Application of Remote Sensing to Monitor Thermal Emission, a Case Study of Accra Metropolitan Area

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Key words: thermal radiated energy, urban heat islands, urbanization, remote sensing, land cover/land use

SUMMARY

The predicted rise in surface temperatures due to climate change is exacerbated in urban area by the heat island effect, which has also been predicted to increase if the necessary precautions are not put in place. This model attempts to simulate urban absorption of solar radiation within the Accra Metropolitan Area of Ghana, a vibrant urban centre in the country, and its resultant effect on the changes in surface temperature over a twenty-five (25) year period. It examines the thermal characteristic component and the land use/ land cover change detection of the region with the use of an integrated remote sensing approach from the years 1991, 2002, 2013 and 2016. The change in land use is attributed to factors such as the conversion of forest and agriculture lands to pave way for the rapid increase in urban growth and the tarring of the surface by impervious materials. The results showed that there has been a significant increase in surface temperatures by 5^{o} C due to urban sprawl and massive developments within the Metropolis which can lead to resultant effects on climate change. The study also employed the use of a questionnaire survey which supported the empirical evidence derived from the analysed images that the loss in the vegetative cover is a major reason that accounts for the change in surface temperatures. Other contributing factors identified were congested settlements, the emission from AC/cars, the shape of buildings and an increase in tarred road networks. Accounts from the study also discovered several effects faced by the people in the study area due to increasing surface temperatures. These effects include the increased reliance on AC/ fans, the use of lighter clothing gear on day to day activities, health implications such as respiratory disorder and skin rashes, avoidance of overcrowded spaces and the decrease in business activities.

Thermal infrared remote sensing technology has therefore been demonstrated to be an effective and efficient approach of studying the thermal characteristic of the land surface.

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1. INTRODUCTION

In recent times, the issue of thermal emission has caught the attention of many scholars and academicians due to its direct relation to the earth's climate (Landsberg 1981, Oke 1987, Howell 2001, and Weng 2001). Thermal emission, basically a cycle of nature, is a phenomenon where heat energy radiated from the surface of the earth is released into the atmosphere. The earth's surface emits absorbed radiation from the sun which is then absorbed or scattered by the atmosphere. Though some radiated heat escapes into space, most are absorbed and then re-emitted by atmospheric gases. It is this spectral selectivity of the atmosphere that is responsible for the planetary greenhouse effect, contributing to global warming and climate change in general but also critically contributing to climate stability when the composition and properties of the atmosphere are not changing (Howell, 2001). Whenever electromagnetic waves from the sun are emitted and then absorbed, heat is released basically heating the surface of the earth. Global analysis by the National Climatic Data Centre (US) done in July, 2015 indicates that the combined average temperature over global land and ocean surfaces for July 2015 was the highest for July in the 136-year period of record, at 0.81°C (1.46°F) above the 20th century average of 15.8°C (60.4°F), surpassing the previous record set in 1998 by 0.08°C (0.14°F) (National Climatic Data Centre, 2015). Also, the average surface temperatures for Africa were the second highest for 2015 on record, with regional record warmth across much of eastern Africa into central areas of the continent. Consistent with the observed trends globally and the rest of Africa, Ghana's average surface temperatures has been on a steady rise for the past decade. A case study of the Accra Metropolitan Area, a robust urbanized area, to monitor thermal emission between 1991 and 2016 would lay emphasis on the effects of rapid urbanization on increasing surface temperatures.

In light of this, the study examined the following questions:

- How has the state of thermal emission in Accra changed between 1991 and 2016?
- What is the rate of change of thermal emission in Accra?
- What are the causes for the change over the years?
- What are the effects of the changes over the years?

2. REMOTE SENSING AND THERMAL EMISSION

Remote sensing technologies play a significant role in understanding the trends and dynamics of thermal emission. Remote sensing is the science (and to some extent, art) of acquiring information about the earth's surface without actually being in contact with it. This is done by sensing and recording emitted energy, processing, analysing, and applying that information (CCRS, 2004). Thus, remote sensing can be applied to inaccessible areas and regions that inhibit the use of conventional surveys. Traditional survey and mapping approaches do not offer the necessary information in a timely and cost-effective manner. Remotely-sensed data, with their advantages in spectral, spatial, and temporal resolution, have demonstrated their usefulness in provision of information about the physical characteristics of urban areas; including size, shape, and rates of change, and have been used widely for mapping and monitoring of urban biophysical features (Haack et al., 1997; Jensen and Cowen, 1999). Thermal emission in general is a global phenomenon that occurs in areas characterized by surface objects that emit heat which has a direct effect on the atmosphere. Research on thermal emission have been related to urbanization and have been measured successfully with the application of remote sensing and other statistical methods. High spatial resolution imagery obtained primarily from airborne remote sensing has been used to assess the thermal behaviour of urban surfaces in relation to surface characteristics such as sky view factors. (Eliasson, 1992) Also, with increasing sensor resolution and low altitude flights, it is possible to extract temperatures from specific urban surfaces for analysis (Quattroch &Ridd, 1994; Shoshany, Aminov &Goldreich 1994).

2.1 Driving Forces in the Changes in Thermal Emission

<u>2.1.1 Urbanization</u>

Urbanization is known to be a major contributing factor to thermal emission. Urbanization may be defined as the proportion of the population of a nation or a region that is to be found living in towns and cities (Potter et al, 2008). According to Trusilova (2006), urbanization is can also be described as the movement of people into urban spaces. Urban population has been increasing for several decades at an accelerated pace (World Urbanization Prospects and Revision, 2009). The statistics provided proves the contribution of population to thermal emission. In 2009, about half of the world's population (3.42 billion out of 6.83 billion) lived in urban areas and projections show this will increase to 68.7% by 2050 (World Urbanization Prospects and Revision, 2009).While the developed world is more urban, 76% urban in 2000, developing countries have much faster urban population growth estimated 2.3% annually, which far exceeds the developed world's urban growth rate of 0.4% (Drescher and Iaquinta, 2002).Africa is rated among the least urbanized regions of the world and has hardly any mega-cities although its process of urbanization is very rapid (UNCHS-Habitat, 1996). Africa, with a 3.3% growth rate per year between 2000 and 2005, the rate of change of Africa's urban population is currently the highest in the world. The growth rates of 4.02% and 4.05% respectively for the West and Central Africa and East Africa regions are the fastest growing regions in Africa (UN-HABITAT, 2008). Accra, Ghana's capital since 1877; is today one of the most populated and fast-growing metropolis of Africa with an annual growth of 3.36% (Ghana Districts, 2006). Urbanization is the outcome of social, economic and political developments that lead to urban concentration and growth of large cities (Stemn, 2013). The factors that induce the rapid urbanization in Africa presently are the types of migration; rural-urban migration and international immigration and natural increase within the vicinity. Concerning the internal factors of urbanization, rural-urban migration involves the movement of people from less developed rural areas to developing or developed urban areas. This activity in addition to the external form of migration being international migration, according to Stemn (2013) involves the movement of individuals across national boundaries. This contributes to the concentration of heat in urban areas as a result of the increased use of CFC (chlorofluorocarbon) products such as air conditioners and refrigerators, carbon monoxide emitting cars and construction vehicles, impervious heat infrastructures and the natural emitted heat from human beings.

In Accra, the acceleration of urbanization in order to comply with the demands of the large population size has increased the density of built-up areas which lead to raised temperature and heat island intensity. Buildings modify the wind, the radiant balance and the temperature conditions near the ground level (M.M. Tahir et al, 2010). In addition, urban centres tend to have higher energy demands than surrounding areas as a result of their high population density. The pollution created by emissions from power generation increases absorption of radiation in the boundary layer (Oke, 1982) and contributes to the creation of inversion layers. Inversion layers prevent rising air from cooling at the normal rate and slow the dispersion of pollutants produced in urban areas (Sahashi et al. 2004).

2.1.2 Urban Heat Islands

The alteration of the land cover modifies the urban climate causing it to be warmer than surrounding rural environment and is referred to as Urban Heat Island (UHI). It is a well known proposition that all urban centres create local temperature anomalies, in general leading to a higher average temperature than adjacent rural areas. It is therefore to be expected that the effects of climate change on rising temperature will be felt first and most severely in the world's cities (Watkins et al, 2007). Perhaps the clearest illustration of human impact on synoptic-scale climate is the urban heat island (UHI) phenomenon, i.e. the increase of the sub-surface, surface, or air temperatures observed in an urban environment compared to the undeveloped rural surroundings (Landsberg, 1981). Several factors have been postulated to explain the extra warmth of cities. They are the increased absorption of short-wave radiation, increased storage of sensible heat, anthropogenic heat production, reduced long-wave radiation losses, lower evapo transpiration rates and lower sensible heat loss due to reduced turbulence in urban canyons (Oke, 1987). Other factors, such as synoptic weather conditions (e.g. wind speed, cloud amount and height) (Oke, 1998), topography (Goldreich, 1984), city morphology, and size (Oke, 1973) modify the magnitude of UHI intensity.

Formation of the UHI begins as urban areas of the city absorb greater amounts of solar radiation and exhibit reduced cooling due to materials such as concrete and asphalt retaining this heat in the late afternoon and into the evening. The greatest difference between cooler rural and warmer urban areas typically occurs 3-5 hr after sunset in all seasons (Oke 1987, Geiger et al. 2003). According to Watkins et al. (2007), the increase in temperature of the urban centres could be attributed to other factors and conditions including building facades, albedo and vegetation. Urban growth both in population and in a real extent transforms the landscape from natural cover types to increasingly impervious urban land. The result of this change can have significant effects on local weather and climate (Landsbergis, 1981).

According to Vogt et al. (2003), replacing the landscape with impervious materials such as asphalt buildings, roads, and parking lots have a high solar radiation absorption, a great thermal conductivity and capacity such that heat is stored during the day and released at night. They further explained that the removal of natural cover types and subsequent introduction of these urban impervious materials modify the energy balance of the earth surface with a successive rise in surface temperature. Materials such as stone, concrete and asphalt tend to trap heat at the surfaces (Landsberg 1981; Oke 1982; Quattrochi et. Al 2000). These kinds of materials absorb and retain solar radiation in urban fabric during the night and this stored heat is released slowly from the urban surfaces. In Accra, most of the urban construction materials are concrete and asphalt with low albedo and non-reflective surfaces which absorb solar radiation and cause higher temperature and UHI formation.

The nature of the surfaces at a site and the access to the sky for energy receipt and re-emission are critical factors in influencing the thermal characteristics of an area. The eight categories represent increasing urbanization, i.e. increasing local heat capacity, and decreasing vegetation and sky view (Watkins, 2007). Many studies have used thermal remote sensing to examine the spatial structure of urban thermal patterns and their relation to urban surface characteristics. Also, cities create urban heat islands with air temperatures up to 10ºC greater than surrounding areas (Pickett et al., 2001). According to Shmaefsky (2006), the urban centres can be about 2ºC to 5ºC warmer than the surrounding forest and suburban areas of which the difference in temperature is most present in warm summer days with calm winds. He colligated this change to certain factors that precede the 'Urban Heat Island' which include; fewer trees or vegetation to block intense solar radiation and fewer trees to execute evapo-transpiration which has cooling effects on soils. Therefore, it is a requirement to address such extreme urban heat causes in order to curb the occurrence of extreme thermal emissions. In addition, the intensity of a heat island depends very much on the wind speed (Watkins, 2007). The speed at which air moves over the surface of the body is highly influential on the heat balance and therefore essential in monitoring thermal emitted radiations. Generally, increasing air speeds remove heat from the body causing the sensation of a cooler environment (Watkins, 2007). For the reduction of the urban heat island intensity, higher air velocities are potentially beneficial to remove the urban radiated heat within a region.

2.1.3 Change in Vegetative Cover

Vegetative cover in remote sensing is observed by using a Normalized Difference Vegetation Index (NDVI) and has been studied as one of the contributing factors in the changes in thermal emission. Also, much emphasis has been placed on using the NDVI as the major indicator of urban climate. For example, Gallo et al. (1993) assessed the influence of the urban environment on observed minimum air temperatures by analysing urban–rural differences in NDVI and surface temperatures.

Lo et al. (1997) studied changes in the thermal responses of urban land cover types between day and night and examined the relation between land cover radiance and vegetation amount using NDVI derived from Advanced Thermal and Land Applications Sensor (ATLAS) data. Gallo and Owen (1999) evaluated seasonal trends in temperature and NDVI and found that differences in NDVI and satellite-based surface temperature accounted for 40% of the variation in urban–rural temperature differences. The NDVI–temperature relationship has also been utilized in various studies to derive or evaluate two variables, fractional vegetation covers and surface soil water content for climate modeling (Carlson et al., 1977; Gillies and Carlson, 1995; Goward et al., 2002).

Vegetation, especially in the presence of high moisture levels, plays a significant role in the regulation of surface temperatures (Goward et al. 1985) and a lack of vegetation reduces heat loss due to evapo-transpiration (Lougeay et al. 1996). In Accra Metropolitan area, the construction of new buildings has crowded out the vegetation. Destroying vegetation and green spaces has been identified as a result in the reduction of evapo-transpiration rates and hence higher surface temperature (Shamohamadi et al, 2011).

2.3 Conceptual Framework

Below is a simple but dynamic conceptual framework describing the links between urbanization, its resultant effects on the urban heat island and how it affects thermal emission.

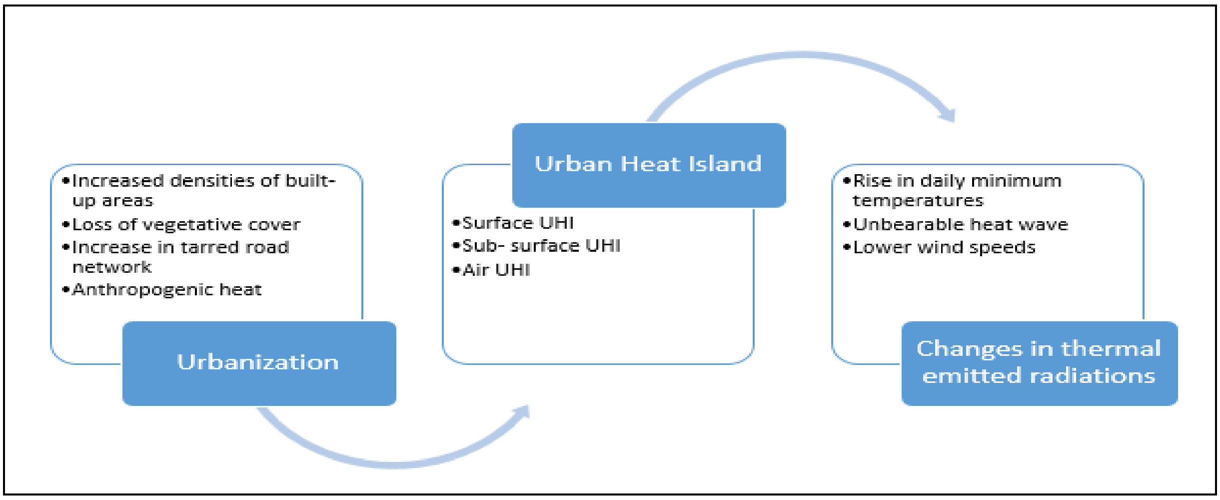


Figure 1.0 Interaction amongst Urbanization, Urban Heat Island and Changes in thermal emitted radiations

Source: Adapted from Oke (1987), Landsberg (1981) and Watkins (2007)

3. STUDY AREA

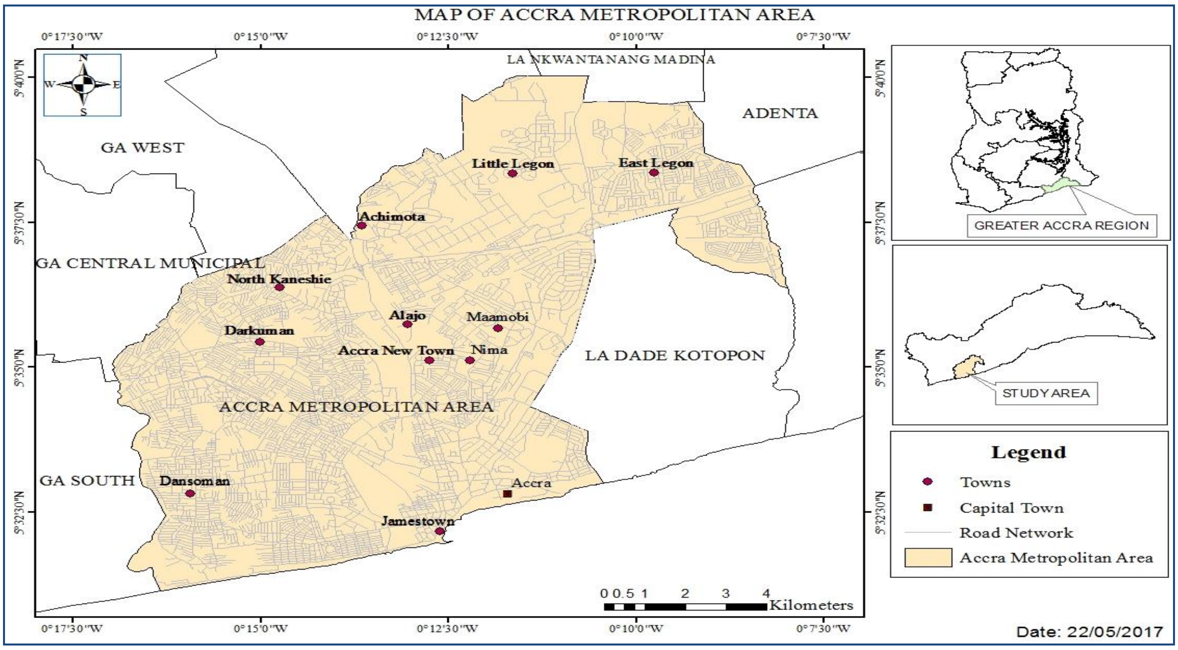


Figure 2.0 Map showing the study area

Source: Author's own construct, 2017

Accra Metropolitan Area is located between 5^0 33’ 0” North, 0^0 13’ 0” West in Ghana, West Africa of the equator. It covers an area of 173sq.km. The area is relatively dry since it falls within the dry coastal equatorial climatic zone. Due to its closeness to the equator, the daylight hours are practically uniform during the year with an average relative humidity of 81% (AMA, 2016). There is very little variation in temperature throughout the year. The mean monthly temperature ranges from 24.7^0 C in August (the coolest) to 33^0 C in March (the hottest) with an annual average of 26.8^0 C (Dickson and Benneh, 2001). The vegetation within the metropolis of Accra is mainly coastal savannah shrubs interspersed with thickets. There are a number of wetlands and water bodies which create micro-climates in some part of the metropolitan area. However, there is evidence to suggest that the original vegetation of the area has been altered in the more recent past century by climatic and human factors. Much of the metropolitan area was believed to have been covered by a dense forest of which only a few remnant trees survive as a result of urbanization and increased industrialization. (AMA, 2016) The population of Accra Metropolitan Area according to the 2010 Population and Housing Census is 1,665, 086 representing 42% of the region’s total population. The metropolis is entirely urban (100%). At the regional level, Greater Accra recorded the highest population growth rates of 3.1%. It is the most densely populated region with a density of approximately 1,236 persons per square kilometre in 2010 compared to 895.5 persons per square kilometre in 2000. The increase in population density implies more pressure on the existing social amenities, infrastructure and other resources in the country. (Ghana Statistical Service, 2014)

4. RESEARCH METHODOLOGY

The principal sources of data are Land sat images downloaded from the United States Geological Survey (USGS) website to monitor changes in thermal emitted radiations and in land use/ land cover changes. The images used included Land sat Thematic Mapper (TM) image of 1991 and Land sat Enhanced Thematic Mapper Plus (ETM +) images of 2002, 2013 and 2016. This primary source was adopted because the sensors of TM and ETM+ acquire temperature data and store this information as a digital number (DN) in band 6 with a high spectral resolution can be converted to Kelvin and Degrees Celsius (Yale Center for Earth Observation, 2010). Aside band 6, band 7, 4, 3 and band 2 were also calibrated for the purpose of supervised classification and Normalized Difference Vegetation Index. These Land sat images were also used to analyse the changes in land use/ land cover changes in relation to how it affects the change in the thermal characteristic component of the area. Accurate analysis of the downloaded images was critical for the success of the research. Also, questionnaires were administered to the residents within the metropolis to analyse their perception on the changes in surface temperatures.

4.1 Flow chart

Below is a diagram illustrating the systematic way data collated was processed and analysed in order to monitor the thermal emissive rates of the Accra Metropolitan Assembly using remote sensing technologies and qualitative research methods through the administration of questionnaires.

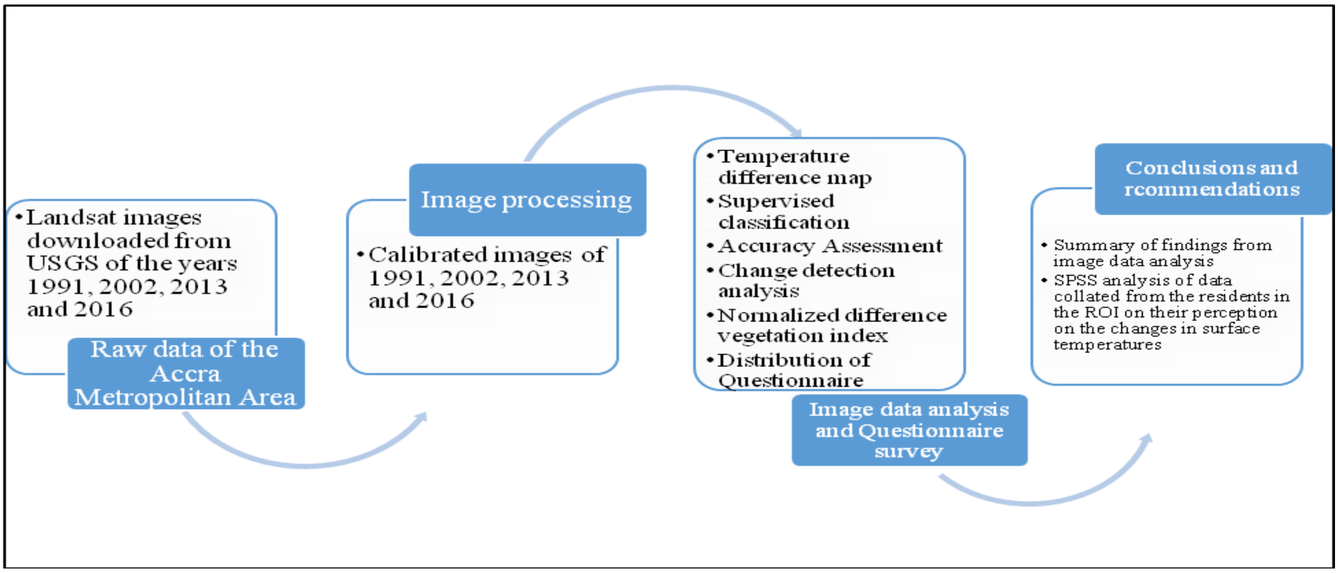


Figure 3.0: A flow chart illustrating the processes undertaken in the study

Source: Author's own construct, 2017

4.2. Data Analysis

The analysis of the data was done in two parts. The first part was the analysis of the Land sat images. The satellite imagery were loaded into ENVI 5.0 using band 6(#2) which has a high spectral resolution to determine the surface temperature of 1991, 2002, 2013 and 2016.The images were calibrated to their correct atmospheric effect and geometric errors. In order to process the calibrated images from the various years, the digital numbers which were converted to radiance during calibration are then converted to temperature in Kelvin with the formula;

$$T = \frac{K_2}{In\left(\frac{K_{1*\varepsilon}}{CV_{R1}} + 1\right)}$$

Where T is degrees in Kelvin

CV_{R1} is the cell value as radiance

e is emissivity (standard value 0.95)

	Land sat TM	Land sat ETM+

K_1	607.76	666.09
K_2	1260.56	1282.71

Source: The Yale Centre for Earth Observation (2010)

Hence the formula in band math ENVI for Land sat TM will be;

1260.56/alog ((607.76*0.95)/ (b6+1))

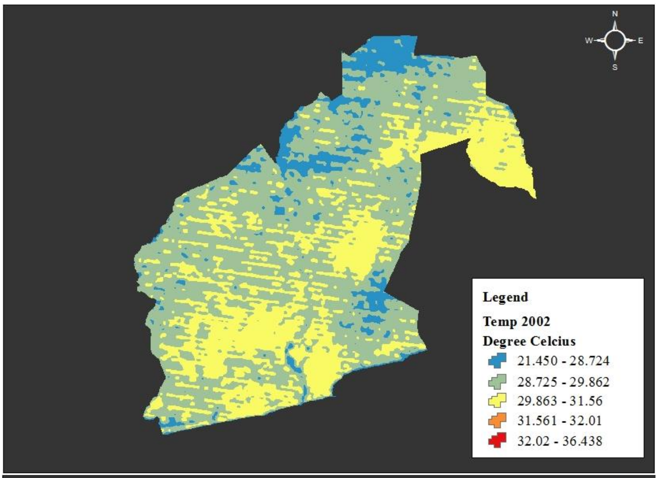
The formula in band math ratio in ENVI for Land sat ETM will be;

1282.71/alog ((666.09*0.95)/ (b6+1))

The Kelvin values were then converted to Degrees Celsius with Band math (B6-273.15). A spatial subset was done to the respective years of 1991, 2002, 2013 and 2016 to obtain the Region of Interest (ROI) of the Accra Metropolitan Area. These processed images were then imported into Google Earth to identify the exact areas that show the changes in heat energy. Also, the processed images were loaded into to run a supervised classification of the image to determine the percentage change in land use/ land cover changes over the period of 15 years from 2002 and 2016 as empirical evidence that urban development has resultant effects on the changes in thermal emitted heat within the metropolis. An overall accuracy assessment and Kappa coefficient was obtained to check the accuracy of the processed images. Change detection analysis was run to examine the changes in land use/ land cover within the region. Also, NDVI analysis was applied to the spatial subset images masking the Region of Interest (ROI) in ENVI 5.0 to examine the change in vegetative cover from 1991 to 2002 and 2013 to 2016 using the band math float (B4-B3)/ (B4+B3). This served as evidence to support the fact that less vegetative cover influences the changes in thermal emission. In addition, relevant data collected from the residents within the metropolis by the use of questionnaires were processed and analysed by the use of SPSS and Excel to aid in understanding the perception and knowledge people have on issues related to the changes in surface temperatures. This was also done to identify the anthropogenic factors that contribute to the changes in thermal energy. Literature from various authors on surface heat-related issues was also consulted from articles, journals, reports and on the internet.

5. FINDINGS AND DATA ANALYSIS

5.1 Surface Temperature Analysis for AMA



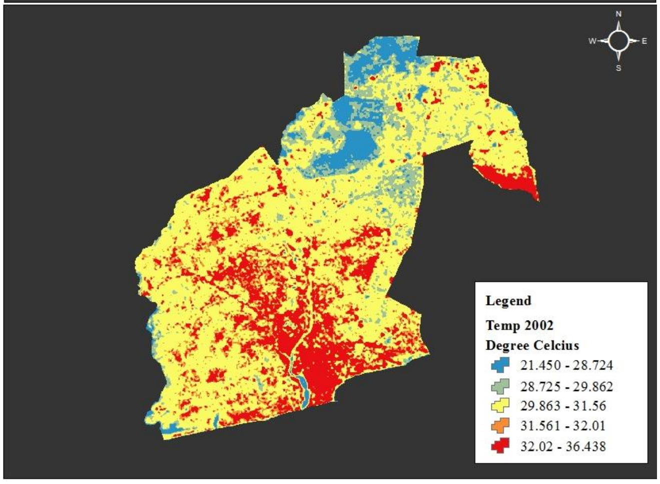
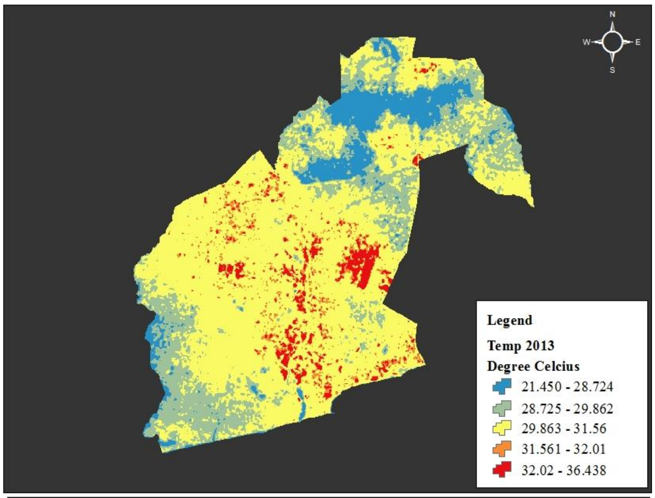


Figure 4.0 Surface Temperature Map of AMA in 1991

Figure 4.1 Surface Temperature Map of AMA in 2002

Figure 4.0 and Figure 4.1 above shows the resultant temperature difference map for the year 1991 and 2002. In 1991 after the analysis was run it was identified using cursor values that the minimum surface temperature was 25. 43°C and the maximum temperatures were 31.76°C within the ROI. Also, 2002 recorded minimum surface temperatures of 21.45°C and maximum temperatures of 36.43°C. Areas with the shade of blue indicate regions with lower surface temperatures whiles regions in red shows areas with very high surface temperatures. Areas indentified in blue are regions that contain water bodies and vegetative cover. Furthermore, areas in green are regions of bare lands whiles regions in yellow, orange and red are areas of urban development. It is essential to note that areas that recorded the lowest surface temperatures where regions that had high levels of vegetative cover. From the resultant images of 1991 and 2002, it must be noted that there has been an increase in maximum surface temperatures of 4.67^{o}C. This can be attributed to rapid urban developments within the area through infrastructural growth of high rising building such as construction of the Accra Conference Centre, an increase in tarred road networks and a sharp increase in population estimated at 1, 197,000 in 1991 to 1, 674,000 in 2002 (The State of African Cities; Governance, Inequalities and Urban Land Markets, 2010). The analysis performed on the 1991 to 2002 images also showed a drop in minimum surface temperature by 3.98^{o} C. This can be attributed to the micro climatic differences in the month of December and January observed in the study area. From the resultant images shown in Figure 5.0 below, the minimum surface temperatures recorded was 22.94^{0} C and 34^{0} C is the maximum recorded surface temperature in 2013. In 2016, the minimum surface temperature was 24.41^{0} C and recorded maximum surface temperatures of 36.16^{0} C.



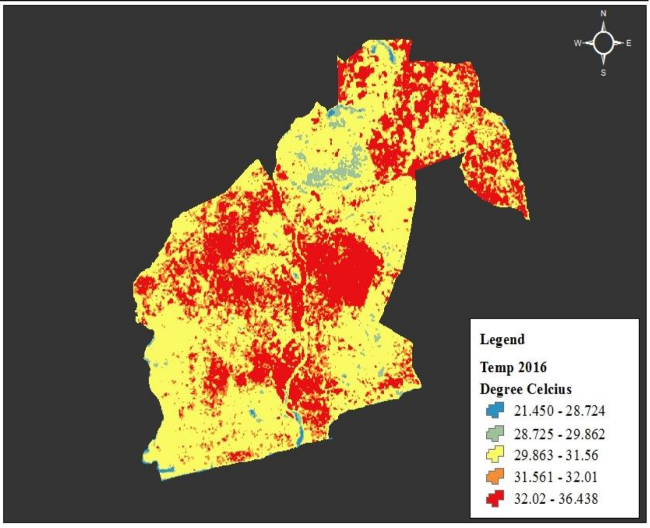


Figure 5.0 Surface Temperature Map for 2013

Figure 5.1 Surface Temperature Map for 2016

The difference in minimum temperatures is -1.47 whiles the difference in maximum temperatures recorded is -2.16^{0} C. Hence the resultant images of 2013 to 2016 show there was an increase in maximum and minimum surface temperatures within the study area. Below is a graphical illustration of the changes in surface temperatures from 1991 to 2016.

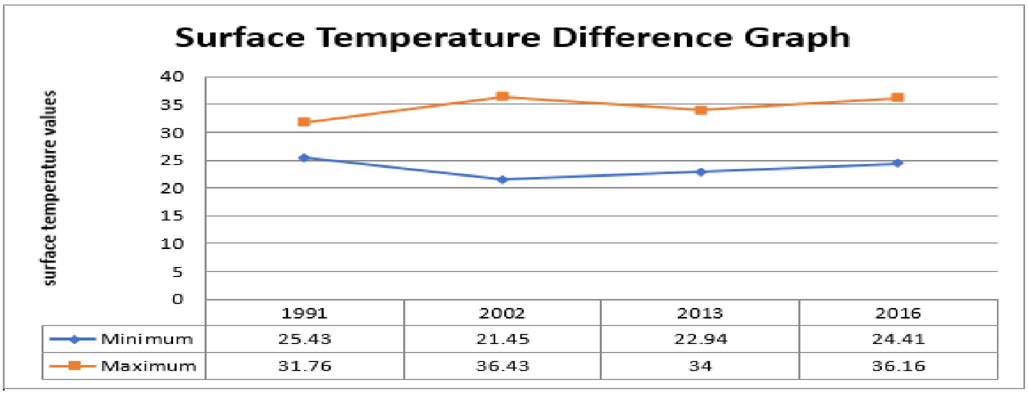


Figure 6.0: Surface temperature difference graph from the Land sat Images

5.2 Supervised Classification

Supervised image classification uses samples of known land use / land cover type to categorize pixels of unknown identity. This procedure relies heavily on the researcher's ability to locate representative examples of the cover type(s) of interest and develop comparatively consistent spectral response patterns from them. This can be used to train the classification algorithm to find similar patterns in the image. Land cover is the physical features that occupy the surface of the earth which consists of built-up areas, vegetation, bare land and water bodies. Basically, there are two primary means by which Land Cover can be captured: conventional field survey and through remote sensing. Land use, however, is distinct from Land cover but the two are often used interchangeably. Land use is an account of how people utilize the land and socio-economic activities in urban spaces and agricultural land uses.

In this research, a supervised classification was performed in the year 2002 and 2016. The two years were chosen because over the 15-year period land use/ land cover changes occurred drastically within the study area and the Land sat images were acquired in the same month. To understand the changes over time, it was essential to classify the data in classes that were identified within Accra. Supervised classification was selected because this method allows the researcher to have independence over categorizing of all pixels in the analysis under appropriate themes or classes.

For the purpose of this research, four (4) classes were obtained namely as shown

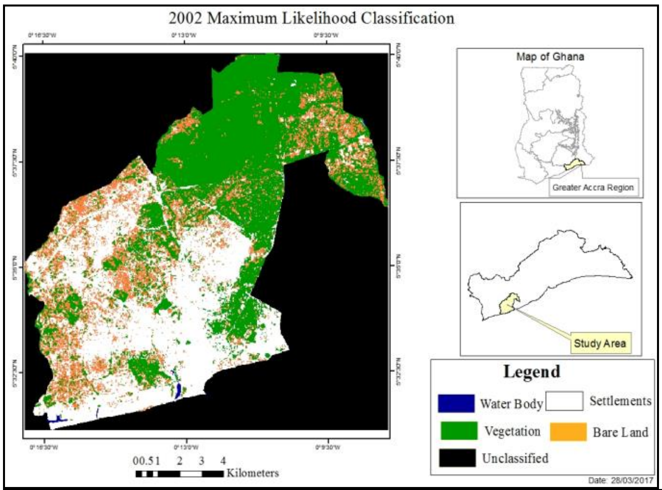
- Settlements – this included temporary structures such as chalets and kiosk, permanent buildings and paved surfaces

- Water Body- this includes all flowing water surfaces within the study area, for example, the Korle Lagoon, ponds, etc.

- Bare Land – this was identified by soil, exposed rocks, cleared farmlands and e-waste dumping sites

- Vegetation- this includes forest, grassland, farmlands, shrubs, and bushes within the metropolis

After the training of the sites, maximum likelihood classifications were run on the images.



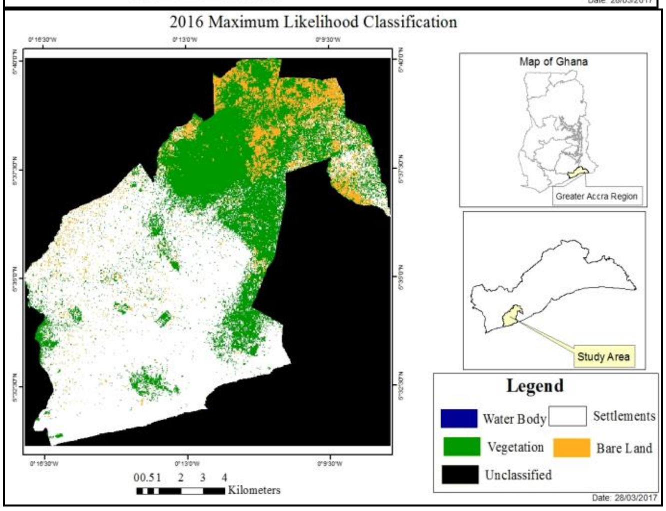


Figure 7.0: 2002 Maximum Likelihood Classified Image

Figure 7.1: 2016 Maximum Likelihood Classified Image

From Figure 7.0 and Figure 7.1, the resultant images show the land use/ land cover changes from 2002 to 2016. Areas in white represent areas occupied by settlements. The green colour represents areas with vegetative cover. The brown colour represents bare lands whiles the colour blue represents regions that have water bodies occupying space. A look at the resultant images shows clearly that over the 15-year period there has been a sharp rise in settlements within the district and a sharp decline in the space allocated to vegetative cover. Most spaces allocated for bare lands has also been occupied by settlements

5.3 Accuracy Assessment

The accuracy assessment is run to compare the supervised classification of the ROI and to evaluate how well the classification represents the actual ground conditions. Hence, this level of the research tests the usability of the classification result that was performed on the data acquired. Since supervised classification was performed, the likelihood that the researcher can influence the mismatch of classes is probable. In order to maintain the efficiency of the research, an overall accuracy and kappa coefficient was obtained. Kappa coefficient is used as a measure of agreement between the classified image and the real-world scenario. To do this, a matrix was generated for 40 referenced points selected from each class of the initial year of 2002 and the final year of 2016 taking on the pre-classified data. The formula is presented below.

$$K= \frac{N \sum_{i=1}^{r} Xii - \sum_{i=1}^{r} (x_{i+} * x_{+i})}{N^2 - \sum_{i=1}^{r} (x_{i+} * x_{+i})}$$

Where N is the total number of the reference points,

r is the number of rows in the matrix

x_{ii} is the number in row *i* and column *i*

x_{+i} is the total for row *i*

x_{i+} is the total for column *i*

Hence,

K=1 means there is perfect agreement between reality and classified image

K=0 means complete randomness

Table 1.0: Accuracy analysis on the classified image in 2002

Features	Sample classes from the original stacked data				Ground truth
	Water Body	Vegetation	Settlements	Bare Lands	
Water body	40	0	0	0	40
Vegetation	0	39	0	0	39
Settlements	0	0	39	7	46
Bare lands	0	1	1	33	35
Total	40	40	40	40	160

Therefore, to analyse the accuracy of the supervised classified images, the following are analysis are employed.

1. Overall accuracy = correctly classified cells/Total number of reference points

$$\text{Overall accuracy} = \frac{(40+39+39+33)}{160}$$

∴ **Overall accuracy= 0.94375**

2. Using the formula above, hence the Kappa co efficient of the supervised classified image of 2002 is calculated below;

$$K = \frac{(160*(40+39+39+33))-((40+40)+(39+40)+(46+40)+(35+40))}{160^2-((40+40)+(39+40)+(46+40)+(35+40))}$$

K= 0.94303

Table 2.0: Accuracy analysis on the supervised classified image of 2016

Features	Sample classes from the original stacked data				Ground truth
	Water Body	Settlements	Vegetation	Bare Lands	
Water body	32	0	0	0	32
Settlements	5	38	0	0	43

Vegetation	3	1	40	4	48
Bare lands	0	1	0	36	37
Total	40	40	40	40	160

Therefore, in order to run the assess the accuracy of the classified image of 2016 to the real world, the following processes are employed;

1. Overall accuracy = correctly classified cells/Total number of reference points

$$\text{Overall accuracy} = \frac{(32+38+40+36)}{160}$$

∴ **Overall accuracy= 0.9125**

2. Using the formula above, hence the Kappa coefficient of the supervised classified image of 2002 is calculated below;

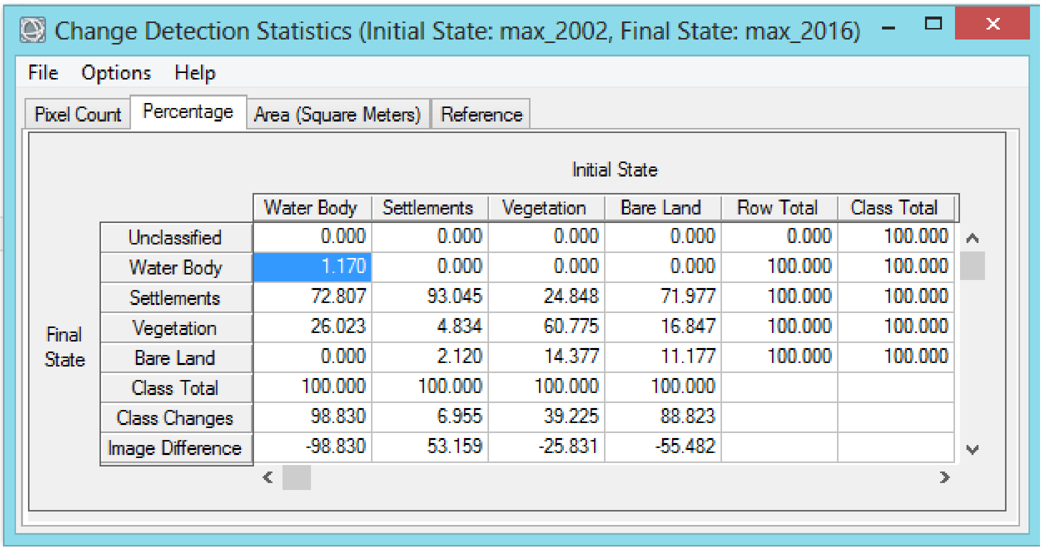
$$K = \frac{(160*(32+38+40+36)) - ((32+40)+(43+40)+(48+40)+(37+40))}{160^2 - ((40+40)+(39+40)+(46+40)+(35+40))}$$

K= 0.9114

Hence in conclusion, the results proved that the overall accuracy of the classified image in 2002 is 94.4% and 91.25% in 2016. It was also identified that the Kappa coefficient calculated for 2002 is 94.3% and in 2016 the Kappa coefficient was 91.1%.

5.4 Change Detection Analysis

To be able to determine the changes in the land use/ land cover over the 15 year period in the study area. A change detection analysis was done on the resultant supervised classified images with the year 2002 as an initial stage and the year 2016 as the final stage. Change Detection Analysis encompasses a broad range of methods used to identify, describe, and quantify differences between images of the same scene at different times or under different conditions (Harris Geospatial Docs Centre, 2017). Also, it involves the application of multi-temporal datasets to quantitatively analyse the changes in land cover classes over a given time (Afify, 2011) The basic premise behind using remote sensed data changes in land cover/ land use changes in this research is because the changes in land use/ land cover results in differences in radiance values that can be critically examined to identify changes the region has experienced. By using the change detection statistical tool from the post classification analysis, the matrix table of the changes from the initial state of 2002 to a final state in 2016 is shown in the Figure 8.0 below.



Final State	Initial State	Water Body	Settlements	Vegetation	Bare Land	Row Total	Class Total
	Unclassified	0.000	0.000	0.000	0.000	0.000	100.000
	Water Body	1.170	0.000	0.000	0.000	100.000	100.000
	Settlements	72.807	93.045	24.848	71.977	100.000	100.000
	Vegetation	26.023	4.834	60.775	16.847	100.000	100.000
	Bare Land	0.000	2.120	14.377	11.177	100.000	100.000
	Class Total	100.000	100.000	100.000	100.000		
	Class Changes	98.830	6.955	39.225	88.823		
	Image Difference	-98.830	53.159	-25.831	-55.482		

Figure 8.0: Change Detection Statistics from 2002 to 2016

The change detection statistics table above shows the change in land use and land cover between an initial state of 2002 and a final state in 2016. From the table, it shows that water bodies which include streams and lakes within the study area occupy 1.170 percent of its initial area. Settlements (that is, buildings, tarred road networks and the mass accumulation of refuse) over the 14-year period have taken a greater percentage of the land area allocated for water bodies of 72.8 percent. 26.02 percent of the area allocated for water bodies has been occupied by vegetative cover. Hence from 2002 to 2016, there has been a 98.83 percentage decrease in change in the land cover/ land use area allocated for water bodies. In addition, the table shows that settlements occupy 93.04 percent of the total land cover/ land use within the region. 4.83 percent has been accumulated by vegetative cover over the 14-year period whiles bare lands has accumulated 2.12 percent of the space allocated to settlements. Hence from the analysis above it shows that there has been a 6.93 percent increase in change of the land use/ land cover for settlement purposes and an increase in its area by 53.15 percent. Also, the table indicates that 60.76 percent has been occupied by vegetation within 2002 and 2016 out of a 100 percent. 24.85 percent has been absorbed by settlements whiles bare land took 14.37 percent of the land area. From the table, this shows that there has been a 39.22 decrease in the total land space allocated to vegetation. Hence within the 14-year time frame, there has been a total decrease in land use/ land cover area for vegetative cover by 25.83 percent. The table also shows that bare land occupied 11.78 percent out of a 100 percent of the total land use/ land cover of the metropolitan area. 71. 79 percent has been absorbed by settlements while 16.85 percent is occupied by vegetative cover. Hence from the initial year in 2002 to 2016, there has been an 88.82 percent change in the total land use/ land cover within the area. This change recorded a 55. 42 percent decrease in the land area allocated to bare lands. The coverage area of the Accra Metropolitan Area (AMA) was calculated based on the change detection results that were generated. The resolution of a Land sat image is 30m * 30m for each pixel. By this, the background information obtained was used to derive the actual coverage of the study area by aggregating the total number of pixel of all the identified classes.

Total pixel (Accra Metropolitan Area) = Total pixel (Water Body) + Total pixel (Settlements) + Total pixel (Vegetation) + Total pixel (Bare Land)

Total pixel (AMA) = 342+62678+61841+30653

Total pixel (AMA) = 155,514

In reality 1 pixel represent 900m^{2}on the ground.

Hence the coverage area of AMA =155,514 * 900 m^2 = 139,962,600 m2

In Hectares, it means the total area of AMA is equal to 13,996.26 hectares. Figure 9.0 would serve as a visual aid to analyse the changes in land use/ land cover changes within the Accra Metropolitan Area. This was done in order to establish the areal extent and the spatial changes in land use/ land cover.

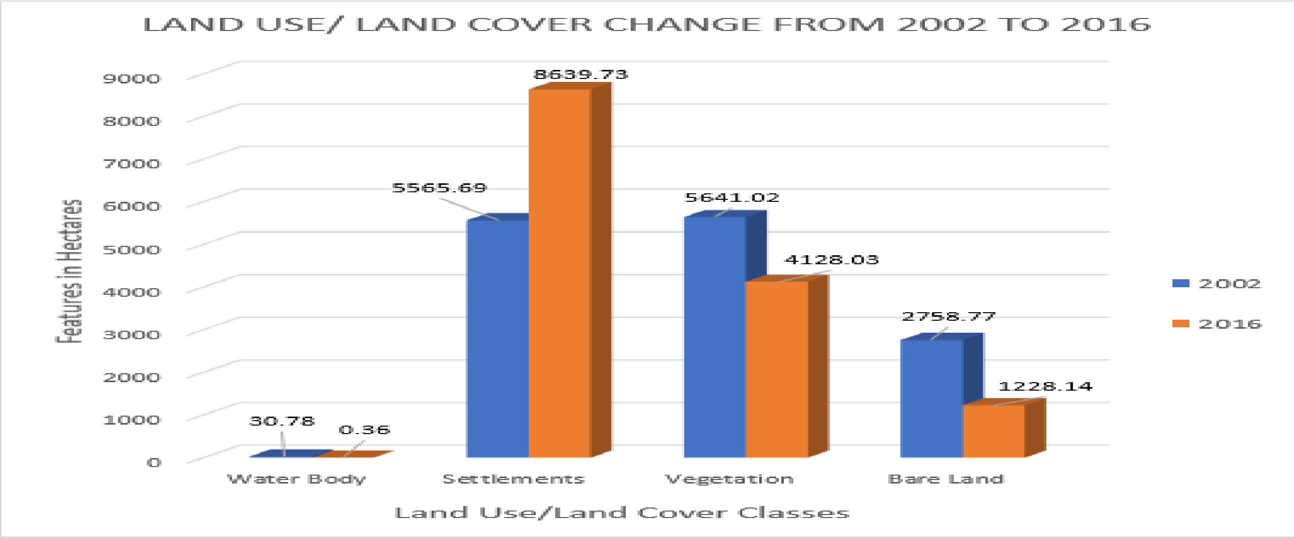


Figure 9.0 Land use/ Land cover changes from 2002 to 2016

5.5 Normalised Difference Vegetation Index (NDVI)

Researchers determine the density of vegetative cover on the surface of the earth by observing the distinct wavelengths of visible and near-infrared sunlight reflected by plants (NASA, 2017). The green pigment in plant leaves can strongly absorb visible light (from 0.4 to 0.7

μm) and strongly reflects near- infrared light (from 0.7 to 1.1 μm). By comparing visible and invisible light scientists measure the relative amount of vegetation (NASA, 2017). The NDVI instrument is a major tool used in remotely sensed data to run analysis on vegetative cover. It is calculated by the visible and near-infrared light reflected by vegetation. Healthy vegetation absorbs most of the visible light and reflects a large portion of the near- infrared light while unhealthy or sparse vegetative cover reflects more visible light and less near- infrared light (Simmons, 2009).

The NDVI analysis can be written mathematically as; NDVI= (NIR- R)/ (NIR + R)

Where NIR is the near-infrared light reflected by plants and R is the red light

The band maths ratio employed under ENVI was: Band math = (b4 – b3)/ (b4 + b3)

Hence, NDVI values range from -1 to 1

NDVI values ≤ 0 or values indicate non-vegetated surface

NDVI values > 0 are vegetated but values close to +1 (0.8- 0.9) show high density of vegetation

NDVI values = 0<0.25 show open land or less green vegetative cover

In this research, NDVI analysis is performed on bands 3 and 4 of Land sat images of 1991, 2002, 2013 and 2016 respectively. The images below show the resultant images.

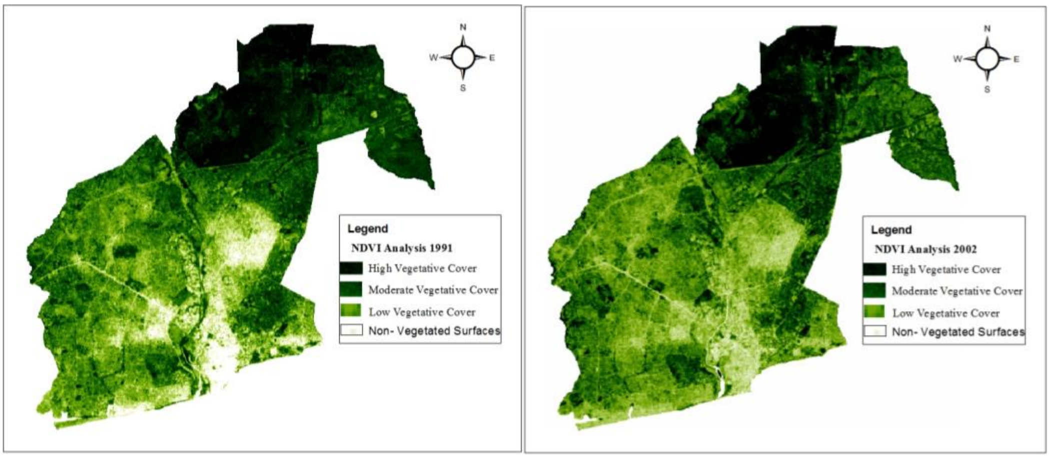


Figure 10.0 NDVI Analysis for 1991 and 2002

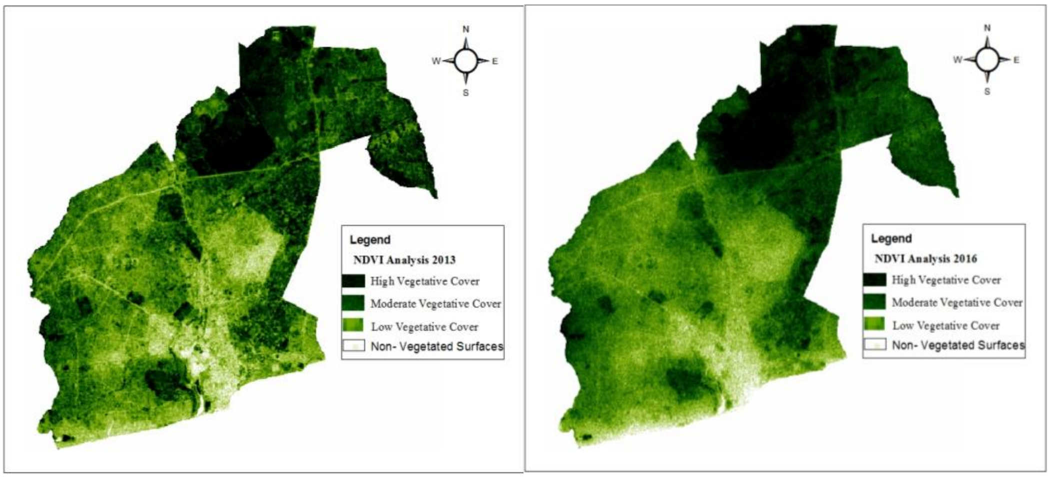


Figure 11.0 NDVI Analysis for 2013 and 2016

A green/ white linear colour was then employed on the resultant images and then reversed in order to give a clearer visual presentation in the changes in vegetative cover within the ROI.

The dark green areas indicate areas of high vegetative cover. As the density in the vegetation decreases, lighter shade of green is recorded indicate moderate and low vegetative cover. Areas showing white patches are regions with non-vegetated surfaces. This includes water bodies, road networks, and settlements.

Below is a matrix showing the range of NDVI values of the Accra Metropolitan Area of 1991, 2002, 2013 and 2016 to compare the properties of the vegetative cover within the respective years and evaluate the changes.

Table 3.0: Summary of NDVI values

NDVI values	1991	2002	2013	2016
Minimum range	-0.05	-0.21	-0.15	-0.05
Maximum range	0.43	0.59	0.46	0.18

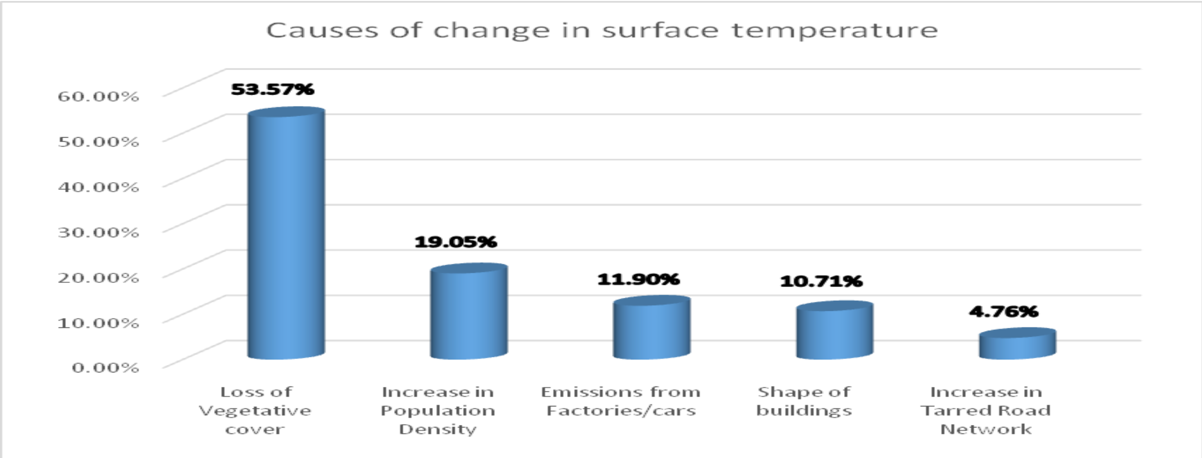
The Normalized Difference Vegetation Index (NDVI) values calculated from the reflected solar radiation in the near-infrared (NIR) and red (RED)/ visible light wavelength bands valid results in ENVI ranges from -1 to 1. Hence, from the matrix above, 1991 shows that the maximum density in the vegetative cover is 0.43. This implies that the region has a fair amount of vegetative cover whiles its minimum range values indicate that it has high amount of non-vegetated surfaces as well. Comparing the figures with the year 2002 it must be noted that there was a slight increase in vegetated cover within the Region of Interest but these values declined sharply in 2013 and in 2016 which records the lowest vegetative index since

1991 of 0.18. The matrix also shows an increase in open spaces in 2016 most likely due to the rise in urban development and increase in population densities leading to more infrastructural development.

6. CAUSES AND EFFECTS OF INCREASING SURFACE TEMPERATURES

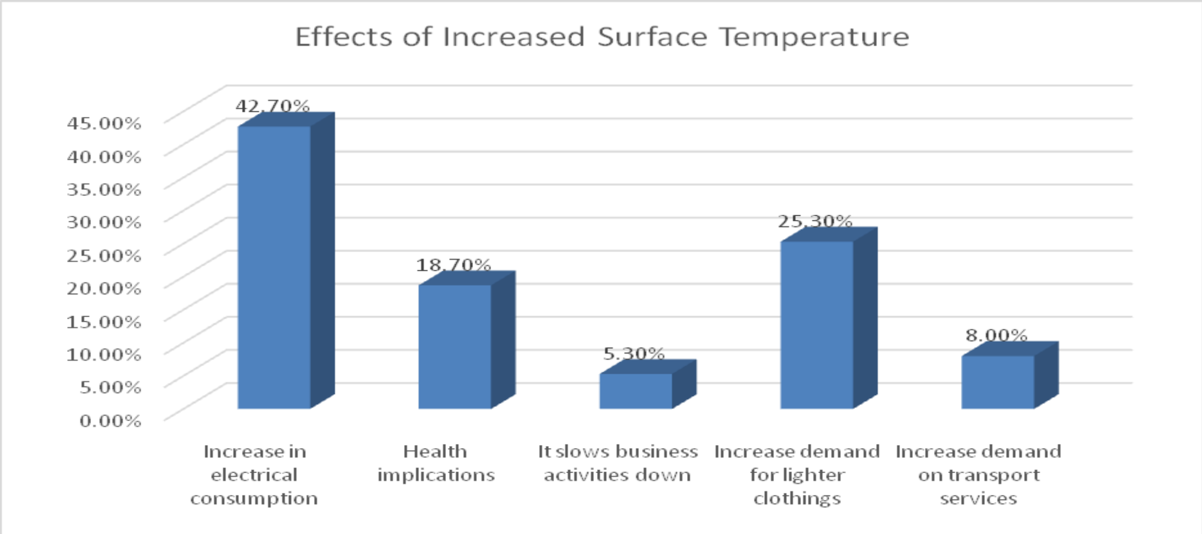
6.1 Causes of Increased Surface Temperatures

Questionnaires were also administered to residents within the study area about their perception of whether they had experienced perceptible changes in surface temperatures and the causes of these changes on surface temperatures. Below is a graphical representation of their perceptive views



The diagram above illustrates the respondent's perception on the causes of the increase in surface temperature. 53.7% of the respondents identified the loss in vegetative cover as the major reason why surface temperatures within the urban space of the Accra Metropolitan Area have changed from 1991 to 2016. Also, 19.05% identified the increase in population density as a cause of increasing surface temperatures. 11.9% stated the emissions from factories/ cars whiles 10.71% identified the shape of buildings within the metropolis as causes for the changes in surface temperatures. However, 4.76% of the respondents also identified the increase in tarred road networks as other contributing factors to the changes in surface temperature.

6.2 Effects of Increased Surface Temperatures



Following the completion of the field allocated to the causes that influence surface temperatures, the respondents were also queried on the effects the changes in thermal emissions affect their current day to day activities. From the diagram below, the analysis shows the effects of increased surface temperatures in the day to day activities of the residents in the study area. The majority of the respondents identified increase in electrical consumption through the use of Air conditioners (A/Cs) and fans as one major effect of increased surface temperatures which comprises of 42.7% of the respondents. Also, 25.3% of the respondents stated that the increase in demand of lighter clothing as an effect of increasing surface temperatures. The respondents further explained that they are forced to wear light coloured clothes and sometimes nothing at all especially in the night when temperatures seem unbearably high within the ROI. 18.7% of the respondents stated health implications as one of the effects experienced due to increasing surface temperatures. Some of the health complications stated by them include skin rashes, respiratory issues, and severe discomfort.

The respondents also stated that they believed the increasing surface temperatures affects wind speeds, especially at night hence the need for light clothes to be worn (Watkins, 2007). This supports the evidence stated in the literature as an effect of increasing surface temperatures.8% cited that they avoid crowded places and rely more on the use transport services to prevent being in a crowd due to the increase in surface temperatures. Some crowded areas cited during the survey were Makola Market, Accra Central, Kaneshie Market and Lorry stations within the study area. This supports the data analysed using remote sensing techniques. The respondents further stated they sacrifice spending more on cab services to avoid being in a crowd in Accra due to unbearable heat waves. 5.3% of the respondents stated that increasing surface temperatures slows business activities down. They further explained that the unbearable temperatures especially in the central business district of Accra have forced people to conduct business activities at the outskirts of the metropolis.

7. CONCLUSION

The research through the use of ENVI to analyse Land sat (TM and ETM+) images of 1991, 2002, 2013 and 2016 was effective in monitoring the thermal emitted radiations in the Accra Metropolitan Area. The study identified an increase in thermal emitted radiations in the study area, its causes and resultant effects. In monitoring thermal radiations within Accra, it was noted there has been an increase in thermal emitted radiations which implies an increase in surface temperatures from 1991 to 2016. This increase in surface temperature was by 5^{o} C. One objective sited in the study was to access the effects of rapid urbanization on UHI, a major constituent in increasing surface temperatures. This was employed using remote sensing technologies to access the Land use/ Land cover changes within the metropolis. It was discovered that Land use/ Land cover changes had occurred massively in Accra with an increase in settlements by 53.16% from 2002 to 2016. It must however be noted that in the change detection analysis run settlements occupied 72. 81% of the area allocated to water bodies and 71.98% of the area allocated to bare lands. These changes in Land use/ Land cover within the study area is attributed to rapid urbanization and increasing the UHI effects in the study area.The changes in vegetative cover within the study area was also explored and investigated. This was employed because more vegetative cover within an area implies an increase in evapo transpiration rates which aides in cooling surface temperatures. Hence the effects of UHIs can be controlled when the vegetative cover of a region is high. As a result, ENVI was used to run NDVI analysis on the study area to identify the changes in vegetative cover. It was discovered that there has been a reduction in vegetative cover in the study area by 52.08% from 1991 to 2016. The loss in vegetative cover in Accra is attributed to rapid urbanization which requires the conversion of forest to agricultural lands and urban lands. Hence, the loss in vegetative was identified as a dominant cause for increasing surface temperatures.

Also, data collated from a questionnaire survey on the perceived changes in surface temperatures supported the evidence discovered through remote sensed data on increasing surface temperatures. Major causes identified by the residents within the study area include the loss in vegetative cover, congested settlements, increase in tarred road networks, shape of the buildings and emissions from cars/ factories. However, the loss in vegetative cover was ranked the dominant cause by the residents of 100% which supports the empirical evidence collated through remote sensed data. The effects increasing surface temperatures had on the residents were also identified. This included an increased reliance on fans/ AC which has negative repercussions as one of the factors resulting in climate change issues. The use of lighter clothing, health implication, decrease in business activities and the avoidances of crowded spaces were other identified effects in the increase in surface temperatures.

RECOMMENDATION

The analysis of remote sensed data and the findings discovered in the study has encouraged the formulation of recommendations by the researcher, directed at policy makers together with researchers in future to conduct a more elaborate research on thermal emitted radiations to ensure the preservation of the environment for future generations. In order to ensure that the spread in urban development do not result in total destruction of the natural environment the following recommendations are proposed:

- Adopt a policy such as in the US where stringent bye-laws are formulated and implemented to ensure that a quarter of land is devoted to green spaces in every household and fines should be awarded to people who fail to comply with these bye-laws.

- Awareness should be made to the people through media campaigns on the factors contributing to increasing surface temperatures since most people are not aware of the gravity of issues related to increase in thermal emitted radiations. This will make people more enlightened on issues relating to their environment hence prevent activities that contribute to the change in surface temperatures

- There should be an enforcement of laws protecting forest lands by the Environmental Protection Agency, Accra Metropolitan Assembly and the District/ Municipal Assemblies to prevent the indiscriminate felling of trees for cooking purposes.

- Law enforcement agencies and Traffic Control Regulators should ensure that over aged vehicles that ply the streets of Accra should be eliminated because they emit poisonous gases which contributes to the retention of heat on the surface of the earth

- Government should enforce laws governing proper and planned infrastructures within the metropolis which conform with environmental laws in order to prevent congested settlements

- The Accra Metropolitan Assembly must formulate policies that are geared towards open space management and maintenance such as the creation of parks and avenues within the urban sphere of the metropolis.

- Bare spaces within the metropolis should be covered by vegetative cover to prevent dust particles from circulating in the atmosphere since they absorb green house gases and thereby result in increasing thermal radiated energy.

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