can be explained that there was very small urban area, which was concentrated at one place (**Error! Reference source not found.**) but had increased in 2014. Overall, the Shannon entropy of the region ranged from 0.4019 – 0.9199 in 1985 to 0.8162 – 0.9923 in 2014, an indication of continuous sprawling of the region.

5. Conclusion

The study investigated the urban sprawl phenomenon occurring in the Greater Accra Region area and found that there has been an overall growth in built-up area. With the Shannon's entropy analysis, the study was able to identify where the sprawl was taking place and the extent. The results of the analysis also showed non-urban land decreased from 83.77% in 1985 to 74.54% in 2014 of the total landmass of the area, representing an annual decrease of 0.38%. The area covered by water decreased from 11.80% in 1985 to 11.00% of the total landmass at an annual rate of 0.23%, while urban land increased from 4.43% in 1985 to 14.46% in 2014 representing 7.8% annual rate of increase. The urban area is mainly sprawled around city centers and along the main road. The major road that cuts across the region as well as the city centers in the region was identified as the main cause of sprawl in the region.

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Author Profile

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Bolarinwa Olutayo Balogun is a research scientist with a background in Environmental Management and Control. My research interest is in the utilization of Earth Observation Systems to monitor, assess and manage the environment and natural resources in Africa. In this regard, I have been working with scientists with different scientific backgrounds in Africa and still hope to work with many more, even beyond the African shores, who share my passion.

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