KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

Geoinformation Modelling of Peri-Urban Land Use and Land Cover Dynamics for Climate Variability and Climate Change in the Bosomtwe District, Ghana

by

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DOCTOR OF PHILOSOPHY

in

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DECLARATION

I hereby declare that this PhD thesis is my own production under supervision of my academic advisors. To the best of my knowledge, except for the references cited which have been duly acknowledged, no section of the work is a reproduction or submitted wholly or in part, for the award of any degree in any University elsewhere.

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ABSTRACT

This study modelled the socioeconomic drivers and the actual land use and land cover (LULC) changes, with special reference to vegetation cover and local climate variability and change, in the peri-urban Bosomtwe District of the Ashanti region of Ghana. A triangulation of qualitative and quantitative design was used among 270 household respondents. Using a multistage sampling technique, partially pre-coded questionnaires were administered in 14 communities. Data were analyzed using non-parametric tools as Pearson's Chi-square, Nagelkerke R^2 and Cramer's *V*, and step-wise binary logistic regression analyses embedded in the Statistical Package for Social Scientists (SPSS v.16). Remote Sensing and Geographic Information System algorithms were used in ENVI, ERDAS Imagine ESRI and ArcGIS environment, to classify LULC, using maximum likelihood classifier to analyze Landsat Thematic Mapper and Enhanced Thematic Mapper+ images, and Landsat 8, Operational Land Imager and Thermal Infrared Sensor (OLI/TIRS) images of 1986, 2002, 2007/2008, 2010 and 2014 respectively. The best *Kappa hat* statistic of classification accuracy is 83%. A MannKendall trend analysis was also done on the climatic data, using MAKESEN Solver in EXCEL. At a confidence level of 99.9%, perceived drivers of peri-urban land use changes in the communities were significant at $p < .000$. The Cramer's V test of a strong association between two nominal variables was 0.412. The logistic regression model reported confidence intervals (CIs) of $1.218 \leq \text{CI} \leq 4.234$, for the three main predictors of the land use conversion outcome, indicating the odds of up to 4 times of conversion likelihood. The normalized difference vegetation indices (NDVIs) for forest cover, plantation and other cultivated lands ranged between 0.384 and 0.570; while recent fallows and grassland as well as bare lands had NDVI values of between 0.081 and 0.250. Over the period, dense forest decreased by 1380 ha in 2014, while low forest (which included some oil palm and citrus plantation farms), increased by 1766 ha in 2014. However, Built up, bare and concrete land uses increased by 3360 ha, while recent fallows and grasslands decreased by 3356 ha, over the

same period. Inter-quarterly rainfall and temperature anomalies depicted generally increasing trends in the mean monthly temperature over the last two inter-decadal periods (1990-2000 and 2001 to 2011). Land surface temperature profile extracted from the satellite images cohered with the LULC characteristics, expressed in the novel concepts of Rural Cool Troughs (RuCT) and Peri-urban Heat Troughs (PuHT). The study indicates major changes in the deteriorating livelihoods, easy access to, as well as changing demand for land are affecting peri-urban landscape of the Bosomtwe district. The study recommends that a strict enforcement of district land use plans by the Bosomtwe District Assembly. For further research, the use of high resolution images is recommended to forestall the inherent minor misclassification. Relationship between DEM and LULC in a mountainous landscape as the Bosomtwe district should be explored along-side policy mechanisms.

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LIST OF ACRONYMS

AFOLU - Agriculture, Forestry and Other Land Uses

AGRA - Alliance for a Green Revolution in Africa

APF - African Partnership Forum

BMBF- Federal Ministry of Education and Research

CCAFS - Climate Change, Agriculture and Food Security

CDM - Clean Development Mechanism COMESA - Common Market for Eastern and Southern Africa

CO_2 - Carbon Dioxide CVCC – Climate Variability and Climate Change

DFID- Department for International Development

DPSIR – Driver, Pressure, State, Impact and Response

ENSO - El Niño-Southern Oscillation EPA- Environmental Protection Agency

ETM+- Enhanced Thematic Mapper plus

FANRPAN - Food, Agriculture and Natural Resources Policy Analysis Network

G-META- Ghana Meteorological Agency

FAO – Food and Agricultural Organization GDP – Gross Domestic Product GHG - Greenhouse gases

IET - International Emissions Trading

IPCC – Intergovernmental Panel on Climate Change

ITCZ - Inter Tropical Convection Zone JI - Joint Implementation

LULC- Land use and Land Cover

LST – Land Surface Temperature

LULUCF – Land Use Land Use Change and Forestry

MICCA - Mitigation of Climate Change in Agriculture

MoFA - Ministry of Food and Agriculture

NAMAs - National Appropriate Mitigation Actions

NAPAs - National Adaptation Programs of Action NCAR - National Center for

Atmospheric Research

NCCC- National Climate Change Committee

NDPC- National Development Planning Commission

NDVI- Normalized Difference Vegetation Index

NGO - Non-Governmental Organizations

OLI- Operational Land Imager

PuTH- Peri-Urban Heat Trough

REDD - Reducing Emissions from Deforestation and Forest Degradation REDD+ - Reducing Emissions from Deforestation and Forest Degradation with conservation and sustainable management RuCT- Rural Cool Trough

SPSS – Statistical Package for Social Sciences

SSA - Sub-Saharan Africa

TIS - Thermal Infrared Sensor

UNFCCC - United Nations Framework Convention on Climate Change

USAID - United States Agency for International Development

WASCAL – West Africa Science Service Centre for Climate Change and Adapted Land Use

WMO - World Meteorological Organization

ZEF - Centre for Development Research

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CHAPTER 1: SYNOPTIC PERSPECTIVES OF THE STUDY

1.1 Introduction

Peri-urbanization has been identified as a ubiquitous process caused by the rapid population growth (Shalaby and Gad, 2010). Expanding the urban frontiers onto arable lands has potentials to degrade vegetation (Shalaby *et al*., 2004), with dire implication on climate variability and change.

In earlier studies, land-use changes have been established to have had some influence on local climate and may further impact on climate variations at the regional level (Salvati *et al*., 2013). Globally, reduced precipitation for instance, is a clear evidence of variable climates under changing land use and land cover (LULC) in peri-urban areas. The continuous vegetation decrease in peri-urban areas leads to greater surface sensible heat which enhances convective circulation. The reduced vegetation also decreases the latent heat flux at the surface, which reduces the amount of moisture available for cloud formation (Cheng and Chan 2012).

Although climate change is not a new phenomenon, it has in this present age, taken the centre stage in the development agenda due to the alarming rate of anthropo-driven land use activities and their adverse impacts on the climate system. This is, perhaps due to the compelling evidence it has shown in the areas of aggressive human demands on the nature for resources, considered as critical drivers for socio-economic development

(IPCC, 2008). According to Fall *et al.*, (2010), recent scientific studies have demonstrated that climate forcing from LULC dynamics have significantly impacted on temperature trends.

In this study the operational definition of LULC are defined as follows; *land cover is the entire complex attribute coverage on the earth surface; while land use is the anthropogenic value put on a particular land cover type*. The Bosomtwe district is one of the fast expanding peri-urban settings in the Kumasi Metropolis (Afriyie *et al.*, 2013). It has one of fastest growing rates of private land acquisition and residential sprawl in response to the changing human populations' choice of relocation, away from the Kumasi city centre. The ever-increasing concentration of residential and commercial activities, however, are reducing the vegetation cover and gradually urbanizing the rural landscapes through peri-urbanization continuum.

The real life manifestation of this LULC conversion problem is that climate change is a global phenomenon that has attracted a lot of attention in recent years. Governments and policy makers are now considering climate change in their policy framework and national programmes (IPCC, 2008). According to CARE (2010) climate change scenarios for Africa present an even bleaker picture for the future. This study seeks to address the research questions that have enormous potential for Regional Planning Units, the Bosomtwe Local Government Agencies (LGAs) and indeed the entire country to address and monitor rural-urban land uses and land cover and their impacts on climate variability and change.

The tenets of human ecology as applied to this study, is engraved in the core discourse of human and environment interactions, based on certain identified and, sometimes the unknown, yet inherent drivers of the spatial processes. These processes, are driven by such factors as type of location of phenomena (rural, peri-urban and urban), human demographic change dynamics, location of settlements, the income of the people, the type of natural resources and the elasticity of the demand for them, technology as well as legal and political considerations as intrinsic attribute of social cohesion.

In view of the dominance of agrarian households in the district, it makes analytical convenient to offer a household level analysis and explanation between human and their environment relations (Zimmerer, 2004). This is because, unlike the macro-scale district and regional level analysis of peri-urbanization and land use, household-level analysis as prescribed by this study can offer a much-needed level of finer resolution relative to the spatially aggregated attributes of human-environment interaction that are up-scaled to the community, region and national levels. This assumption underpins the choice of this study to consider the various variables of interest that impinge on the LULC and climate variability and climate change nexus at the various scales of decision making.

1.2 The Research Problem and Knowledge Gaps

This sub-section, espouses the research problem and the research knowledge gaps identified from the literature review. These gaps are the driving forces of the problem statement and hypotheses underlying the study.

1.2.1 Research problem

There is general paucity of scientific data and information on the nexus between LULC dynamics coupled with the vagaries of climate variability and climate change, particularly in the Bosomtwe district and Ghana in general. Although some studies have demonstrated this linkages, these researches concentrated efforts in the arid and semiarid regions (Olesen and Bindi, 2002; Danfeng *et al.*, 2006; Sivakumar, 2007; Verstraete *et al.*, 2008; Lindner *et al.*, 2010). As a result, very little research attention has been offered to the semi-deciduous forest eco-climatic zones, especially in Ghana and in the Bosomtwe district in particular.

It suffices to note that earlier scientific works undertaken in the lake Bosomtwe District, concentrated on the paleogeological, geotechnical paleoclimatic analysis of the origins of the lake bed materials (Shanahan *et al.*, 2012). The climate change dimensions of these earlier researches did not consider *per se*, the LULC dynamics, which have greater social, political and economic implications for the populations of the 66 agrarian communities in the district.

The ever-increasing human populations with its concomitant growth in settlements, has had considerable effects on the land uses in the Bosomtwe District. Forest cover in the district is reducing as a result of the conversion of forests and agricultural lands into commercial and industrial land uses. Again, human activities of sand winning, tree logging, slush and burn agriculture, among other land uses, are also altering original

LULCs.

The processes of peri-urbanization in the Bosomtwe District of the Ashanti region of Ghana are considerably rapid (Afriyie *et al.*, 2013). There are conversions of arable lands and forest covers into residential and commercial land uses. These land use and cover processes with potentially adverse effects on sensitive local climatic variables such as rainfall, temperature, humidity and wind systems have not been adequately explored by research, for the Bosomtwe district. The absence of adequate reliable LULC data has the potential, to hamper effective policy planning for rural and urban space under climate variability and climate change for the Bosomtwe District.

1.2.2 The Knowledge gap

Remote sensing and geographic information system (RS/GIS) hold much prospect for analyzing the urban and peri-urban environment with a higher degree of effectiveness and clarity (Appiah *et al.*, 2015; Olokeogun *et al.*, 2014; Weng, 2001; Rimal, 2011; Asiyanbola, 2014). In spite of the potentials of the strengths of the application of this tool, within the context of the Bosomtwe district and indeed Ghana, the literature has remained sparse on the integration of the application of the geoinformation tools with socioeconomic surveys in studying the synergy between changing peri-urban land use dynamics and climate variability and climate change in the Bosomtwe district of the Ashanti region of Ghana.

Many studies have concentrated attention on the generation of temperature profiles to measure the urban heat island (UHI) fluxes (Liu and Zhang, 2011; Srivastava *et al*., 2010; Mbithi *et al., nd*; Weng *et al*., 2004; Weng, 2001). Climate change may well modify the urban heat island and rainfall effects, but the quantitative extents are unknown at this time (Blake *et al*., 2011). Most of these studies have not considered explicitly, the potential effects of peri-urban heat trough (PuHT) systems that become heat islands in transition from the rural cooling troughs (RuCT), into ultimately, the socalled urban heat islands (Liu and Zhang, 2011). Operationally, this study defines the Peri-urban heat trough concept as the concentration of surface up-welling heat energy that can be sensed as evidence of changing land use patterns, in a peri-urban environment. These PuHT have the potential to become UHI as LULC change into urbanized landscapes.

Furthermore, various studies on land surface heating fluxes have largely focused on core urban heat islands as surrogates of extraction local urban climates (Liu and Zhang, 2011; Widyasamratri *et al*., 2013). There is limited literature, however, on the conspicuous role of peri-urban areas in generating the ultimate heat island system. This study proposes that, considering the rapidity with which rural landscapes are being modified into peri-urban land uses with different surface reflectance as well as the increasing trends in built up and paved land uses, it is imperative to analyze the connections between the RuCT and PuHT systems, as potentially driving cells of full-fledge heat island areas.

In view of this the study sought to fill this yawning lacuna by applying the coupling methodology of Remote sensing and Socioeconomic sensing (RS/SS) approaches to address the problems of changing LULC dynamics and climate variability and climate change in the Bosomtwe District of the Ashanti region of Ghana. In this context, the study examined the intricate nexus between the consequences on the peri-urban LULC dynamics on vegetation cover changes as well as the local land surface temperature profiles as proxies of analyzing the local climate variability and change for the Bosomtwe district of the Ashanti region of Ghana.

1.3 Research Objectives and Questions

This sub-section also elucidates the main objective and the specific objectives underlying the study. It does so, by identifying and disaggregating the main objectives into the specific objectives as well as their corresponding research questions, from which the hypotheses are also derived for the study.

1.3.1 Main objective

The main objective of the study was to apply spatial correlation of Remote Sensing of earth observing data and socioeconomic data based on spatial analysis with the help of

Geographic information systems (GIS), to analyze the peri-urban land-use and land cover dynamics and their impacts on vegetation cover and local climate variability and climate change.

1.3.2 The specific objectives are to:

1. Determine the extent and trends of peri-urban LULC dynamics of the Bosomtwe District
2. Assess the effect of LULC Change on vegetation abundance and resilience in the Bosomtwe district
3. Identify and map the socioeconomic drivers of peri-urban LULC change in the Bosomtwe district
4. Analyze temperature and rainfall data from 1981—2011 for local climatic trends
5. Analyze satellite data for land surface temperature dynamics as proxies for local climate variability and climate change in the district

1.3.3 The Research questions

Within the perimeters of the identified problem and objectives, the research questions are:

1. To what extent and trends are the peri-urban land uses and land cover in the Bosomtwe District changing?

2. What are the effects of LULC Change on vegetation abundance and resilience in the Bosomtwe district?
3. What are the socioeconomic drivers of peri-urban LULC change in the Bosomtwe district?
4. What are the climatic (temperature and rainfall) trend patterns in the district over 31 year (1981-2011) period?
5. How can satellite data be used to analyze land surface temperature dynamics as proxies for local climate variability and climate change in the district?

1.4 Hypotheses

The study is guided by the surmises that:

H0: There is no significant relationship between socioeconomic drivers and LULC change patterns.

H1: There is a significant relationship between socioeconomic drivers and LULC change patterns

H0: There is no significant relationship between peri-urban LULC dynamics and vegetation cover reduction in the district.

H1: There is significant relationship between peri-urban LULC dynamics and vegetation cover reduction in the district.

H_0: There is no significant difference between land surface temperature and LULC types.

H_1: There is a significant difference between land surface temperature and LULC types.

1.5 Justifications for the Study

There is the need to ascertain the current impacts of surface LULC changes on climate. The essence is to fill the knowledge gaps that exist as identified by the problem statement. The availability of knowledge generated on these conditions in the area, would help predict the future scenario for land use; particularly agriculture and forest land uses. This study has replicable prospects for the Kumasi Metropolitan and other District Assemblies nationwide, in their effective urban and peri-urban land use zoning and planning policies under climate change.

In recent times, knowledge generation and dissemination put emphasis on the exigencies for integrated approach and interdisciplinary knowledge cross-fertilization. The research is clearly an attempt of integrating the social science with the natural science that has blended techniques of the two disciplines to communicate the research results. In view of this, the research deliverables could be up-taken by both the scientific and nonscientific oriented persons, especially at the local government institutions, for their planning purposes. The research deliverables have the flair to deliver that crossdiscipline communication to the target audience.

The research output (data, thesis report and scientific publications etc.) therefore, would be made available from local to national government scales, for policy formulation and implementation. This is especially crucial in our preparation to take-off with the United Nation's Global Development Agenda (UNGDA) of Sustainable Development Goals (SDGs), especially the goals numbers 11, 13 and 15, which emphasize sustainable cities and communities, climate action and life on land respectively into the next 15 years.

1.6 Structure of the Thesis Report

Chapter one sets the tone of the study with the general introduction, research problem and knowledge gaps, and the objectives of the study as well as the outline of the hypotheses. To place the study in its theoretical perspective, Chapter two was devoted to the analysis, review and synthesis of the relevant literatures as well as the conceptual and theoretical ramifications of the study. These have been structured under relevant themes with sub-sections.

Chapter three describes profile of the Bosomtwe district and the Material and methods; both the socioeconomic and geoinformation procedures used to collect and analyze the data. Chapter four presents the results of the socioeconomic survey, by delivering the outcomes of the drivers of the peri-urbanization and the peri-urban land use dynamics in the Bosomtwe district. Chapter five is also devoted solely to the presentation of the analyses of the geo-spatial data from the use of remote sensing and GIS techniques to extract and model the LULC dynamics in the Bosomtwe district.

In order to realize the objective of analyzing the effect of peri-urban land use changes on the vegetation cover of the district, Chapter Six was developed to present the results of the normalize difference vegetation index (NDVI) analysis in the district. Chapter seven contained the results of the analysis of rainfall and temperature as surrogate for local climate variability in the district.

Chapter eight also details the results from the land surface temperature extraction and analysis from the satellite images. This was used to explain the new concept of the Periurban Cool and Peri-urban Heat Troughs of the Bosomtwe district. The implications of the results so obtained were discussed in Chapter nine, to discuss and synthesize in the context of the study objectives as well as, for policy recommendations. Finally, Chapter ten summarizes the key findings, Conclusions and contributions to knowledge, policy recommendations and further research.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In chapter one, the study espoused the main tenets of the nexus between land use and land cover dynamics and its implication for local climate variability and climate change. It does so, by highlighting, from global to local perspectives the definition of the problem statement and the identification of the knowledge gaps as well as the enumeration of the main and specific objectives set for the study.

In the context of the Bosomtwe district, which is the focus of area of study, this chapter is a review of the contextual arguments and dissection of the relevant literature on the nexus between peri-urban land use dynamics and climate change, using geo-information modelling techniques.

This chapter is structured under the following broad and sub-headings for analytical convenience. These include; peri-urban area and associated land use dynamics, drivers of the peri-urban LULC dynamics, application of geo-information models in LULC dynamics and the nexus between climate variability and climate change and land use dynamics in peri-urban areas. This has been done from the general global picture to the local perspectives of the study.

There is a complex relationship between peri-urban LULC change dynamics and the local climate variability and climate change (Davoudi *et al.*, 2010; Blanco *et al.*, 2009; Simon, 2008; Ewing *et al*., 2007). The direction of these interactions usually depends on the strength of the two phenomena in influencing the other. The impacts of LULC on climate change is invariably translated from the depletion of the earth surfaces vegetation cover, which serve as a global sink to carbon dioxide emissions and other greenhouse gases (GHGs) emissions (Pielke *et al*., 2011; Verburg *et al*., 2011; UNFCCC 2012).

Land use and land cover dynamics are the defining features of the morphologic picturesque of every naturally or human-organized space. Using appropriate policy instruments, Dutta (2012) suggests that urbanization and for that matter periurbanization becomes synonymous with frequent land use changes that have varying impacts on the environment. In addressing the issues of sustainability, Allen *et al* (2006; 21), suggest that the peri-urban interface comprises a heterogenous mosaic of environmental and productive ecosystems working in combination with socioeconomic peculiarities.

In the peri-urban milieu, the lifestyle of land owners both old and new may still be strongly linked to the immediate urban areas in terms of social, cultural and occupational relationships (Busck, *et al.*, 2006). These are made possible, by improved infrastructure and mobility (Ravetz *et al.*, 2013). In addition, the structural development within the agricultural sector in the peri-urban areas has forced many former full-time farmers to seek stronger relations to nearby urban areas.

Land use configuration in peri-urban areas therefore, follows a certain pattern of hierarchy which, depending on the direction and strength of force of influence would control the spatial spread of populations, infrastructure and the entire space economy. The directions and strengths of the rates of influences are measured by the various pull and push factors in the rural and the urban settings respectively. All these migration determinants, to a larger extent, are regulated by relevant community and state actors. In the event of laxed controls LULC on peri-urban to urban continuum there would be a disjointed and a disarray of peri-urban infrastructural development springing up, ahead of planning.

2.1.1 Peri-urbanization and land use competitions

According to Simon (2008), peri-urban areas are increasingly attracting middle-class and higher-income people whose lives exhibit lifestyles, reflective of inner-city dwellers in a predominantly rural setting. Conversely, the integration of such infrastructure as transport, information and communications technology (ICT) revolutions and the introduction of super-structure with its commercial replicates in the peri-urban areas, have enabled people from the core urban areas to relocate to these semi-urban localities; such areas described as, the edge cities (Simon, 2008:169) or peri-urban fringes (Narrain and Nischal (2007), Afriyie *et al.*, 2013).

Peri-urban land use alterations have dire implications for climate change. In the works of Gimona *et al*., (2012), many landscapes including rural to the peri-urban landscapes that are object of conservation policy, are increasingly becoming a part of a network of exchanges of agricultural and forest commodities on the national to the international exchange arenas. These changes in rural to urban land use conversions lead to local climate changes. For instance the removal of vegetation and emissions of greenhouse gases that characterized urban life dynamics, alter the local climatic patterns. These climate variability and climate changes are expressed in the form of erratic rainfall patterns, increasing temperature, intense solar radiation and associated derived storms.

In peri-urban environments, scramble for land and its associated use conversions are due to economic globalization and land speculation in the peri-urban milieu due to urban expansion (Salvati and Carlucci, 2014). This has caused intensification of land use with a consequent increase of the human footprint (Appiah *et al*., 2014a) and reduction in natural ecosystem habitat diversity (Appiah *et al*., 2014a; Kleijn and Sutherland, 2003). Land fragmentation and attendant degradation have climate variability and climate change implications (Gimona *et al*., 2012).

2.1.2 The Land Use and Land Cover and the Climate Change Arguments

Over the years, concerns on the impacts of LULC change have been increasing both locally and globally because of their impacts on land management practices, economic sustainability, social processes and climate change (IPCC, 2007). The rapidly accelerating change in the landscape is associated with a wide variety of issues, including declining biodiversity global climate change and food security as well as land degradation, which amply applies to soils, vegetation, and water depletion (Darkoh, 2003). Much of the LULC changes occur by the anthropogenic forces (Kok *et al*., 2001), impacting negatively and creating avenues for increased greenhouse gas emissions and accumulation in the atmosphere, with potential for climate variability and climate changes (Pielke, 2011; Houghton, 2012).

In recent decades, issues relating to land use and climate variation have come to the forefront of many environmental activists. Equally, specialized scientists and international organizations have realized the extent of influence of land surface dynamics on climate. In response to this, institutions have been established at international and national levels to research into land use and climate change, predict likely changes, assess likely impacts, and propose responses in terms of adaptation to climate change and mitigation to reduce the likely rate of change (Garnaut, 2011; Department of Environment and Resource Management, 2011).

Practicably, the most influential of these international organizations is the Intergovernmental Panel on Climate Change (IPCC), which was established in 1988 by two United Nations organizations, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) (Kaindji *et al*., 2007; Sara *et al*

2009). Although human activities have continually been causing changes to the land from one use to another, the IPCC was, yet to include these effects in their future climate reports (Kaindji *et al*., 2007). Increasingly, more studies are pointing to how crucially important it is to include these LULC changes and their effects to better predict how climate will change in the ensuing years.

2.2 General and Operational Definition and Measurement of Concepts and Terminologies

2.2.1 Peri-Urban Areas and Peri-Urbanization

Peri-urbanization occurs as a complex suite of processes of change, including counterurbanization and trends towards non-urban lifestyle preferences, pressure for urban expansion. They include the context of declining suburban housing affordability and increased mobility and the expanding reach of urban employment opportunities. Periurban regions have become central to international debates about urban expansion. They further present the uncertainties of future rural land management and the identity of rural communities in a globalizing and urbanizing countryside (McCarthy, 2008; Cadieux and Hurley, 2011), or processes of rural gentrification involving the entry of a postindustrial middle class (Hines, 2010).

2.2.2 Concepts and Conception of LULC Change

The conceptual perspective of land use changes and their environmental impact in rural areas is a research theme that has attracted considerable attention (Libby, 2002;

Polyakov and Zhang, 2008; Heimlich and Anderson, 2001; Dale *et al.,* 2005). The terms LULC are not synonymous and the literature point to their differences so as to be clearly understood in their rightful context of study. Land cover is the biophysical state of the earth's surface and immediate subsurface (Kummer and Turner, 1994).

In other words, land cover describes the physical state of the land surface: as in cropland, mountains, or forests including the quantity and type of surface vegetation, water, and earth materials (Moser and Dilling, 1997; Meyer 1996). The term originally referred to the type of vegetation that covered the land surface, but has broadened subsequently to include human structures, such as buildings or pavement, and other aspects of the physical environment, such as soils, biodiversity, and surfaces water (Houdon *et al.,* 2014). Land use involves both the manner in which the biophysical attributes of the land are manipulated by human within models for environmental decision making (Addison *et al.*, 2013).

In a similar vein, Moser and Dilling (1997), state that land uses are the purposes to which human beings employ the land and its resources. Lambin and others expand further and state that Land use itself is the human employment of a land-cover type, the means by which human activity appropriates the results of net primary production (NPP) as determined by a complexity of socio-economic factors (Lambin *et al*., 2000).

Finally, the Food and Agriculture Organization (FAO) has defined the term land use to concern the function or purpose for which the land is used by the local human population and can be defined as the human activities, akin to that submitted by Kummer and Turner (1994). The distinction between land use and land cover, although relatively easy to make at a conceptual level, is not so straightforward in practice as available data do not make this distinction clear all the time, a fact that complicates the explanations of either one of them.

2.3 Overview of Land Use Policy of Ghana

The national land use planning guidelines regulates the judicious use of any land in Ghana for the purposes of sustainable development (EPA, 2010). It does so by protecting environmental resources from land use activities purported to be a threat on these resources (Appiah *et al.*, 2014a). This is in tandem with the recognition of the fact that land is increasingly seen as a crucial factor of production. To buttress this view,

Bugri (2007) in his study of the perception of stakeholders on land in Ghana‘s Northeast, observed that land is considered more as a means of production than was seen as an ancestral heritage.

In this regard, Appiah *et al.* (2014a); Longa *et al.* (2007), stipulate that land use policies meant to promote economic development should integrate the pluralistic uses for sustainable development. It therefore suffices to posit that human settlement, industry, large-scale intensive agriculture or their expansion will have to make adequate provisions of land, in anticipation of the changing demographic characteristics and mobility patterns in response to the changing location preferences.

With the exception of compulsory land acquisition by the state, of private lands for which compensations are paid (WaterAid, 2009), there are no comprehensive legal provisions that guarantee the right to compensation for loss of livelihood, specify resettlement and rehabilitation procedures, or assign responsibilities to this effect (Kasanga and Kotey, 2001). Although the Lands Commission has to approve and ultimately allocate the formal leasehold title to the investor, land laws fail to specify criteria for approval; they merely stipulate that the Lands Commission determines whether or not the project is in congruence with existing development plans (Ghana Land Policy, 1999).

Currently, there are over 166 legal instruments in the statute books with some overlapping and others conflicting (Bugri, 2012a). These laws operate alongside customary laws in the country, creating a plural legal environment for land administration. Key among these laws are: Local Government Act, 1993 (Act 462); Town and Country Planning Ordinance of 1945 (CAP 84); the Fourth (4th) Republican Constitution of the Republic of Ghana, 1992; and the Administration of Stool Lands Act, 1994 (Act 481) which repealed the Administration of Stool Lands Act, 1962 (Act 123).

2.3.1 Land Ownership and Use Dynamics in Ghana

The essence of regarding land as the main pillar for measuring economic growth in terms of capital and wealth in addition to its agrarian value cannot be overemphasized (Ding, 2004). Land ownership in Ghana can be classified into two broad categories: customary ownership (constituting 78% of the total land ownership) and that controlled by the state (20% of the total land area), with the remaining area under some form of mixed ownership (Kasanga and Kotey, 2001).

The Ghanaian Constitution of 1992 forbids the sale of customary land; it only allows for temporary alienation through leasehold titling. Customary land can only be reclassified to state land through the use of the state‘s right to eminent domain, which enables involuntary expropriation of customary land for the provision of public utility.

Customary law freehold (or usufruct title) can be acquired by sub-groups or individuals within traditional areas‘, typically by being the first to cultivate that land, through inheritance or through allocation by traditional authorities (Fiadzigbey, 2006) with *allodial* title holding capacities.

Thus far, the land use policy and use dynamics in Ghana assumes a complex mix of institutions, regulations and ownership as well as the use dimensions. In view of this there is compliance confusion about the use of land within the confines of the laws/regulations, especially in areas such as peri- and urban areas, where the demographic changes create pressure on existing lands. This explains why, in most cases land use plans and development activities in peri-and urban areas, seem tangential in their trajectories, towards any form of sustainability.

2.4 Theories and Models of LULC Change Underpinning the Study

2.4.1 Introduction

A theory is typically a model that tries to provide a general explanation for how some part of the world works as the ultimate abstraction (Weiss and D'Mello, 1997). Models on the other hand are the replication of the reality under controlled conditions, embedded with assumptions, which help in the evolution of and explanations in spatial dynamic systems (Batty *et al*., 1999; Spicher *et al*., 2014; Wilson, 2006). A theory is not just a description of what happens in a system (model), but a statement of the underlying rationale for why something (model) works in the way it does. Consequently, these approaches underlie the analysis of land use change (Alcamo *et al*., 2011).

Theories are important to different categories of people and research-based activities. They have diverse applicability depending on the type of profession and intent for which they are applied, succinctly. They are relevant, whether teachers, researchers and policy makers. They guide our decisions about what to observe and how to make meaning out of the data gathered for a particular purpose (Huitt, 2009). Theories help us to find a coherent structure for organizing our data, and to predict beyond isolated observations by transforming the data into evidence from which to make generalizations. Sometimes inquiry helps to confirm a theory, and at other times the theory has to be modified in view of unexpected outcomes.

In view of this, the test of theory validity does not only depend on the empirical evidence but, the coherence and, especially, the applicability of same (Barlas, 2013). Realists argue that because societies are open systems in which the same conditions are rarely reproduced, theories cannot, operate as universal dictum, as asserted by positivist. At best, they can only enlighten the present of the events and meanings of events in the past whiles providing guidance to a clearer appreciation of the future (Johnston *et al*., 1994).

The most plausible macro state of land use dynamics is subject to some constraints and opportunities. These include constraints of LULC change possibilities, especially occurring in a dynamically upward setting, like the Bosomtwe peri-urban area. Given the myriad of driving factors embedded in the demand and supply of land and associated resources, the hedonic tendencies of an area, as well as policy restrictions for instance, need to be tackled from multi-level power play discourse. Consideration must also be taken in the analysis of the inherent (in)abilities of potential changing agents to effect any change due to environmental, social and political opportunities and limitations in place. These interactions are usually considered appropriate for ensuring peri-urban space optimization. These approaches have been used, to explain the approximate distribution of actual LULC patterns in the Bosomtwe peri-urban district.

2.4.2 Political Ecological Theory

Political ecology (PE), according to Walker (2006) offers powerful analytical tools to understand more holistically the social and environmental problems. It places the analytical discourse of the relationship between environmental processes and societal interactions into perspective (Forsyth, 2008). PE obtained its structure from the interdisciplinary interplay of established subject areas as the new material from different social science disciplines such as Economics, Anthropology, Sociology, Geography, Environmental Sociology and Political Science. These social science disciplines, by virtue of their constant interaction with nature, needed a framework of socialenvironmental unison, to understand human societies and spatial organization in a holistic way. PE therefore, presented the possibility of a new organizing framework where natural sciences and social sciences could re-negotiate their subjects (Blaike, 2008).

PE is a combinative approach using a myriad ecological perspectives applied to different aspects of social sciences (Little, 2007). These sub-themes have their respectively, peculiar body of knowledge-generative capabilities, with variant insights, which can be used to understand different dimensions of socio-environmental realities. It must be understood that PE discourse does not intend to synthesize the respective knowledge generated from other socio-environmental analyses (Blaike, 2008). As was posited by Walker (2006: 391) *that "...if political ecology can mean almost anything, it can also mean almost nothing. The danger is that, to those outside, political ecology may come to appear as little more than disarticulated intellectual sprawl under a catchy label"*. The main intents of PE in bridging the cultural and natural ecological divide, however, is to place the human environment interactions within a power and influence perspective. This means that PE approach to the human-environment dichotomy provides unique theoretical perspectives for understanding of the complex interrelations existing between human and environmental equilibrium (Muldavin, 2008).

2.4.2.1 The relevance of human ecological thinking to the study

For the purpose of this study, human ecology (HE) which aptly places the roles of human beings and their interactions with the natural and social environments is identified as more appropriate sub-theme/theory under the PE (Stokols *et al*., 2013). HE is a term originating from a sociological approach which borrows concepts and ideas from the field of Ecology and applies them to the analysis of human interactions with their physical and social environment (Lawrence, 2001). The issue of concern was the application of the concept to the explanations of the complex relationships existing between urban populace and their environmental milieus (Alberti *et al*., 2003). HE advances the conception of cities as areas of outward manifestation of processes of spatial competition and adaptation by social groups; these spaces correspond to areas of ecological struggle for environmental and social adaptation. An expression of this dictum tends to characterize the Bosomtwe district and the changing land use and land cover dynamics in response to the changing population dynamics as well as the out-push of the pressures on land from the urban core to the peri-urban fringes.

In this context, the study examined the intricate nexus between peri-urban residents' responses to peri-urbanization and its consequences on the peri-urban LULC dynamics of the Bosomtwe district of the Ashanti region of Ghana. The tenets of HE is engraved in the core discourse of human and environment interactions, base of certain identified and, sometimes the unknown, yet inherent drivers of the spatial processes. These processes, are driven by such factors as type of location of phenomena (rural, peri-urban and urban), human demographic change dynamics, location of settlements, the income of the people, the type of natural resources and the elasticity of the demand for them, technology as well as legal and political considerations as intrinsic attribute of social cohesion.

Considering the demographic dynamics of the district, predominated by agrarian households, it was analytically convenient to offer a household scale explanation between human and environment relations (Zimmerer, 2004). This is because

household-level analysis can offer a much-needed level of finer resolution relative to the spatially aggregated attributes of human-environment interaction that are scaled to the community, region and national scales. This assumption underpins the choice of this study to consider the various variables of interest at the household level.

2.4.3 Urban and Regional Mathematical Ecology (URME)

Urban and Regional Mathematical Ecology (URME), is another theoretical stream concerned with the study of processes leading to some complex patterns of urban systems approach to understand complex theory in the context of systems theory (Batty *et al.*, 1999 and Wilson, 2006). It borrows ideas and concepts from Ecology as well as from the general concept of Human Ecology and applies theories from urban entropy (Cabral, *et al*., 2013; Wilson 2006; Lawrence, 2001; Mugerauer, 2010), to explain the changing dynamics of the peri- and urban regions.

Urban and rural populations residing at the peri-urban areas of the Bosomtwe district can be likened to the ecological system, where species' interactions are governed by symbiotic, predator-prey, competitive and other types of ecological relationships (Elmqvist and Maltby, 2010; McPherson and DeStefano 2003). These parallels are transferred to land uses which are seen emerging in certain places and growing while other land uses in other locations dwindling in size or disappear completely. The socioecological characteristics of the Bosomtwe district as a peri-urban area, certainly, exhibits traits of both rural and urban LULC mixes. These land use and cover mosaic is based on the inherent, interactions between humans (predations) and the land and its resources as the prey at the receiving end of the interactions.

Human agents, wielding the power of decision making, are able to influence their immediate as well as expanded territorial domains, leading to various LULC change outcomes. These ecological relations are analyzed both within and between cities, and in this context, the rural to the peri-urban interface even in a regulated rent market, with the ultimate aim to obtain the spatial and growth patterns which result from these relations (Alberti *et al*., 2003).

The main tenet of this theoretical stream is based on macroscopic features of urban and regional phenomena. This can, however, be analyzed by focusing on the most important qualitative features of an urban area looking at it from peri-urban evolution perspective and progressing over a particular time frame (Kombe, 2005). Urban and Regional Mathematical Ecology attempts further to analyze the dynamic behaviour of urban and indeed peri-urban area systems in response to the existence of urban and peri-urban cycles of rapid growth or disappearance of certain land uses, arbitrary sub-urbanization, urban sprawling into slum settlements and associated conundrums (Cabral, *et al*., 2013). It addresses the issue of dynamic, non-linear interdependencies, stability, orderly and heuristic changes, with multiple equilibra of spatial interactions.

Although these principles form the bases of most agent-based modelling, their assumptions are such that they tend to marginalize the erratic human behavioural changes in response to environmental and social conditions. In this regard, URME has been described as adulterated from origin in its quest to solve social and environmental dynamics. Indeed these theories have been described as having theoretical ambitions of delivering to the social-sphere, their insufficiencies in solving explicitly socioenvironmental problems. The criticisms though may contain some merits, their ability to first pushing the social frontiers towards some law and order seeking tendencies and secondly their ability to integrate human behaviour under some tenable assumptions, makes them worth trying.

2.4.4 Statistical Modelling

Application of statistical techniques to derive the mathematical relationships between dependent (response) variables and sets of independent or predictor variables data exploration is widespread in modelling socio-economic and other systems of interest (Stephenson, 2008). The most commonly used statistical technique is simple and multiple regression analysis. These also have their variations such as stepwise logistic regression in their very simple to more complex dimensions (Davison, 2008). The application of other multivariate techniques is also not uncommon; such as factor analysis, principal components analysis, etc. in the analysis and interpretation of data.

The direct object of statistical models is to analyze land use change, using determinant variables in a statistical model. They constitute components of larger models employed for the analysis of land use changes and their determinants (Odoemena, 2010). A distinction can be drawn between continuous models which treat land use as a continuous variable, with land devoted to a specific use type, and discrete models those which treat land use as a discrete variable in which different land use types are categorized (Irwin and Wrenn, 2012). In modelling land use change, usually, the study area is categorized into a group of pixels (gridded system) the size and shape of each corresponding to the collection of the particular land use type. The aggregation of the land use types employs the principles of some maximum likelihood of cell allocation to particular cell category.

In the continuous instance, for each zone, the distribution of land use types identified as the dependent variables as well as the values of other environmental and socio-economic determinants, also called the predictor variables, such as population, employment, soil conditions, slope and climate are given. A multiple regression equation for each land use type is fit to these data (usually referring to a given year). The general form of the equation is:

$$LUT_i = a + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \ldots\ldots\ldots\ldots \beta_n X_n + \varepsilon \qquad 2.1$$

Where; LUT is the area of land occupied by land use type i (in each pixel) and X_1, X_2, X_3 … X_n are the predictor variables. The β_n are the coefficients of the predictor variables while the term ε is the error term of the model, usually resulting from heuristic tendencies in the predictor variables.

This model format can be used to assess the degree and probabilities of land use types conversion and changes under various assumptions of the predictor variables characteristic in the equation.

2.5 Applying the Driver-Pressure-State-Impact and Response (DPSIR) Model

The conceptual framework underpinning the study is the Driver-Pressure-State-ImpactResponse (DPSIR) model. The Model framework was first adopted by the European Environment Agency (Zacharias *et al.*, 2008; Smeets and Weterings, 1999). The DPSIR approach is an upgraded development form of the Pressure–State–Response (PSR) framework developed by OECD (1993).

This framework is used to organize information about the state of environmental resources and the relationship between human activities with possible environmental changes. The DPSIR analysis is a valuable model, as it enables the parallel assessment of socio-economic and environmental parameters (Walmsey, 2002; Elliot, 2002) and cited in Zacharias *et al*., (2008). Social and economic developments acting as the drivers, exert pressures on the environmental resources and result in changes in its state; i.e. the physical, chemical and biological features of the environment (Pirrone *et al.*, 2005).

Furthermore, these changes lead to Impacts on ecosystems, human health and natural processes and these impacts eventually, generate social and political Responses (Smeets and Weterings, 1999), which are needed for remedies to ensure environmental equilibrium. Such responses can affect any element of the DPSIR variables which can then create a feedback directly on the state of the environment or on the driving forces, hence, on human activities.

The DPSIR was particularly used for the analysis of sustainable management of the periurban LULC changes in the Bosomtwe district. This is because in such an area the major anthropogenic drivers derived from activities (Lin *et al*., 2007), were the conversion of agriculture (arable) lands for the purposes of commercial and residential facilities. On forest frontiers, agricultural land expansion has led to the modification of some dense (closed canopy) and low (open canopy) forests to recent fallows/grassland covers.

This theoretical framework (Figure 2.1) is amenable to the study in order to detect and analyze the driving forces and their pressures on the LULC conditions, assess their state, identify the associated impacts and eventually, propose the necessary responses in order to restore, protect and preserve to ensure sustainable land uses in the Bosomtwe district. The development of the DPSIR model incorporated a profound analysis of the vegetation and non-vegetation land uses and covers in the district, taking the local social and economic characteristics into consideration.

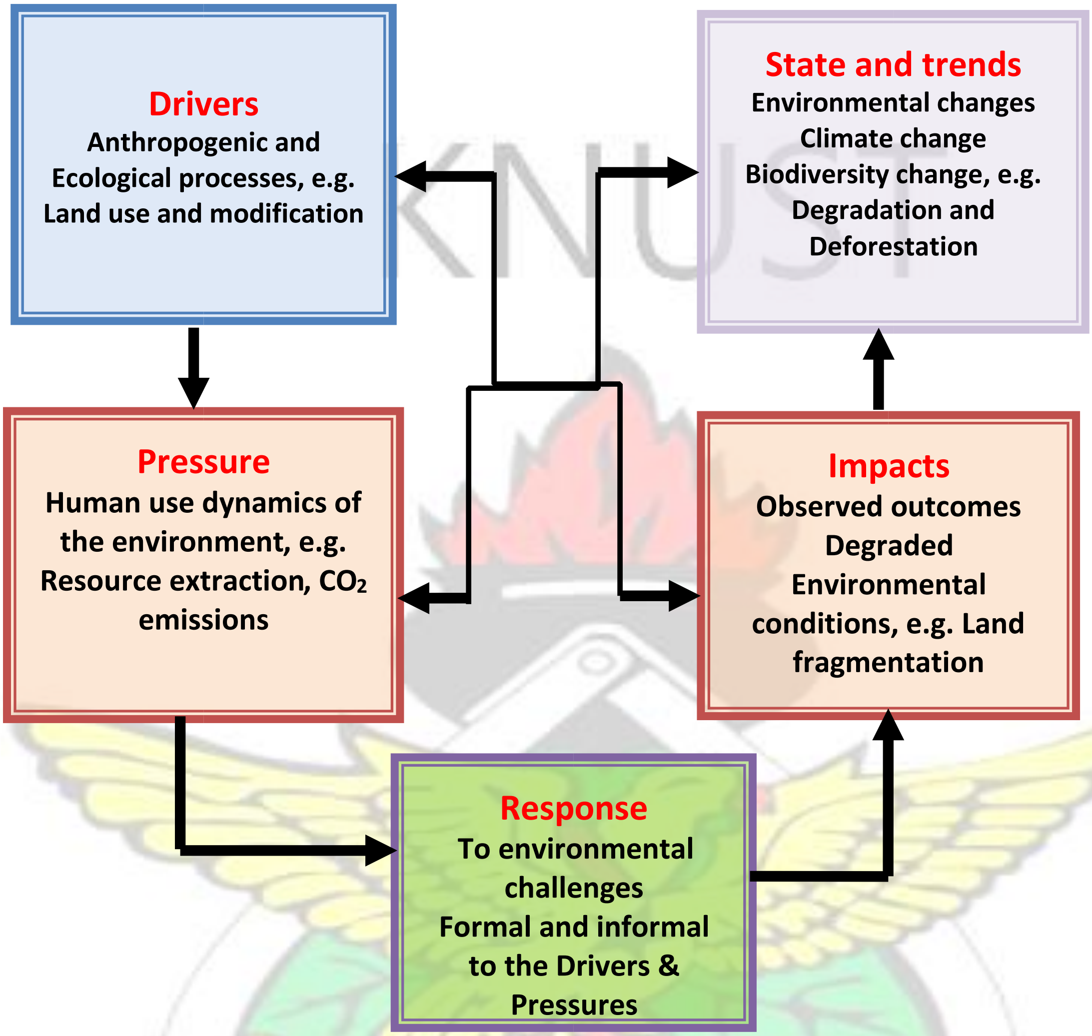


Figure 2.1: The Driver, Pressure State Impact Response Model; After Smeets and Weterings (1999).

2.5.1 The Modified DPSIR Model for the Study

The modified model, encapsulates the human and natural attributes with their outcomes under interactions governed by spatial mathematical and statistical analyses. These entail the dependent (LULC changes and/or climate variability) and independent variables (human decisions on social and natural environment) based on plausible, as well as feasible assumptions. The LULC changes exhibit interactive forward and backward impacts linkages on climate variability and climate change in the Bosomtwe district (Figure 2.2).

These variables operating within the geographic information system (GIS) environment, yield varying spatial variability and configuration of the LULC types. It is upon these that human decisions are based for effective land use management. Thus, the drivers can be defined as the social and economic activities and processes in the broader Bosomtwe peri-urban area. These drivers create and exert the pressures for land in terms of demand and use competitions, resulting in the alteration of status of natural habitats (Kristensen and Alongi, 2006).

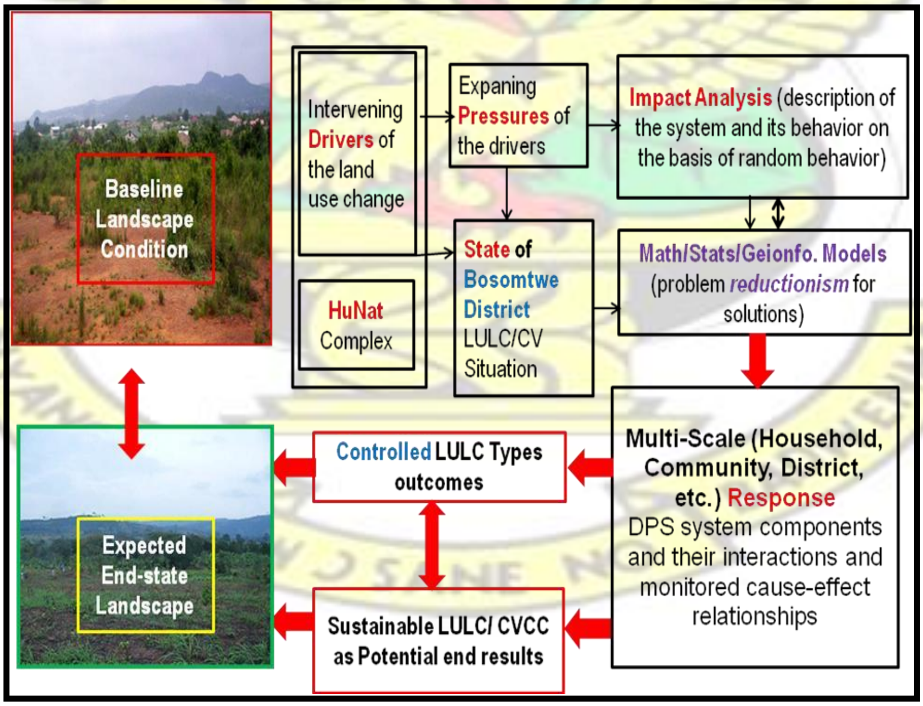


Figure 2.2: The modified DPSIR framework; Adapted from Smeets and Weterings (1999).

This approach is based on the concept of causal links that start with the increasing human populations and activities mixtures within the Bosomtwe district (driving forces); in the form of migration, rapid urbanization, demand for residential housing, commercialization of the landscape and recreation. These result in land use types that claim different territorial areas hitherto reserved for vegetation conservation and arable land purposes. The exerting pressures on the LULC changes affect the quantity of natural resource, expressed in the form of reduced forest covers, agriculture land expansion as well as built up and open up areas, replacing forested areas. Certainly, the state of the LULC lead to certain impacts (outcomes) which would require both positive and negative responses. These can be categorized as promotional as well as restrictive responses, depending on the rate and type of use categories of the resources (land) by human societies.

The utility of the DPSIR model (Smeets and Weterings, 1999; Pirrone *et al.*, 2005) with its variables/indicators (sets of physical, biological or chemicals variables) is limited because of the absence of the balanced choice of management offered to policy makers. It fails to offer clear and specific strategies for sustainable management of LULC, in the case of the peri-urban system of the Bosomtwe district.

The DPSIR framework approach has over-emphasized only the negative impacts without the due consideration to the possible positive connotation it could also bring. Impacts component of the framework could be highlighted as per the recommended enhancing and restrictive responses that is used to manage the resources. The response variable 'R' of the DPSIR, should also be seen as a managerial, rather than a remedial tool with both positive and negative dimensions to address the positive impacts (outcomes) and negative impacts (outcomes) of the use of the environmental resources, respectively.

2.6 Application of Integrated Models of Land Use Change

LULC dynamics are the current defining features of the peri-urban morphologic picturesque of every naturally or human-organized space, particularly in the Bosomtwe district of the Ashanti region of Ghana. This viewpoint has been supported by (Mandere *et al*., 2010) that the peri-urban area seems to be characterized by a flux of rapid changes in land-use, built forms, economic activities, defined as places of conflict or competition which exist in between new (urban) and traditional (rural) land uses (Obeng-Odoom, 2012).

The changing land uses in the peri-urban areas have considerable impact on the local environmental changes in the Bosomtwe district. Using appropriate policy instruments Dutta (2012), suggests that urbanization and for that matter peri-urbanization becomes synonymous with frequent land use changes that has varying impacts on the rural environment. Supporting this assertion further, Vejre (2008) submits that land in urban and peri-urban areas in particular have become extremely important objects for planning and management, with increasing conflicting interests for their uses.

In addressing the issues of sustainability, Busck *et al.*, (2006), suggested that the periurban interface comprises a heterogeneous mosaic of environmental and productive ecosystems working in combination with socio-economic lifestyles of land owners' peculiar relationships with the immediate urban areas. In sub-Saharan African cities, functional decentralization and infrastructure provisioning are often advocated as sustainable solutions for improving unplanned and underserviced lands (Ricci, 2011). However, these postulates alone do not actually solve the problem of plausible unplanned land use at emerging urban fringes. It is widely argued that improved urban planning and provision of public services and infrastructure are crucial for the development and promotion of resilient cities (Stern, 2007) and for addressing individual and community interests (Arko-Adjei, 2011). In a similar manner, Larbi and KakrabaAmpeh (2013), have argued that land use in the peri-urban and rural areas of Ghana consists of a complex interdependence of different factors of livelihood support.

In the peri-urban milieu, the lifestyle of land owners both old and new may still be strongly linked to the immediate urban areas in terms of social, cultural and occupational relationships (Busck *et al.*, 2006). These are made possible, by improved infrastructure and mobility (Ravetz *et al.*, 2013), as well as the changing socio-economic demands of society with respect to rural and peri-urban land uses. In addition, the structural development within the agricultural sector in the peri-urban areas has forced many former full-time farmers to seek stronger relations with nearby urban areas; this is due to little incentive for farmers to invest fully in any conservation measures, particularly with land tenure insecurity (Marshall *et al.,* 2009 and Busck *et al.*, 2006).

The response of subsistent farmer land owners and users, expressed as human agents to the changing conditions of the environment, determines to a larger extent the main determining factors of peri-urban LULC change. However, differentiating the complex of new peri-urbanisms in aggregate is diverse (Butt, 2013); yet such an approach can move towards an appreciation of the morphology and distribution of peri-urbanization. These are evident by fragmented and uneven landscape that facilitates decentralization and encourages suburban sprawl. It then makes the formulation and implementation of strategic urban plans in major emerging cities untenable (Bourne *et al*., 2003).

These multiple motivations for movement into peri-urban regions are not necessarily geographically discrete, although landscape character, urban accessibility, housing affordability, and the patterning of land use and land markets play a role in influencing the characteristics of inward migration to peri-urban regions (Lawanson *et al.*, 2012; Butt, 2013). According to Simon, 2008 peri-urban areas are increasingly attracting middle-class and higher-income people whose lives exhibit lifestyles, reflective of innercity dwellers in a predominantly rural setting.

Conversely, the integration of infrastructure in the form of transport and information and communications technology (ICT) revolutions as well as introduction of super-structure commercial centres has been replicated in the peri-urban areas. These have enabled people and industries to relocate to engage in work, from high-amenity rural or semiurban localities; area described as the edge cities (Simon 2008; *p.169*) or peri-urban fringes (Afriyie *et al.*, 2013).

2.6.1 Situational Perspectives of LULC Dynamics in Ghana

The LULC configuration in peri-urban areas therefore, follows patterns of hierarchy which, are dependent on the direction and strength of force of influence. These forces of influence are the main determining factors, which induce people to acquire and put to use the land, to a particular purpose. These land use patterns are based on availability and accessibility, including tenure securities. In particular, the gender disparities in terms of access to land and use are invariably unfavourable to women.

Accordingly, Kasanga and Kotey (2001), have indicated that in peri-urban Ghana, landlessness is pronounced among women. This has the tendency to control the spatial disaggregation by gender, of populations, infrastructure and land use patterns in the entire space economy. The directions and strengths of the rates of influences are measured by the various pull and push factors in the rural and the urban settings respectively. All these forces are to a larger extent according to Bugri (2008), regulated by the relevant state departments and agencies responsible for preventing anthropogenic causes of environmental degradation.

The Bosomtwe district is one of the fast-expanding peri-urban settings in the Ashanti region of Ghana. It has one of fastest growing rates of private land acquisition and residential sprawl in response to the changing human populations' choice of relocating away from the city centre. The ever-increasing concentration of residential and commercial activities, are having different implication for LULC dynamics. As the region is gradually urbanizing the rural landscapes are merging into the changing periurban continuum. Characteristics of most peri-urban areas, the Bosomtwe district is faced with the dilemma of rational land use conversion and modification decision among land owners.

In spite of the far-reaching implications this complex land use changes could have on the district's land use plans, however, there is the limited scientific information to inform appropriate policy direction (Appiah *et al.*, 2014b). These thorny questions that shroud the future uncertainties include; what are the land use change potentials in the peri-urban areas as well as; what are the probable future land use conversion and modification direction in the peri-urban Bosomtwe district? Occasionally, systemic laxity in controls by the district assembly on land use plans in the urban to the peri-urban areas has invariably engendered chaotic physical development ahead of land use plans (Larbi, 1996). The Peri-urban land use and land cover dynamics operate in the moderate probability outcomes of conversions and modification in the Bosomtwe district (Appiah, 2016).

2.7 Drivers of Peri-Urban Land Use

The processes of environmental change and their implications for the sustainable management of the resource base and quality of life of peri-urban areas are different from the urban and rural landscapes, in so far as they constitute particular ecological and socioeconomic systems (Simon *et al*., 2009). The transformations of the peri-urban environment are, to a large extent, driven by the pressures exerted through external, and often nearby, systems. These pressures underlie the driving forces behind the spatial land use changes in the peri-urban area. According to Adriana *et al*., (1999), these pressures includes; inadequate development processes, unequal distribution of services and investments, the conditions of the natural environment, the lack of provision of adequate services, the scale and nature of demographic growth etc.

2.7.1 Outcomes of Intrinsic and Extrinsic Peri-Urban Land Use Conversion Decision

Human interactions with the bio-physical environment create the usable spaces of land that are extracted from the original land uses and land covers (LULC). Converting or modifying these land uses from their original states, require agents to make certain decisions that are endogenically determined by the individual intrinsic households circumstances. These are usually done with special reference to the main decision taker in that social-arrangement domain; say the land owner, or heads of household (Fenske, 2011). These decisions usually rest on those human agents that have the ownership and or access right to the use of the land in question.

Operating under human rationality *a priori*, land use economics hypothesizes that land use modification and conversion are purely driven by changing economic variables which are measurable and ascertainable in econometric models (Irwin and Georghegan, 2001). The impacts of systematic policies, expressed in socio-political directives, notwithstanding, human decision in converting or restraining are balanced within individual rational choices. These are purported to work out gains and relative opportunity costs forgone, within reasonable time continuums. By modelling the human behavior directly, rather than the outcome of human behavior within the uncertain decision rules, makes it possible to predict human behaviours better than under direct human outcomes which are indeed subjected to individual whims and caprices.

Spatial land use conversions therefore are driven invariably by both exogenous and endogenous factors, some extrinsic and others intrinsic. Hence, land use conversion patterns and pathways as they trend within time frames are therefore, characterized by complex decisions in order to establish the equilibrium between the net gains and the opportunity costs expropriating the land for a different use (Fenske, 2011). The later decision point is also a gain of a sort, at different time lag changes of LULC changes (Kline *et al.*, 2009).

By identifying the potential values as well as the intrinsic probabilities of converting an original land use to another, it stands to reason from economic modelling perspectives that land owners are rational agents. It suffices to posit that some of these agents operate within local to national policy constraints, yet manage to maximize land use conversion gains. The aforementioned argument characterizes the peri-urban land use conversion probabilities of the Bosomtwe district of the Ashanti region of Ghana.

Apart from the economic gains of converting land uses from one type, say, agriculture to residential and sometimes residential to commercial, it is also imperative to expand the conversion spectrum to embrace the dimensions of all spatial and temporal as well as exogenous that serve as both positive (desirable) and negative (repulsive) incentives and influences of land use conversion in dynamic urban areas (Alcamo *et al.*, 2011), especially in the peri-urban milieu. These aspects of the broader decision include the heterogeneity of the bio-physical environments and the degree of landed resources endowments, population density variations, spatial differentials in the social and economic infrastructure bases of the area of interests, the proximity and nearest neighbourliness of land uses, as well as other non spatial intangible attributes such as satisfaction, desire to own a particular land use type.

This is because, according to Fenske (2011), land use conversion probabilities are governed intricately by land owner investment decision models. These models tend to relate the actuality of known decision variables that are parameterized and the unknown variables that serve as the uncertain terms under reasonable assumptions (Parrott, 2011). To be able to establish to any degree of certainty the land use conversion probability in any given area, a conscious effort to unravel the extent of uncertainty surrounding other plausible decisions. This would justify the relative significance and confidence for land use conversion model predictions (Kline *et al.*, 2009).

2.8 Implications of LULC Drivers for Climate Variability and Climate Change Land use is a significant and inescapable driver of environmental change with a lot of implications specifically to climate change, such as vegetation cover depletion. The IPCC defines Climate Change to be the statistical change in climatic variables, whether due to its natural variability or as a result of human activities (IPCC, 2007). Ghana has experienced dramatic peri-urban land use changes including decline in agricultural land, decrease in forests, and accelerated expansion of urban areas. These are not quite different from the trends identified in other areas over previous decades (McCusker and Carr, 2006; Schindler, 2009).

These rapid changes in land use produce noticeable undesirable effects with implications for ecosystem reduction, biodiversity degradation and global climate change. Several land use issues in Ghana have been figured out prominently in most international negotiations on climate change. Under the Kyoto Protocol and the Global Carbon Partnership Trade, Ghana is entitled to incentives and credit for equalizing carbon dioxide (CO_2) emissions through changes in land use and land management (Simon, 2008; Ewing *et al*., 2007).

The dynamism of peri-urban landscapes attests to the different evolution of land cover changing over time in response to numerous interacting drivers of change. These drivers include economic growth and decline, demographic change and politics. Improving understanding of this dynamism is an important, yet under-researched, element of recognizing the implications and developing adaptation responses towards climate change. It is broadly acknowledged that spatial land use planning has a strong role to play in the development of climate change adaptation responses (Blanco *et al.*, 2009; Davoudi *et al.,* 2010). Processes linking the development and use of peri-urban lands in Ghana are highly influenced by spatial planning. Thus, the implications, nature and severity of climate change impacts and the form and function of adaptation responses that can be employed will highly depend on the institutional forces.

The effects of changes in land cover on weather and climate is dependent on land use practice. Land cover changes affect the exchange of water, energy, and gases within the atmosphere through changes in surface albedo and transpiration. This alters surface temperature and latent heat flux, ultimately leading to changes in regional temperature and precipitation patterns (Dale *et al.*, 1993). Land-cover changes can also initiate a wide range of other global changes including water-resources alterations and modifications to habitat as attested by Verburg *et al*. (2011) and UNFCCC (2012). These are eventually manifested into long-term adversities of weather and climate variability and change.

Fall *et al*. (2010) held firmly, a standpoint on LULC changes and its implications for climate change. They provided that, air temperatures and near-surface moisture have been changing and will continue to change in areas where natural vegetation has been converted to agriculture, grazing lands and other injudicious land uses. Bonan (2001) and Karl *et al*. (2012) have also corroborated Fall *et al.*, that, regional daily maximum temperatures have experienced fluctuations in areas where uncultivated and conservation forest are being cleared for agriculture and increases in areas of forests re-growth due to abandonment of agriculture.

It has succinctly been argued that LULC change modifies the physical properties of the land surface thus influencing radiation, momentum as well as the water cycle between the atmosphere and land surface (Pielke *et al*., 2011). This can produce noticeable impacts on regional precipitation and atmospheric general circulation (Fu and Yuan, 2001; Gao *et al*., 2007). If the above arguments and assertions (Pielke *et al*., 2011;Verburg *et al*., 2011; UNFCCC, 2012) are correct then it's worth bringing to light that LULC alters greenhouse gas emissions (e.g., CO_2, N_2O, CH_4) in the atmosphere, affect climatic variable and lead eventually to climate change.

Finally, scientists have come to a better understanding of the role that forests play in the carbon cycle, and how forests burning in certain part of the world are contributing to greenhouse gases emissions and climate change. Clearly, all of these changes impact on the environment and society. The dual role of humanity in contributing to both the causes and experiencing the effects of global climate change processes emphasizes the need for better understanding of the interaction between humans and the terrestrial environment. This need becomes more imperative as changes in land use become more rapid. Understanding the driving forces behind land use changes and developing models to simulate these changes are essential to predicting the effects of climate change and its variability (Veldkamp and Lambin, 2001).

2.9 Geo-Spatial Methodologies for LULC Change Analysis

Globally, quite a substantial amount of research has been done on the use of satellite remote sensing and GIS to model the land use and cover dynamics (Mallupattu and Reddy, 2013; Al-Bakri, *et al*. 2013; Uchegbulam and Ayolabi, 2013 and Forkuo, 2011). Geographic Information System (GIS) is a computerized system, capable of capturing, storing, manipulating, transforming, retrieving, analyzing, and displaying many forms of spatially referenced data (Clarke, 1999).

It further provides a unique platform for spatially referenced data to be assembled, visualized, analyzed and represented. GIS has been adopted and applied in sectors of development worldwide. The main areas of focus have been natural resource mapping and management, transportation planning, urban and regional planning, academic research and private sector uses. It has also contributed significantly to participatory planning and research as well as urban, environmental, population, climatic, land use, and natural resource management studies (NRC, 2002; Ottichilo *et al*. 2002).

In peri-urban research, GIS has been useful in the identification, measurement and description of spatial patterns and change, leading to a more informed understanding of urban growth in the fringe, hence widening the scope of geographic inquiry (Anderson, 2000; Gichuhi, 2002). GIS representations on these rapidly transforming peri-urban landscapes have continued to reflect directly observable impacts of urbanization as perceived from social or environmental scientists' perspectives (Lupton and Mather, 1996; Snel, 1993).

2.10 Influence of Climate Change on Peri-Urban Environment

The peri-urban environment is characterized by dynamic and dramatic changes in its landscape. This obviously demonstrates the potential future climatic influences on various land uses. The underlying climatic influences/forces on the peri-urban system can be synthesized and organized into the following environmental effects: water resources, agriculture and ecosystems.

Climate change is likely to worsen peri-urban agricultural systems. This has gained significant attention over the past few decades due to its potential detrimental effect on food security (Parry *et al*., 2004; Olesen *et al*., 2007; IPCC, 2007). Much of the world‘s urbanized and urbanizing areas depend on agriculture produce from the peri-urban zones for industrial and subsistence use. The influx of population from urban and rural area also contributes to the increasing demand for agricultural produce (Burow *et al*., 2010).

Agricultural production and land-use practices are influenced by climate, land, and water resources. In the peri-urban areas, the climatic change influence on agricultural activities is vividly significant. The anticipated increase in climate variability may influence crop production and agricultural profitability (Wheeler *et al*., 2000; Schär *et al*., 2004; Leckebusch *et al*., 2007; Siva Kumar and Hansen, 2007).

To confirm this further, Garnaut (2008) asserted that, climate change is likely to result in changes in long term weather conditions and an increase in the variability of an already variable climate. The potential impacts include increased fire danger, damage to crops and soils due to flooding, land degradation, crop failure and livestock heat stress and even death. However, the productivity losses in the agriculture sectors as a result of climate change are likely to lead to a fall in gross regional product, and farm incomes in most peri-urban areas. Empirical studies have attested that income loss in peri-urban communities can lead to a range of impacts including increased workload, family conflict and withdrawal from social groups and communities (Paull, 2010).

According to Pielke *et al*., (2011), LULC change can result in meso-scale and regional climate change if the areal extent of the landscape conversion is large enough. A spatial heterogeneity of approximately10–20 km has often been considered sufficient for creating meso-scale circulations under convective conditions; though smaller scales approximately 2–5 km are also often sufficient to trigger changes in boundary layer dynamics.

Pitman *et al*. (2009) used the Atmospheric General Circulation Models (AGCMs) in their studies on the climatic effect of land cover changes from pre-industrial period to present day, to extrapolate how LULC change affects climate variables. The simulations provided substantial changes in latent and sensible heat fluxes, albedo, and therefore absorbed shortwave radiation, and near-surface air temperature over the regions with considerable LULC change, but the magnitude of those bio-geophysically induced changes differed considerably among the models.

Similarly, reduced precipitation is a clear evidence of variable climates under changing LULC in peri-urban areas of the world. The continuous vegetation decrease in periurban areas leads to greater surface sensible heat which enhances convective circulation over the region. However, reduced vegetation also decreases the latent heat flux at the surface, thus the amount of moisture available for cloud formation reduces (Cheng and Chan, 2012). In the summer, there is a great reduction in rainfall over the inland areas of urban fringes, but an increase in rainfall is observed over the coastal areas of urban fringes due to strong positive moisture advection (Zheng *et al.,* 2002).

As a consequence, negative impact on winter precipitation is found in most of the periurban areas of the world. This hypothesis has been demonstrated by the numerical model results in a study on land use changes and climate change in China by Cheng and Chan (2012).

2.11 Summaries and Conclusions of the Literature Synthesis

Human driving forces or macro-forces are those fundamental societal forces that in causal sense link humans to nature and which bring about global environmental changes (Moser and Dilling, 1997). Examples of those forces include: population change, technological change, socio-cultural and socioeconomic organization (economic institutions and the market, political economy, ecology, political institutions). LULC are connected through the proximate causes of change translate the human propelling goals of land use into changed states of land cover. Land use change, which to an extent drives land cover change, is shaped by human driving forces in the form of socio-ecological activities that determine the direction and intensity of land use (Turner and Meyer, 1994). These observations, offer valid, though not sufficient conclusions for the land use conversion probability and intensity in the Bosomtwe district in the Ashanti region of Ghana.

Because of the multiple land uses conversion potentials that compete for space with time trending (Vejre, 2008), certain variables may be multiple correlated in determining the effect of the decision response. This is because land use conversion proxies exist *in tandem* with viable and no-viable land use types. These have various degrees of conversion probabilities for lands located in the communities in the Bosomtwe District. These show different spatial contiguity and relatedness in terms of the biophysical land features to the socio-economic infrastructure. These also have spatial and non-spatial attributes either positively or negatively on land use conversion categories in the district. For instance, in an area experiencing considerable urbanization relocation activities definitely had some degree of land uses conversion potential with competing functionalities (Lambin and Mayfroidt, 2010).

In this regard, non-farm and off-farm economic activities that exhibit high economic and social wellbeing and some extent environmental sustainability should be a new economic model paradigm of sustaining peri-urban livelihoods. Contrary to these rollercoaster expectations, will be the drawback force of emerging and evolving land tenure system in peri-urban areas. This is because while some land tenure arrangements would promote the new paradigm, others would be too rigid to yield to the enticements to any appreciable extent.

Again, considering the obvious environmental connotations of these potential land use conversions, it would be imperative for regulatory authorities to be extra rigorous to ensure that any such conversion undertakings do conform appropriately to rules and regulations. Suffice to say that in the wake of environmental regulatory laxity, an accusation level against spatial land use planning authorities, would present opportunity to the district assemblies and their town and country planning departments (TCPD) to prove their mettle to the general populace.

Given the need for models to explain of LULC changes, the use of these models are not difficult to derive. At first, general use is to provide decision support in various decision and policy making contexts. More specifically, models can be used to describe the spatial and temporal relationships between the drivers and the resulting patterns of land uses and their changes. Concisely, well-specified descriptions grounded on rigorous theory are the cornerstones of understanding and defining the exact problem that land use change decision makers are facing (or, simply, interested in) and act accordingly (if necessary). Models of land use change can be used also as explanatory vehicles of observed relationships. This is a debatable aspect of model use, however, as it depends on what one means by 'explanation'.

Finally, there would be a change in category land use from productive to non-productive land use patterns, in as much as human social and economic needs change over space and with time. This perpetual demand for land use, particularly for residential, commercial and recreational purposes, may ultimately explain the continuous dwindling from time to time in the size of arable land meant for crop production within the study area. The literature has pointed out that in establishing reasonable trade-off between the land use typologies; the various models have prescribed land use prudence in taking the decision for LULC change dynamics.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

The theoretical bases of the study were laid in chapter two, which identified and placed in context, the conceptual and theoretical underpinnings of the study. It discussed the salient aspect of the political ecology and the state of the environment reporting model, the drivers, pressure, state impacts and response (DPSIR) framework, within which the analyses of the results from the study were performed.

This chapter is devoted to the description of the profile of the study area, research materials and methods applicable to the various aspects and sub-sections of the thesis. It entailed the identification and the enumeration of the materials and methods used in the processes of the data analysis, display and reportage. In all, the chapter is segmented into four main parts.

The first part of the thesis was a socioeconomic survey of the driver of LULC change among the inhabitants in the Bosomtwe district. Since this aspect of the research was socioeconomic in nature, it was undertaken using the survey method and the analysis of the same data using the statistical package for social scientist (SPSS V. 17).

The next component was the spatial modelling aspects of the thesis. This section employed the techniques of satellite Remote Sensing with Geographic Information

System in the generation and analysis of geospatial data on LULC dynamics.

3.2 Profile of the Bosomtwe District

This sub-section describes the study area in context. It does so, by outlining the profile of the district in terms of the physical and social characteristics.

3.2.1 Profile of the Study Area

The Bosomtwe District is located in the central part of the Ashanti Region. It lies within Latitude 6°28′N–Latitude 6°40′N and Longitudes 1°2′W–Longitude 1°37′W. Kuntenase is the District Capital. It spans over a land area of 330km^2 (Figure 3.1). The District is bounded to the North by Atwima Nwabiagya and the Kumasi Metropolis as well as to the East by Ejisu-Juaben Municipal. The southern section is bounded by Amansie West and East Districts, all in the Ashanti Region of Ghana (Appiah *et al.*, 2014). The population of Bosomtwe district according to the 2010 population and housing census, is 93,910, representing 2% of the region‘s total population (Ghana Statistical Service, 2014). Males constitute 47.7% and females represent 52.3%. The population of the district is 70% rural in nature (Ghana Statistical Service, 2014).

Lake Bosomtwe, the largest natural (crater) lake in Ghana is located in the district. With the exception of the lake which has an outer ridge that maintains a constant distance of 10 km from the center of the lake and stands at an elevation of 500 to 1500 m, the rest of the district has other varying unique topographical features. The drainage pattern of rivers and streams draining the Bosomtwe District is dendritic and centripetal in outlook. Around Lake Bosomtwe, there is an internal drainage where the streams flow from surrounding highlands into the lake in a centripetal fashion. The streams form a dense network due to the double maxima rainfall regime. Notable rivers in the district are rivers *Oda*, *Butu*, *Siso*, *Supan* and *Adanbanwe*.

3.2.2 Climate and Vegetation

The district falls within the equatorial zone of climate with a rainfall regime typical of the moist semi-deciduous forest zone of the country. There are two well-defined rainfall seasons. The main season occurs from March to July and September to November with mean annual rainfall of about 1400 mm. The mean monthly temperature is about 32°C with a relative humidity of between 60 and 85%.

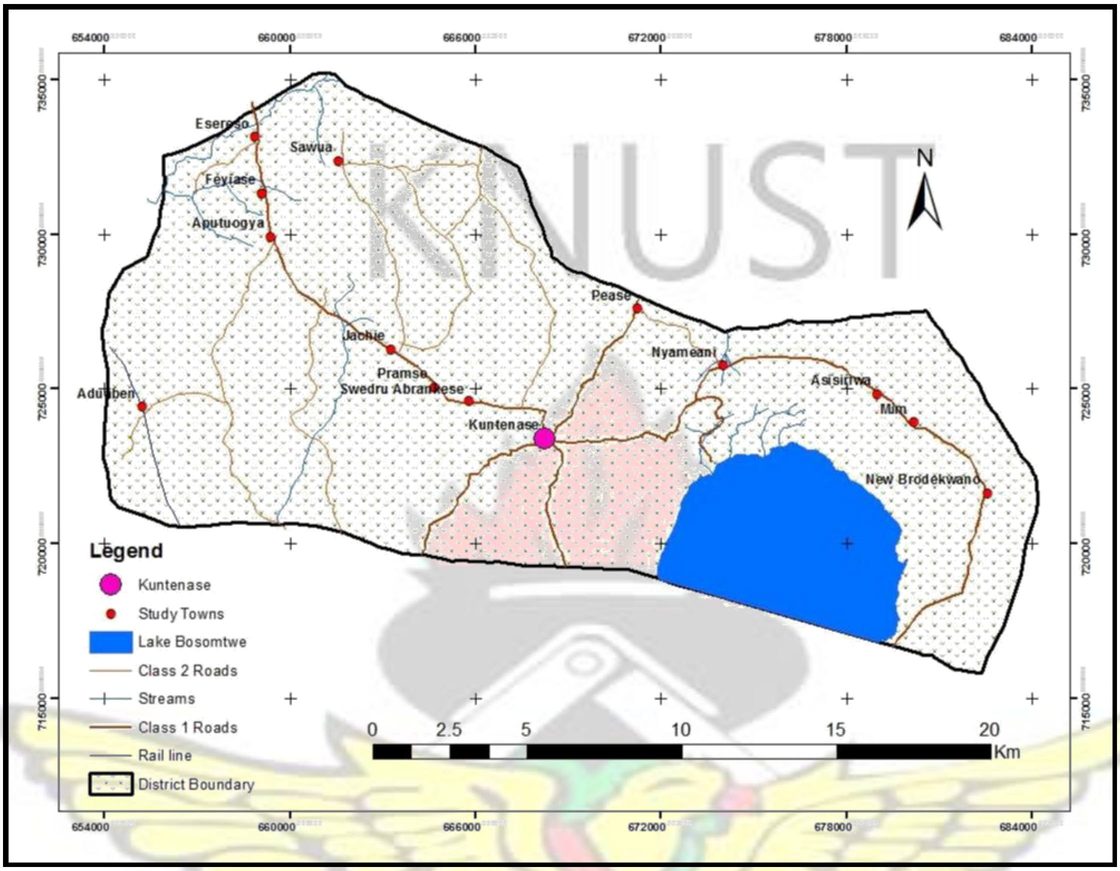


Figure 3.1 Map of the Bosomtwe District showing the study communities in Ghana

The district falls within the Moist Semi-Deciduous Forest zone where different species of tropical hard woods with high economic value can be found. Species of trees found in the district include Wawa *(Triplochiton scleroxylon),* Mahogany *(Khaya ivorensis),* and

Onyina (Ceiba pentandra), among others. In certain parts of the district, however, the original forest cover has been turned into secondary forest and grassland through indiscriminate exploitation of timber and inappropriate farming practices such as the slash and burn system and illegal gold mining activities.

The physical growth of settlements in the district is influenced by distance between the settlement and the Kumasi Metropolis. Further, the presence of infrastructure, socioeconomic activities, the tourism sector improvements are all value additions to various land uses and cover. These make the district one of the potentially boisterous in the Ashanti Region.

3.3 Land Related Practices

The topography of the district is undulating. Cultivable lands are relatively flat with the exception of areas around Lake Bosomtwe where hilly lands are found. Unauthorized lumbering activities are found in most communities. Notable among them are *Mim, Asisiriwa* and *Brodekwano*. Food and cash crop cultivation provide employment for about 53% of the inhabitants in the district (Bosomtwe District Assembly, 2010). The slash and burn land preparation is the main mode of agricultural activities undertaken by the people. Most of the inhabitants use fuel wood obtained from the forest as their main source of energy.

According to the district assembly report, there is substantial indiscriminate bush burning by farmers and other people annually. This attitude by people results in soil degradation, distribution of flora and fauna are affected. Teak trees have been cultivated in most part of the District in afforestation efforts. *Tetrefu* area, records the highest number of these afforestation efforts. There is also a Non-Governmental Organization with Agroforestry programme along the Lake Basin.

Some wildlife sanctuaries in areas of up to 12 ha and exempted from all farming activities can be located at *Jachie* and *Behenase*. Some inhabitants also depend on sand mining and stone quarrying as source of livelihood in the district. This is quite notable among *Adagya, Sawuah, Ayuom, Tetrefu, Atobiase, Jachie, Abuontem* communities.

Lake Bosomtwe, with an area of about 4900 ha, holds prospects for the tourism industry in Ghana. There are about 24 surrounding villages by the Lake. At the moment, only one settlement *Abono*, a fishing community with a population of about 1549, has its tourism potential relatively developed. There is good road network leading to *Abono* from Kumasi, a 30-minute drive. There is also the availability of 24-hour electricity, lake transport, telecommunication and toilet facilities.

3.4 Occupational Distribution

The major occupation in the district is agriculture that employs 62.6% of the labour force (Bosomtwe District Profile, 2010). Of this, crop farming employs 57.4% and fishing 5.2%. About 41% of those engaged in other occupation still take up agriculture as a minor occupation as indicated in Figure 3.2.

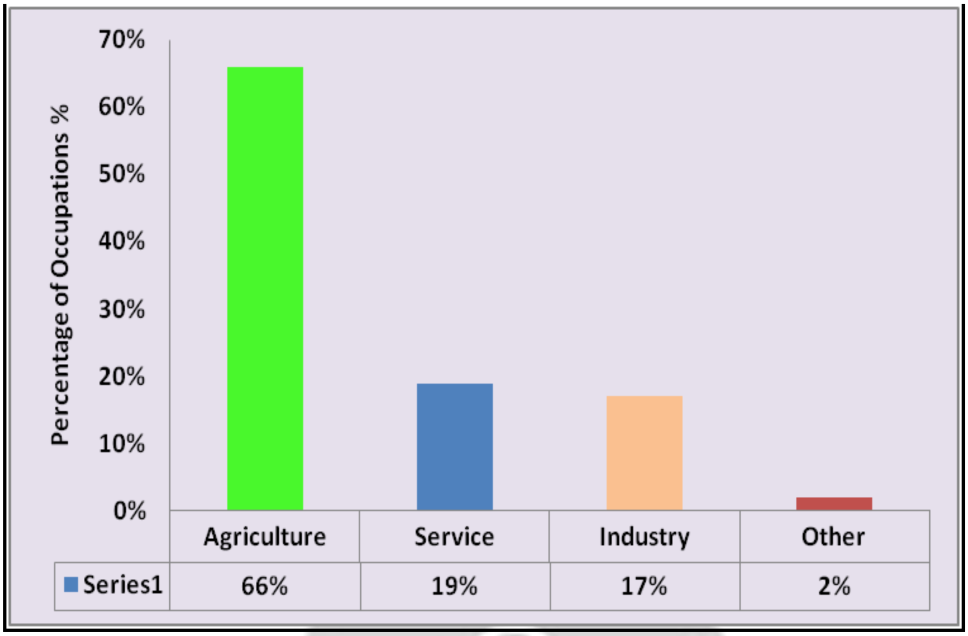


Figure 3.2: District Occupational Structure
Source: 2000 Population and Housing Report, 2005

The second highest occupation is service. It employs about 19.1% of the working population. This sector comprises government employees, private employees and other workers (Figure 3.2). The educated labour force dominates this sector. Industrial activities are undertaken in both small and medium scales. It also employs 16.7% of the working population. The problem with the industrial sector is its weak backward and forward linkages with the agricultural sector. Most of the industries are agro-based.

The average household income is Gh¢ 7.40 a month, with a per capita income of about Gh¢1.48 a month (*USD 1.00 = Gh¢ 3.70 as at 14/11/2015*). This gives an indication of the low standard of living in the district (Bosomtwe District Profile, 2010).

3.5 Materials and Methods

This sub-section enumerates the material and methods as outlined and explained in terms of, the data and procedures employed in arriving at the results generated.

3.5.1 Acquisition of Satellite Images for LULC Analysis

To do the temporal LULC change detection, Landsat satellite images obtainable from the United State Geological Survey (USGS) at their earth explorer website, were classified and analyzed. The Landsat images obtained for the purpose of the study were images with Path 194 and Roll 55 (P195R55), for Landsat Thematic Mapper (TM) 1986, Landsat Enhanced Thematic Mapper (ETM) 2002, Landsat Thematic Mapper plus (ETM+) 2007 and 2008, Landsat Thematic Mapper plus (ETM+) 2010 and Landsat 8 Operational Land Image and Thermal Infrared Sensor (OLI/TIRS) image for 2014 (Table 3.1).

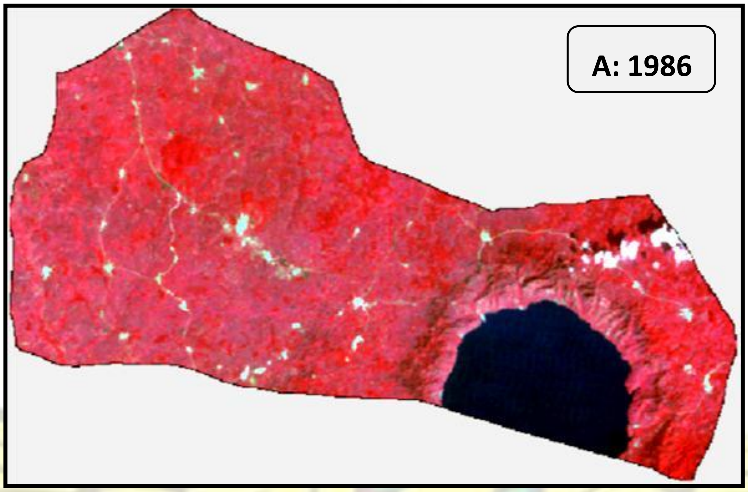
Table 3.1: The Meta data on the satellite images acquired

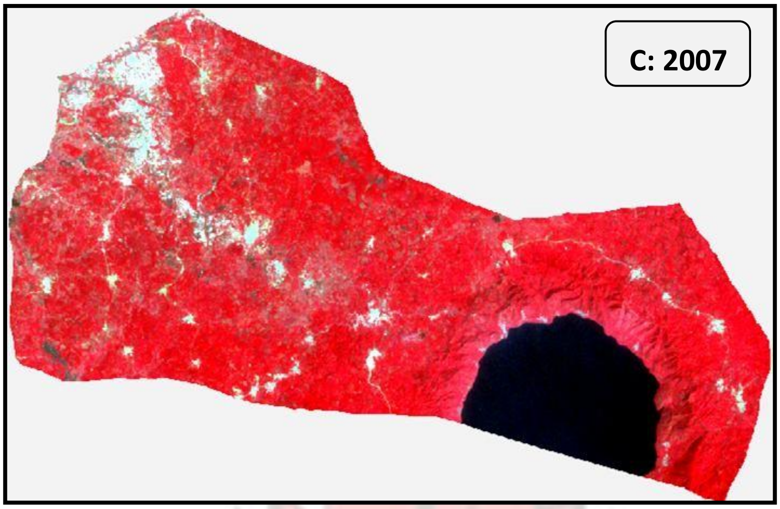
Year	Satellite Sensor	Date acquired	No. of bands
1986	Landsat TM	29th of December	7
2002	Landsat ETM	7th of May	8
2007	Landsat ETM+	16th of February	8
2008*	Landsat ETM+	1st of February	8
2010	Landsat ETM+	6th of February	8
2014	Landsat OLI/TIS	8th of January	11

** Images used to extract land surface Temperature in place of 2007 which had no Meta data in image header file*

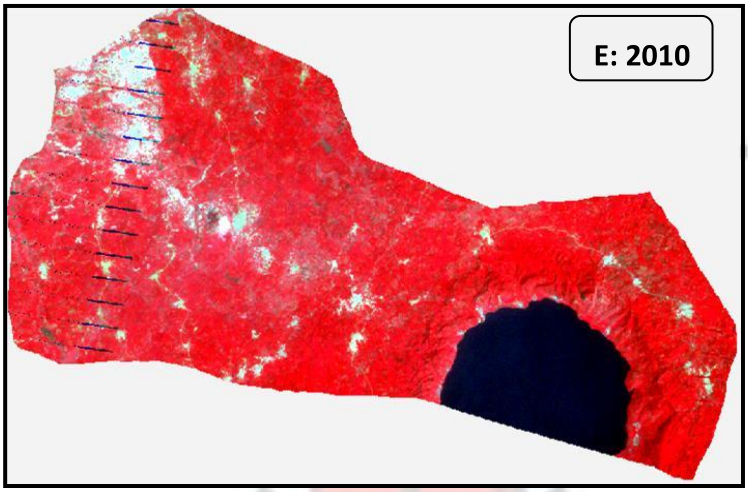
These images have similar spatial and spectral resolution, which is 30m x 30m.

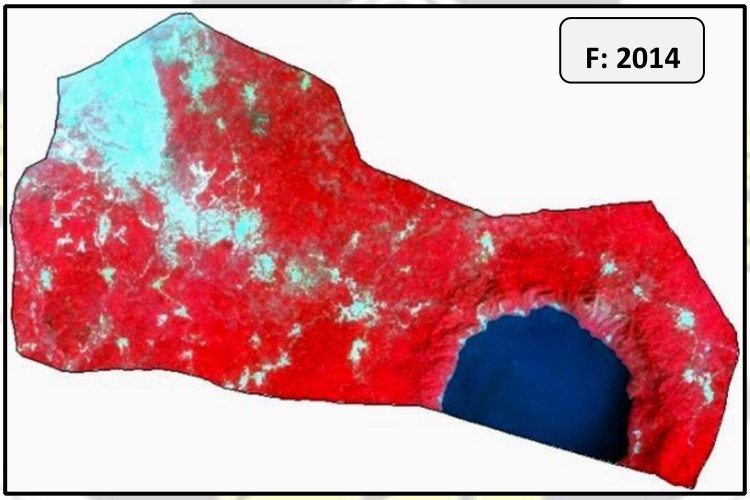
Therefore, they were used to define the study for different purposes. The 1986, 2002, 2007, 2010 and 2014 were used for LULC classification. In addition to these 5 images, 2008 image was used for the land surface temperature extraction.




C: 2007


D: 2008





Figures 3.3 (`A-F): The Landsat ETM/ETM+ Satellite Images for 1986, 2002, 2007, 2008, 2010 and OLI/TIS Image of 2014 respectively, used in the classification of the LULC types.

3.5.2 Other Materials Used

Survey instruments (pre-coded questionnaires and interview guide) were designed to collect the socioeconomic data. Topographical maps of 1:50,000 were combined as aid to select the 14 study locations in the district. This also facilitated the field global position system (GPS) survey.

A map of the Bosomtwe district at a scale of 1:75,000 was scanned and georeferenced to aid in the extraction of the district boundary. High resolution Google image and street maps were also used as the base maps to facilitate the map projection.

The Garmin GPS receiver was also used to collect 58 ground control points (GCPs) of the intended land use classes; the GPS instrument's accuracy was at ±3m. The coordinates of the 14 communities studied were picked to aid in the generation of the maps. These measurements were taken and used for ground in situ verification (ground truthing) for the image classification accuracy assessment.

3.6 Socioeconomic Survey Method

This sub-section outlines the socioeconomic sensing (survey) methods used. These included the research and sampling design, as well as the research process and instruments used in collecting the socioeconomic data.

3.6.1 The Research Design

A cross-sectional mixed method approach, which used a triangulation of the quantitative and qualitative empirical field (primary) and secondary data collection, was done. This was supported by a thorough evidenced-based synthesis of relevant literature (Schreiber and Stern, 2005) on the subject matter under investigation.

The Climatic data (Rainfall and Minimum and Maximum Temperature) as the secondary data were obtained from the Meteorological Services Agency (MSA) of Ghana. Additional data on the district layout and land use scheme was obtained from the Town and Country Planning Department of the Bosomtwe District Assembly (BDA). A socioeconomic sensing (survey) of 14 selected community clusters into rural and peri-urban, were also conducted using questionnaire administration and in depth interviews.

The main issues addressed in the survey included; the demographic characteristics of respondents, the factors that determine peri-urbanization, the factors that drive periurban LULC changes and the perceptions of respondents communities to the trend of agriculture and forest land use and cover (AFLUC) changes, as well as respondents perception of the effects of the LULC changes on the local climate variability and climate change in the district.

3.6.2 Sampling Technique

Socioeconomic data on the drivers and observed effects of LULC changes in the district were surveyed. From a population of 93,910 according to the Ghana Statistical Service (GSS) Population and Housing Census (PHC) of 2010 (GSS, 2014), a multi-stage sampling technique was adopted. This is because of the various levels at which the data needed to be collected. In all, fourteen (14) peri-urban and rural communities were selected from a total of 65 predominantly rural communities. The 14 communities met the definition criterion of population and infrastructure, as determined by the District's Scalogram.

However, because the focus and scope of the study is on peri-urban areas, 9 peri-urban communities and 5 rural communities were stratified on the basis of their respective population. A proportionate sampling method, according to the respective community populations, was used to allocate the sample proportions among the 14 communities.
This was done using the Bosomtwe district‘s Scalogram; which is the detailed district socio-demographic and infrastructural profile of each community in the district. The sample frame of the study was based on the heads of households and their respective occupations as farmers and other occupations as well as their access, ownership and use of land.

The sample frame was disaggregated by gender, before a simple random sample of households was undertaken in each of the identified communities, without return to the same household, to select 270 households for the survey. In situations of multiple households in a house, all households were interviewed using the researcher administered questionnaires, by five trained research assistants. The communities selected as peri-urban settlements were surveyed as displayed in Table 3.2.

3.6.3 Sample Size

The respondents were household heads from fourteen selected communities, namely; *Aduaden, Aputuogya, Asisiriwa, Esereso, Feyiase, Jachie, Kuntenase, Mim, New Brodekwano, Nyameani, Piase, Pramso, Sewua,* and *Swedru (Abrankese).* The sample size was determined using the formula; $n = N/ 1+N (e)^2$ where, n is the sample size. N is the total number of people in the twelve selected communities and e is the margin of error (Gomez and Jones, 2010). This formula was used because of the fact that the sample size determined falls within the expected sample sizes as stipulated by the formula.

With a 5% margin of error (95% confidence level), from a total population of 45,525 the sample size was 270. The respective samples 'p' allocation by quota to the selected communities were then determined by the proportionate sampling method given by equation 3.1:

$$p = \left(\frac{p}{100}\right) x270 \qquad 3.1$$

3.6.4 Survey Instrument used

The survey instrument used was a-270 structured partially pre-coded questionnaires (Appendix 1) that were administered in the 14 communities. The essence was to gather data on respondents' socio-demographic characteristics, their major and minor occupations, the causes and effects of peri-urbanization of the district, drivers of peri-urban LULC dynamics, as well as the perceived implication of the LULC change dynamics on the local climate variability and climate change. Also, explored was how respondents perceive the extent to which the changing local climate variability and climate change has influenced their land use activities, especially agriculture and forest land uses in the district.

Table 3.2: List of Communities Surveyed

SN	Community	Population (p)	Sample Prop. (p)	Sample Size (n)	Status
1	Aduadem	2047	4	12	Rural
2	Aputuogya	1431	3	8	Peri-urban
3	Asiriwa	2145	5	13	Rural
4	Esereso	6358	14	38	Peri-urban
5	Feyiase	2404	5	14	Peri-urban
6	Jachie	9201	20	55	Peri-urban
7	Kuntenase	3947	9	23	Peri-urban
8	Mim	1869	4	11	Rural
9	New Brodekwano	2715	6	16	Rural
10	Nyameani	2625	6	16	Rural
11	Piase	2681	6	16	Peri-urban

12	Pramso	3127	7	19	Peri-urban
13	Sewua	2986	7	18	Peri-urban
14	Swedru (Abrankese)	1945	4	12	Peri-urban
	Total		**100**	**N= 270**	

Source: Author's Construct from Bosomtwe District Assembly Scalogram, 2010

3.6.4.1 Focus Group Discussions and Key Informant Interview

Key informant interviews were conducted among some selected key personalities and tape-copied with consent from the respondents. These were the district assembly officials Town and Country Planning Department (TCPD) the District Forest Officer (DFO) and the district official of the Office of the Stool Lands (OSL).

In all three focus group discussions (FGDs) involving farmer-headed households, land owners, and women group were also performed. The limitation to three groups' performances was that the respondents/discussants from the other communities had homogenous characteristics and were likely to offer possible similar-to-same responses to the questions raised and discussed during the interactions.

3.7 Data Analysis and Results Presentation

The collected data were cleaned and keyed into the Statistical Package for Social Scientist (SPSS v. 17) for Windows application interface, for the analysis and generation of results. Descriptive and inferential statistics were employed, using the analytical tools such as frequency, cross-tabulation, Chi-square, Cramer's V statistic as well as logistic and simple regression analysis, embedded in the (SPSS), to analyze the socio-economic data.

The results of the analyzed data were presented in the form of tables, graphs and charts prepared in Excel for Windows 10. The qualitative data was analyzed thematically and used as direct quotations and to inform and buttress the discussions in some aspects of the quantitative results. The flow of the socio-economic method is presented in Figure 3.4.

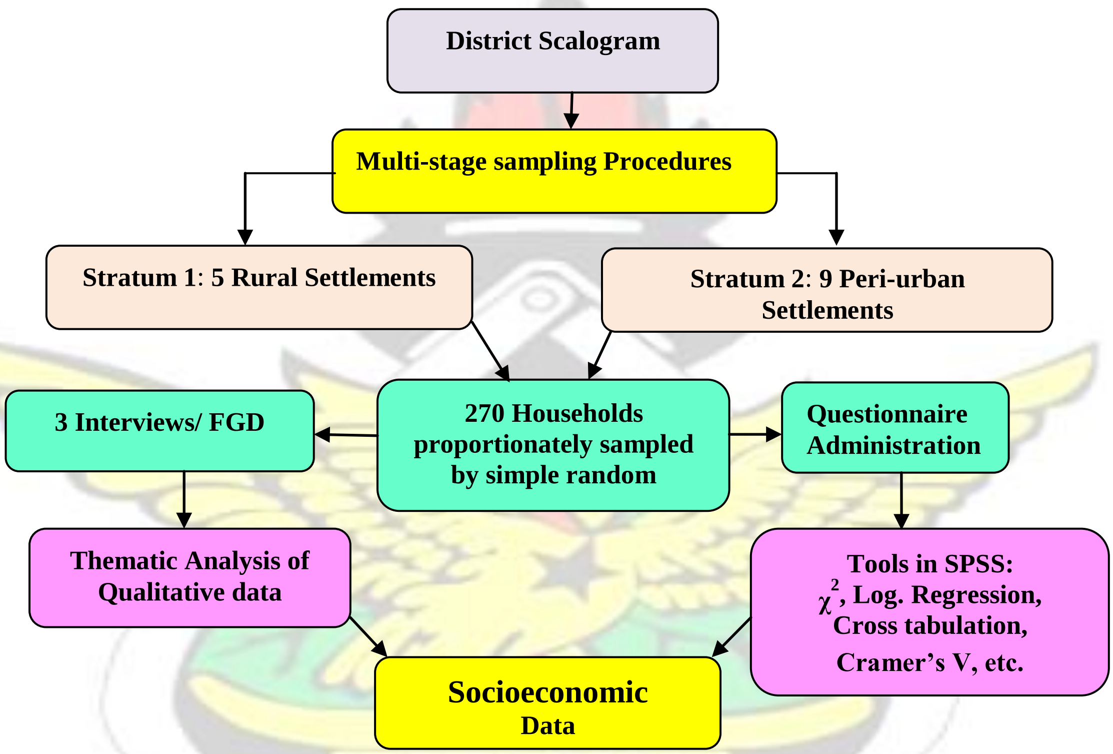


Figure 3.4: the flow chart of the sequence of socioeconomic survey methods

3.8 Spatial Modelling Tools and Data Analysis

This subsection details the spatial analytic methods and procedures used in the analysis of the satellite images and the generation of the results for the various LULC maps.

3.8.1 Spatial Analytical Methods

Landsat TM, ETM/ETM+ and OLI/TIS satellite images as mentioned in Table 3.1, were acquired for image classification. The coordinates of the 14 communities studied were picked to aid in the generation of the maps. The results were used to calculate and ascertain the changing rates as well as the LULC transitions of the various land uses, particularly the rates of vegetation reductions from conversions and residential build up/bare/ concreted areas expansion.

The results were exported to Environmental Science Research Institute (ESRI) ArcGIS environment for modelling and further analysis, to generate interactive maps. This is because remote sensing and geographic information system (RS/GIS) hold much prospect for analyzing the geo-spatial environments with a higher degree of accuracy and clarity (Ramachandran, 2010).

3.8.1.1 Building and Creation of Geo-database for ArcMap Applications

The base map obtained from the Bosomtwe district assembly was scanned and georeferenced by identifying some control points as reference on the map. The root mean square error (RMSE) using the 1st order polynomial method from 6 collinear points was 1.15m. This was performed to the highest accuracy considering the level of distortions arising from the scanning of the district map.

The file geo-database for the project was created in ArcCatalog. The various feature classes needed for the project were created in the file geo-database and geo-referenced with respect to the WGS_1984 and projected using the Universal Transversal Mercator projection, Zone 30 North. The feature classes (FCs) created were: the District boundary polygon, Roads and railroad polylines, the Lake Bosomtwe polygon, the Stream polylines and the Towns point feature classes.

The various FCs were digitized out from the district map and compared with the 2014 Landsat satellite image for conformity. This was to validate the accuracy of the georeferenced map. These FCs were the layers used in the creation of the digital final map of the Bosomtwe district.

3.8.1.2 Satellite Image Sub-setting for LULC Classification

Due to the large image scene, and the irrelevance of other land use classes obtained from the entire classification of one of the entire image scene of Path 194 and Roll 55 of the Landsat images, a sub-setting of the image was performed in Hexagon Geospatial ERDAS Imagine 13 Software. This was done using the map created as the area of interest (AOI). The subset images for the various time series (1986, 2002, 2007/2008, 2010 and 2014), were layer-stacked and saved as files, in the TIF-format. These were classified in turns. The unequal intervals of the images were justified by the absence of quality images with equal intervals.

The Landsat satellite images obtained have been preprocessed from source; therefore there were little geometric and radiometric calibrations done on the images. However, a validation of the images was done using high resolution Google earth image as reference. The images were loaded and layer-stacked in the Software for their display in their various RGB guns in their false-colour and true-colour composite combinations.

3.8.2 Test Classification

A hybrid of both supervised and unsupervised classifications methods were applied on the images. This was because the land use classes from the images were not easily deciphered without an unsupervised classification. To do the classification, the images were first classified using the Software-classified method, also known as unsupervised classification (USC), using K-means. The unsupervised classified images were compared and visualized with the original satellite images. This aided in the training of the pixels in the supervised classification (SC) methods using the maximum likelihood classifier (MLC). This was performed after the assumption of image normality has been established.

3.8.3 Selection of Class Spectral Signatures

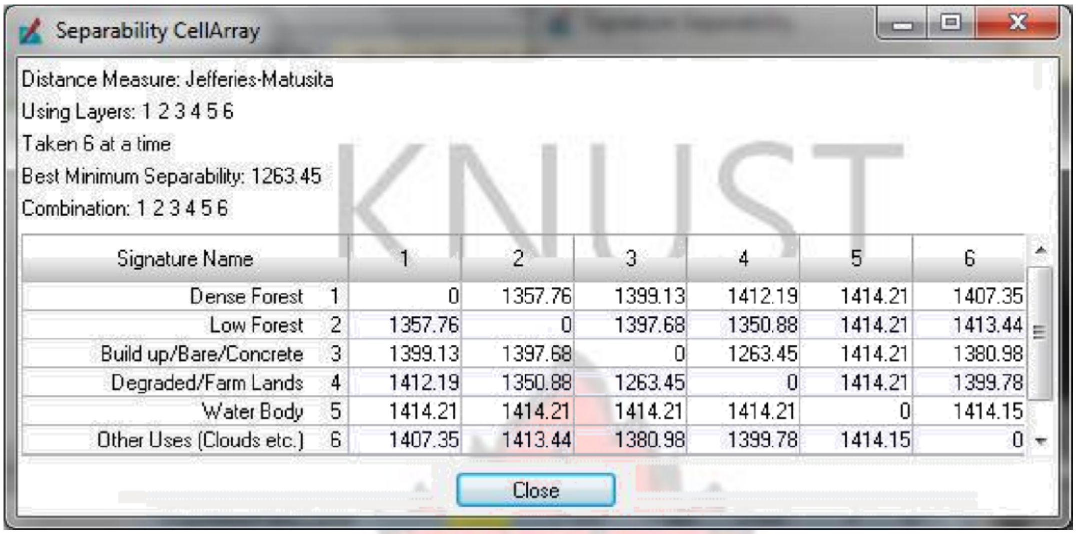
Based on the field experience and familiarity of the study area as well as the spectral characteristics of the images, the land use and cover classes identified were; Dense Forest (DF), Low Forest (LF), Build up/Bare land/Concrete (BBC), Recent Fallows and Grasslands (RFGL), Water Body (WB) and others such as Cloud cover and shadows etc. These land use classes are explained in Table 3.3 and supported by which are the band separability ratios and signature plots Figures (3.5 & 3.6).

Table 3.3: LULC Classification Scheme

LULC Classes	Descriptions of LULC Classes
Dense Forest (DF)	Deciduous and semi-deciduous forest tree cover with closed canopies typical of the tropical rainforest biome. Mostly restricted to the upper elevations of mountains ranges of the area including along the rims of Lake Bosomtwe.
Low Forest (LF)	Vegetative communities dominated by evergreen trees, with open canopies, with mean heights usually between 6 and 15 m. Also included in this class is the plantation agriculture such as oil palm and citrus.
Built Up/Bare Land/Concrete (BBC)	This is a land-use dominated by urban, peri-urban to rural settlements including bare, tarred and un-tarred roads as well as other concrete surfaces.
Recent Fallows/Grasslands (RFGL)	Actively cultivated and recent fallow lands and prepared lands for cultivation. Vegetative communities dominated by perennial and annual grasses with occasional herbaceous species presence.
Water Body (WB)	The only water body classified is the Part of the lake Bosomtwe which falls in the study area.
Others	These refer to the other uses identified as image noise such as cloud cover and shadows.

Adapted from Kepner *et al.*, 2000.

The various identified LULC classes as identified, were trained from the images, using the signature editor under supervised classification functionality. Best Minimum Separability of Jefferies-Matusita = 1263.45 out of the maximum of 1414.21.



Separability CellArray

Distance Measure: Jefferies-Matusita
Using Layers: 1 2 3 4 5 6
Taken 6 at a time
Best Minimum Separability: 1263.45
Combination: 1 2 3 4 5 6

Signature Name		1	2	3	4	5	6
Dense Forest	1	0	1357.76	1399.13	1412.19	1414.21	1407.35
Low Forest	2	1357.76	0	1397.68	1350.88	1414.21	1413.44
Build up/Bare/Concrete	3	1399.13	1397.68	0	1263.45	1414.21	1380.98
Degraded/Farm Lands	4	1412.19	1350.88	1263.45	0	1414.21	1399.78
Water Body	5	1414.21	1414.21	1414.21	1414.21	0	1414.15
Other Uses (Clouds etc.)	6	1407.35	1413.44	1380.98	1399.78	1414.15	0

Close

Figure 3.5: Example of *Jeffries-Matusita* Distance measurement of class separation

Using the results from the unsupervised classified images and also informed by the familiarity of the study district and the ground truth LULC sampled during the field survey, a visual inspection of the images were made. This was to identify the possible land use types as depicted in the images; in order to facilitate in as much precise as possible, identify the appropriate spectral signatures corresponding to the various land uses classes during the supervised classification method. The pixel-based maximum likelihood (MLC) classification of the satellite images were performed on the five images 1986, 2002, 2007, 2010 and 2014 into five main trained classes (Table 3.3).

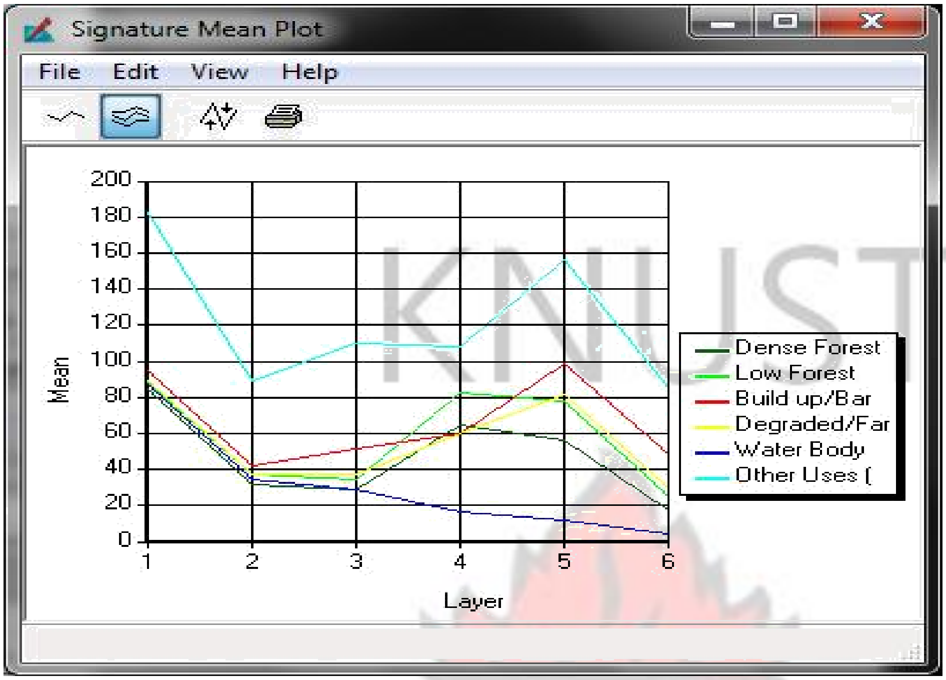


Figure 3.6: Example Bands Separability by signature mean plots

3.9 LULC Classes Separability

In this subsection, the study analyzes the spectral signature using the Jeffries-Matusita distance analysis and the classification accuracy assessment using Kappa Statistics algorithms in ERDAS Software.

3.9.1 Jeffries-Matusita Distance Separability and Kappa Statistic Accuracy Assessment

A spectral separability was also done to ascertain the degree of separation of each of the six (one, two, three, four, five and seven) bands from the other. This was also to appreciate the relative separability performance of each band according to the land use classes and to show the performance of the user in assigning certain pixel to a LULC class. The separability criteria were assessed using *Jeffries-Matusita index* and compared with the divergent index (Foody, 2004). In combination with the Kappa classification accuracy assessment, the quality of the results was checked. As reported in the appropriate sections, the results accuracy ranged from moderate to almost perfect agreement.

3.9.1.1 Spectral Separabilty

The separability listing contains the average divergence and the minimum divergence for the band set. These numbers can be compared to other separability listing (for other band combinations), to determine which set of bands is the most useful for training and classification.

The *Jeffries-Matusita* distance has upper and lower bounds (JM is between zero and 1414). If the calculated divergence is equal to the appropriate upper bound, then the signatures can be said to be totally separable in the bands being studied. A calculated divergence of zero means that the signatures are inseparable. That is, the *JM* values that ERDAS Imagine reports are those resulting from multiplying the values in the formula times 1000. A separability listing is a report of the computed divergence for every class pair and one band combination (Figures 3.6). The Jeffries-Matusita Distance (*JMD*) algorithms (3.2 and 3.3) are follows:

$$JM_{ij} = \sqrt{2\left(1 - e^{-\alpha}\right)} \qquad 3.2$$

$$\alpha = \frac{1}{8}\left(\mu_i - \mu_j\right)^T \left(\frac{C_i + C_j}{2}\right)^{-1}\left(\mu_i - \mu_j\right) + \frac{1}{2}\ln\left(\frac{\left|\left(C_i + C_j\right)/2\right|}{\sqrt{\left|C_i\right| \times \left|C_j\right|}}\right) \qquad 3.3$$

Where; *i* and *j* are two signatures (classes) being compared; *C*i is the covariance matrix of signature *i; μ*i is the mean vector of signature *i; ln* is the natural logarithm function; |*C*i| is the determinant of *C*i (matrix algebra).

3.10 The LULC Classification Procedure

The images were then classified using the unsupervised and supervised classification in K-means and maximum likelihood algorithms respectively, in the Software at 0.95 probabilities for class accuracy for the image. The two images were compared and the best approach was identified as the supervised classification, after fulfilling the assumption of image normality.

3.10.1 Kappa Classification Accuracy Assessment

Classification of LULCs in remote sensing Software, requires the user to ground truth the results through accuracy assessment (Foody, 2002). The classification accuracy of the maximum likelihood method used was ascertained in the ERDAS Imagine Software. Ideally, the accuracy of the classification should be assessed by juxtaposing an already existing LULC map or an aerial photograph showing the LULC classes of the area so classified.

Since there has not been any comprehensive study of the LULC classification for the Bosomtwe district, there were none of the accuracy assessment check list data in the form of previous land use map or aerial photographs. The Garmin GPS receiver was used to pick some 58 coordinates of selected land use land covers as ground control points from the field. The locations of these reference data were determined at random by identifying and locating the land use classes of interest in the field and their GPS points and coordinates picked at ±3m accuracy and recorded.

The field surveys were conducted in early part of February 2013. For the earlier years such as 1986 and 2002 images, Google Earth maps were used to select the coordinates of some land uses as GCPs, as well as from expert knowledge of the study district, for the images' classification accuracy assessment.

3.11 LULC Change Detection and Transition Analyses

The LULC classes were assigned with the help of the classifier based on the user defined classification schema (Kepner *et al*., 200). This scheme was based on the visual interpretation of the images coupled with the researcher‘s familiarity of the study area. In view of the relatively low spatial resolution of 30m × 30m, some of the classes were combined for interpretation convenience, e.g. Built-up/Bare lands/Concretes. The scheme adopted is, described in Table 3.3. This scheme formed the basis for the creation of the training areas which also contained the sampled LULC types from the field as GCPs in the image for the picking up of spectral signatures for the various LULC classes.

The classification algorithm used in the ERDAS Imagine Software was supervised maximum likelihood classifier (MLC). Image differencing was performed in ArcGIS to ascertain the levels of change from one land use type to the other and by how much in terms of area in hectare. The rate of change (r) was calculated using equation 3.4:

$$r = \left(\left(\frac{A_2}{A_1} \right)^{1/t} - 1 \right) \qquad 3.4$$

where, $A1$, $A2$, and t are the LULC map of previous year, the current year and the time in years as duration between the two years respectively (Gambarova *et al*., 2013).

3.11.1 LULC Change Transition

The analysis of the results from the image years between 1986 and 2002 and 2002 and 2007, LULC types were cross-tabulated for their transitional matrix showing that the land use classes transited from one type to another according to some degree of proportions. The Markov transition matrix approach was used to determine the transition rates from one land use type to another under certain intrinsic conditions. This was executed in ArcGIS *cross-tabulation* tool functionality.

This is because land use transitions follow rules that determine the change of a cell's state during a subsequent iteration, according to Samat *et al.* (2011). These have cellular automata (CA) tendencies, which are based on the cell conversion probability, also called the likely rate of transition from one cell state $S_{i,j}$ to another after a time *t*. These five land use classes represent main land use activities in the district as per the classification. The transition of cells from time *t* to *t+1* is determined by a function of its state, cell suitability and its transition probability rule.

This is given by equation 3.5 below:

$$LU^{t+1}_{i,j} = f\left(LU^{t}_{i,j} \times S^{t}_{i,j} \times P^{t}_{x,y;i,j}\right) \quad 3.5$$

where,

$LU^{t+1}_{i,j}$ = the potential of cell i,j to change at time t+1,

$LU^{t}_{i,j}$ = current land use type of cell i,j at time t,

$S^{t}_{i,j}$ = states of cell i,j at time t,

$P^{t}_{x,y,i,j}$ = probability of cell i,j to change from state x to state y at time t+1.

The diagonals of the matrix, indicate for instance, the land use types in area that remained unchanged over the time period (Al-Bakri *et al.*, 2013; Mackenzie, 2009).

3.11.2 Normalized Difference Vegetation Index

The NDVI was calculated in ArcMap, using the raster calculator algorithm embedded in the Software. The NDVI is calculated by determining the ratio of the differences between the NIR and the R bands to the sum of the NIR and the R bands. This is done to normalize and transform the otherwise simplified NIR/R ratio (Zhang *et al*., 2011). The mathematical representation of the index is equation 3.6:

$$NDVI = \frac{\rho_{NIR} - \rho_{R}}{\rho_{NIR} + \rho_{R}} \qquad 3.6$$

Where, ρ is the reflectance values in the indicated spectral bands, *NIR* and *R*, the near infrared band and the visible red band respectively. Theoretically, NDVI values are represented as a ratio ranging in value from -1.0 to +1.0 but in practice, negative values near -1 could represent water, values around zero represent bare soil and values above 0.6 represent dense green vegetation (Ghorbani *et al*., 2012).

The images generated were exported from ENVI to ArcMap for further value range classification and final generation of the various NDVI maps. The geoinformation processes are presented in the flow chart of Figure 3.7.

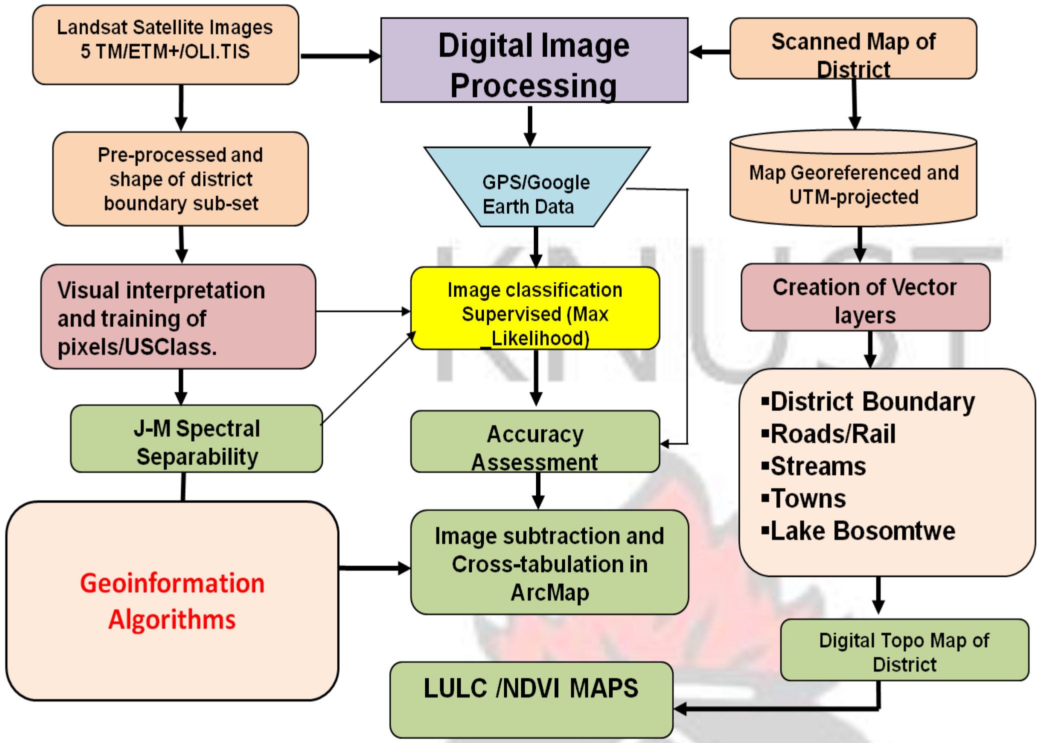


Figure 3.7: Methodological work flow in ERDAS Imagine and ArcGIS

3.12 Analysis of Climatic Data

Climatic data on rainfall, temperature and evapotranspiration were obtained from the Bekwai synoptic weather station of the Meteorological Services Agency (MSA) of Ghana. Data on the above climatic variables spanning from 1982 to 2011 were obtained for the analysis.

Temperature data was analyzed as proxy to climate change for the district.

To couple LULC dynamics with climate variability and possible climate change, the original intent was to downscale a Regional Climate Models (RCM) developed over Ghana, and compared with the climatic data that were collected and to make projections. However, considering the spatial resolution of the study area, in comparison to the regional climate model, the results would have been unrealistic and insignificant for any meaningful projection. This is

2 because, with the 330 km area of the district as against the coarse resolution of any RCM, it would be difficult to project any impact of LULC changes in the district on the local climate to any appreciable accuracy.

Therefore, proxies of variability and change were analyzed from the meteorological data. This was done by correlating land surface temperature with the meteorological data collected. This was also to re-direct the nexus between climate change and land use for the Bosomtwe district from the impacts of land use on climate variability to how climate variability and climate change has influenced the LULC activities in the district. In arriving at the results, the classical additive methods of analyzing trend as well as the Mann-Kendall test or trends were used on the temperature and the rainfall data, using the MAKESEN V.1.0.2, an open source Solver in EXCEL.

3.12.1 Data Validation and Analysis

Mean monthly temperature data spanning a period of 31 years were collected from the Ghana meteorological Agency (GMA) synoptic station located at Bekwae, about 25 Km from the Bosomtwe District. Being the only synoptic station closer to the district, it was imperative to satisfy the maximum radial distance threshold of the world Meteorological acceptable distance for weather stations located in African. Accordingly, the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC), the United Nations Environment Programme (UNEP), and the International Council for Science (ICSU) stipulate that stations classified as functional must meet all target requirements acceptable. This is, the data must be located within a distance of at most 60 to 90 km from the nearest reference station (WMO/IOC/UNEP/ICSU 2010), before accepted as usable.

3.12.2 Time Serial Analysis of Temperature

The data were subjected to statistical analysis such as mean standard deviation and test for normality among others to ensure that the data meets the necessary accuracy and utility standards before the main analysis. The data were then input into the Microsoft Excel software V. 2010 in a spreadsheet for the time series analysis. This was based on the simple classical multiplicative time series analysis given by the formula $Y_t = S_t \times I_t \times T$. Where, S_t I_t and T are the seasonality, irregularity and trend components respectively. A logarithmic transformation can be taken on the both side $Log(Y_t) = Log(S_t \times I_t \times T)$, to transform the data into additive time series (Gillian *et al*. 2006).

To determine the seasonality and irregularity (cyclical and residual) components of the data, a 3year moving average (MA_3) was generated. The actual time series data for the 31-year period (Y_t), was used to generate the seasonality and irregularity components by dividing the Y_t by the moving average (MA_3) (Appiah and Boafo, 2014c). The seasonality component (St) only, was determined by standard deviation the 3-year moving averages from the Seasonality and irregularity component. The seasonality data was de-seasonalized (Ds) by dividing the time series (Y_t) by the seasonality component (S_t).

To determine the trend component of the data, a simple linear regression (SLR) was run, using the de-seasonalized data as the response (Y) and the t, values (t = 1,...t = 31) as the independent (X) variables respectively. The expected equation, which yielded the trend component, is the traditional $y = a + bx$, where a, is the intercept on the y-axis and b, is the slope; known as the linear regression (best fit) equation. Finally the forecast (F) data were calculated by the product of the seasonal component (S_t) and the trend component (T_t). The graphs were the result plots generated in Microsoft Excel V. 2010. The summary of operations (eqn. 3.7) done to arrive at the result plots are as follows;

$$MA_3 = \frac{1}{3}\left(Y_{t-1} + Y_t + Y_{t+1}\right); \; S_tI_t = Y_t / MA_3; \; Ds = Y_t / S_t; \; T_t = a + bx; \; F = S_t * T_t \qquad 3.7$$

3.12.3 Mann-Kendall analysis of trend in Rainfall data

The Mann-Kendall statistical test is a method used to ascertain whether or not there is a trend in a certain time series data. The data values are evaluated as an ordered time series. Each data value is compared to all subsequent data values. The initial value of the Mann-Kendall statistic, S, is assumed to be 0 (for example, no trend). As a non-parametric test, the Mann-Kendall S tests the data randomness against time.

Let $X_1, X_2, \ldots, X_n$ be a sequence of measurements over a period of time, Mann proposed to test the null hypothesis, H_0, that the data come from a population where the random variables are independent and identically distributed; and therefore having no trend. The alternative hypothesis, H_1, is that the data follow a monotonic trend over time. Under H_0, the Mann–

Kendall test statistic is: under the hypothesis of independent and randomly distributed random variables, when $n \geq 18$, the S statistic is approximately normally distributed, with zero mean and variance in equation 3.8—3.11 as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}\left(X_j - X_i\right) \qquad 3.8$$

$$(-1 \ldots\ldots +1)$$

Where $$Sgn(\theta) = \begin{cases} 1 & \text{if } \theta > 0 \\ 0 & \text{if } \theta = 0 \\ -1 & \text{if } \theta < 0 \end{cases} \qquad 3.9$$

$$\sigma^2 = \frac{n(n-1)(2n+5)}{18} \qquad 3.10$$

In this regard, the standardized *Z* statistics follow a normal standardized distribution as follows:

$$Z = \begin{cases} \frac{S-1}{\sigma} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sigma} & if\ S < 0 \end{cases} \qquad 3.11$$

The hypothesis that there is no trend is rejected when the *Z* value computed by Equation (3.9) is greater in absolute value than the critical value $Z\alpha$, at a chosen level of significance α.

3.12.4 Sen's Slope estimate

The method of calculating the Sen's slope estimator used a time series of equally spaced data. Sen's method proceeds by calculating the slope as a change in measurement per change in time, as shown here in equation (3.12):

$$Q = \frac{X_j - X_i}{j - i} \qquad 3.12$$

Where: Q = slope between data points X_j and X_i X_j = data measurement at time j

X_i = data measurement at time i, j = time after time i,

X_j and X_i constitute the pairs of observations identified by place in the series. The median of these estimates is Sen's estimator of slope

3.13 Land surface temperature extractions

The subsection performs the extraction of land surface reflectance signatures as proxies of surface temperature extracts for local surface warming and cooling estimation.

3.13.1 Procedural Algorithms of LST Extraction from Satellite Images

The most suitable procedure used to retrieve LST from a single-channel located in the thermal infrared region, as is the case of the Landsat thermal band, is by the inversion of the radiative transfer equation (RTE) (Cristóbal, *et al*., 2009) based on the following expression applied to a certain sensor channel (or wavelength interval):

$$L_{sensor,\lambda} = \left[\varepsilon B_{\lambda}(T_s) + (1-\varepsilon) L\downarrow_{atm,\lambda}\right]\tau + L\uparrow_{atm,\lambda} \qquad 3.13$$

Where, L_{sensor} is the at-sensor radiance or Top of Atmospheric (TOA) radiance, i.e., the radiance measured by the sensor, $\boldsymbol{\varepsilon}$ is the land surface emissivity, $B_{\lambda}(Ts)$ is the blackbody radiance given by the Planck's law and Ts is the LST, $L\downarrow_{atm,\lambda}$ is the downwelling atmospheric radiance, $\boldsymbol{\tau}$ is the total atmospheric transmissivity between the surface and the sensor and $L\uparrow_{atm,\lambda}$ is the upwelling atmospheric radiance. It should be noted that Eqn. (3.13) depends on the wavelength considered, but also on the observation angle, although for Landsat, the nadir view provides good results.

The atmospheric parameters τ, $L\downarrow_{atm,\lambda}$ and $L\uparrow_{atm,\lambda}$ can be calculated from *in situ* radiosoundings and using a radiative transfer codes like MODTRAN (Mousivand *et al.,* 2015). Therefore, from Eqn. (3.13) it is to find T_s by inversion of the Planck's law. Inversion of Eqn. (3.14) can be interpreted as a correction of the atmospheric and the emissivity effects on the data measured by the sensor. The main constraint of this approach however, is the need for *in situ* radiosounding which is launched simultaneously with the satellite passes (Cristóbal, *et al.,* 2009).

Radiances are in W m^{-2} sr^{-1} μm^{-1} and wavelength in μm; the B term is Planck's law, expressed as follows:

$$B(\lambda, T_s) = \frac{c_1 \lambda^{-5}}{\exp\left(\frac{c_2}{\lambda T_s}\right) - 1} \qquad 3.14$$

Where; c_1 and c_2 are Planck's radiation constants, with values of 1.19104 x 10^8 Wμm^4 m^{-2} sr^{-1} and 1.43877 x 10^4 µm K, respectively, while T_s and λ are the surface temperature in K and thermal bands wavelength in μm. Accordingly, it is pertinent to note that the spectral magnitudes should be integrated over a band pass (filter response function) in the case of Landsat sensor. This coheres with the work by Jiménez-Muñoz and Sobrino (2003), who used a single-channel method based on the radiative transfer equation to extract LST.

3.13.2 Spectral Radiance Scaling Method

Conversion from digital numbers to top of atmosphere (TOA) radiances was carried out using image header parameters. In this regard, the formula to convert cell value as DN to cell value as radiance CV_{R1} for the three images, utilized the formula as shown in equation 3.15 as follows:

$$CV_{R1} = \left(\frac{L\max - L\min}{QCALMax - QCAL\min}\right) X \left(QCAL - QCAL\min\right) + L\min \qquad 3.15$$

Where, CV_{R1} is the cell value as radiance; QCAL is the digital number; Lmin is the spectral radiance scales to QCALmin; Lmax is the spectral radiance scales to QCALmax; QCALmin is the minimum quantized calibrated pixel value (typically as 1); QCALmax is the maximum quantized calibrated pixel value (typically as 255).

3.13.3 Apparent Brightness Temperature

In converting the radiance to Kelvin, the formula to convert radiance to temperature *without* atmospheric correction method was used. The apparent brightness temperature or at-sensor brightness temperature (T_b), was determined by applying blackbody principles which is usually computed by means of Planck's law inversion using the Landsat image series (Coll *et al.*, 2010; Irish 2003), with the following simplified equation 3.15:

$$T_b = \frac{K_2}{\ln\left(\frac{K_1}{CV_{R1}} + 1\right)} \qquad 3.16$$

Where, ε is the emissivity (*typically 0.95, and could as well be derived from the NDVIs*). The K_1 and K_2 (K) (W m^{-2} sr^{-1} mm^{-1}), are calibration constants based on the Landsat thermal band configuration and CV_{R1} is the spectral radiance (W m^{-2} sr^{-1} mm^{-1}). In the case of Landsat 7 ETM/ETM+, K_1 and K_2 are respectively 666.09 and 1282.71. In the case of Landsat 8 OLI/TIS, K_1 and K_2 are 480.89 and 1201.14 (bands 11), respectively.

Surface emissivity was considered in the estimation of Ts for the LULC targets (Tursilowati *et al*., 2012). The land surface temperature (Ts) is estimated using the algorithm in equation 3.16.

$$T_S = \frac{T_b}{1 + \left(\lambda * \frac{T_b}{\rho}\right)\ln \varepsilon} \qquad 3.17$$

Where, Tb is the effective satellite temperature, Ts is the LST in absolute temperature in Kelvin, λ is the wavelength of the radiance emitted (λ = 11.5µm), ρ = (h × c) / σ = 1.438 $\times 10^{-2}$ (m K), h is Planck's constant (6.626 × 10^{-34} Js), c is the velocity of light (2.998 × 10^{8} m/s), σ is the Boltzmann constant (1.38 $\times 10^{-23}$ J/K), and ε is the composite emissivity. In this study, ε = 0.95 was used for the soil and vegetation (Sobrino *et al*., 2003). The operations were performed in ENVI Band Math and the ArcMap Raster calculator functions in ArcToolbox.

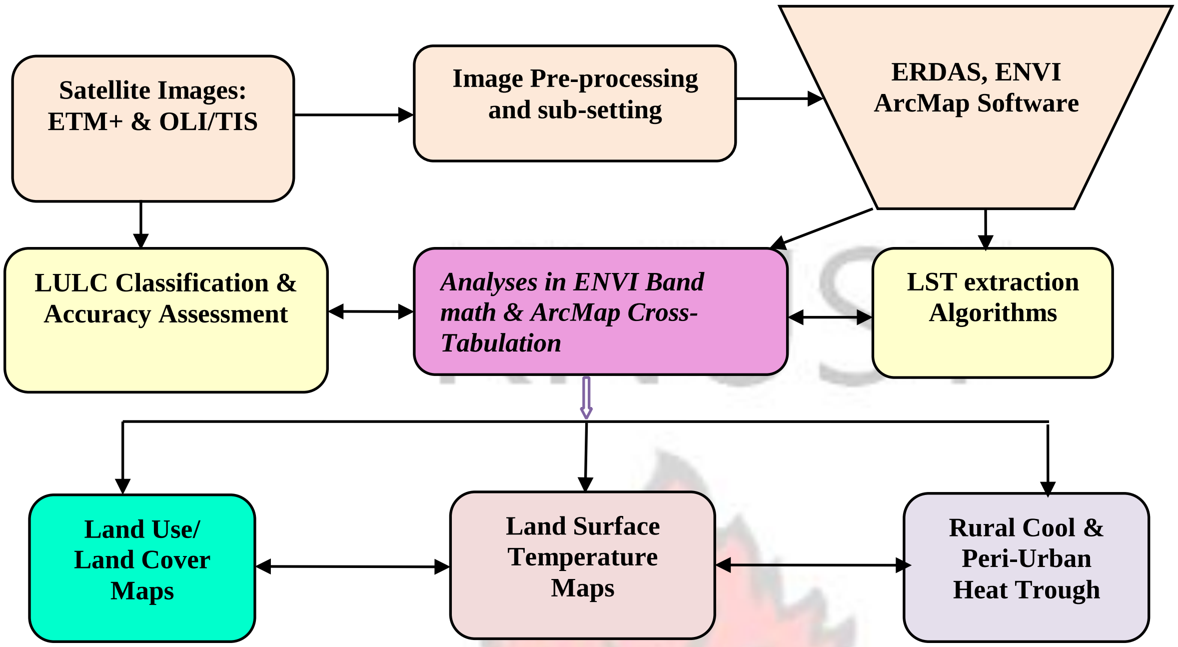


Figure 3.8: Methodological flow chart of the LULC and LST Extraction procedures

3.14 Summary of Materials and Methods

The mixed method approach involving the triangulation of quantitative and qualitative empirical field (primary) and secondary data, which included satellite images and climatic data collected from the Ghana Meteorological Services Agency (GMet). A socio-economic sensing (survey) of 14 selected communities were undertaken. The socio-economic data were analyzed using the embedded tools in the Statistical Package for Social Scientists (SPSS V. 17) for Windows applications.

The geospatial data were analyzed in ENVI 4.7, ERDAS Imagine 13 remote sensing and ArcGIS 10.2 geo-information Software (courtesy the Department of Geoinformation and Photogrammetry of the Stuttgart University of Applied Sciences, during my research visit to Germany) for spatial modelling of the LULC dynamics. These Software were also used to extract and analyze the LST characteristics, covering the study

area. The results were compared with LULC classes, air temperature and rainfall data as proxies to explain local climate variability. The climatic data were collected from the Regional Meteorological Services Agency
(MSA).

Landsat satellite images and *in situ* ground data collection using global position system (GPS) receivers were coupled to derive the desired LULC maps of interest to the study. These were done in order to input data into Geographic information system (GIS) and remote sensing environments directly, for the manipulations, analysis and display.

CHAPTER 4: SOCIOECONOMIC DRIVERS AND RESPONSES TO PERIURBAN LAND USE CHANGES

4.1 Introduction

After the theoretical bases of the study established, and the appropriate methodologies described, in the previous chapters, this chapter is dedicated to the reportage of the results, beginning with the socioeconomic data obtained from the surveys undertaken.

Peri-urban areas (PUAs) are zones between the rural and urban interface, characterized by both urban and rural morphological characteristics and activities. While the urban landscape is mostly characterized by commercial, residence, recreation, administrative and industrial land uses, the rural areas are mostly for agriculture purposes (Simon, 2008).

Although the exact definition of the peri-urban area varies from one area to another, some common ones include the peri-urban zone which is seen as a space between these two areas (rural and urban) where exchange of resources takes place (Dutta, 2012). The peri-urban zone can also be seen as transition from rural to urban. It is neither rural nor urban. It is however seen as an outcome, and to others, a process (Iaquinta, 2000). This is the operational definition this study adopted; the Bosomtwe district is an area which is neither rural nor urban.

In recent years, peri-urban lands available for agriculture in the Bosomtwe district, are relatively dwindling due to the fact that other land uses are increasingly becoming dominant relative to agriculture. In an attempt to ascertain the various drivers of peri -urban land uses and their consequential ramifications, the various views of the respondents were sought. The purpose of this data is to correlate the geo-information data that are analyzed to triangulate from both perspectives, the LULC dynamics in the Bosomtwe district.

In this regard, the analysis has been done, skewed partly in the context of the first objective and partly pulling other objectives along the discourse. This is done, when they became necessary in establishing relationships between the main drivers and decisions behind peri-urban land uses and land covers. Their inherent connotations of the proximate effects on climate variability and climate change in the Bosomtwe district are also espoused.

4.2. Results from the Socioeconomic Survey

This sub-section presents the socioeconomic results analyzed. It presents the socio-demographic characteristics of study participants and the key determinants of peri-urbanization and drivers of peri-urban LULC in the Bosomtwe District.

4.2.1 Socio-demographic Characteristics of the Respondents

A careful look at Table 4.1 (a & b) displays the various socio-demographic characteristics of the respondents surveyed during the study. In order to understand the data that emanates from household respondents, it is imperative to also understand their demographic backgrounds (Kumekpor, 2002). This would enamel the researcher to disaggregate the data along some of these variables, as well as be able to ascertain some of the reasons underpinning the response trends.

Table 4.1a: The Demographic data of Respondents

Variables	N (%)	Mean	St. dev.	p-value
Gender of respondents	*Frequency*			
Male	139 (51.5)	*1.4852*	*.5007*	*.058*
Female	131(48.5)			
Total	**270 (100)**			
Age of respondents	*Frequency*	*3.1593*	*1.63165*	*.002**
20-35 yrs	52 (19.3)			
36-45 yrs	62(23.0)			
46-55 yrs	43 (15.9)			
56-65 yrs	43 (15.9)			
66-75 yrs	44 (16.3)			
76+ yrs	26 (9.6)			
Total	**270 (100)**			
Marital status	*Frequency*	*1.7333*	*1.0397*	*.405*
Married	167 (61.9)			
Single	32(11.9)			
Widow/Widower	47 (17.4)			
Divorced	24 (8.9)			
Total	**270 (100)**			
Educational Level	*Frequency*	*2.6704*	*1.20665*	*.720*
No Formal Education	69 (25.6)			
Primary	26 (9.6)			
JHS/Middle Sch.	122 (45.2)			
SHS/Tech/Voc	31 (11.5)			
Tertiary/Post Sec	22 (8.1)			
Total	**270 (100)**			

**p-values are significant at α.01*

The gender characteristics of the heads revealed that a proportion of 52% of them are males while about 48% of the heads of household interviewed were females. The age category of respondents was identified as between 22-35 years as the lowest and 76 years or more as the highest age cohorts, at 10 years interval respectively. Most of the respondents, however, emanated from the 36-45 age cohort; the category that can best be described as the working and middle-aged group. Either of the respondents were married-62%, Single-12%, Widowed-17% or divorced with nine percent respectively (Appiah *et al.,* 2014b).

Table 4.1b: The Demographic data of Respondents cont.

Household size	*Frequency*	*1.6037*	*1.03578*	*.876*
1-5 people	172 (63.7)			
6-10 people	66 (24.4)			
11-15 people	13 (4.8)			
16-20 people	5 (1.9)			
20+ People	14(5.2)			
Total	**270 (100)**			
Main occupation	*Frequency*	*3.6148*	*2.59535*	*.002**
Farming	129 (48)			
Artisans	11 (4)			
Public/Civil Servant	28 (10)			
Trading/Food vending	50 (19)			
Other Jobs	51 (19)			
Total	**270 (100)**			

**p-values are significant at α.01*

The highest level of educational attainments of the respondents was tertiary and post-secondary education. However, majority of the respondents in the communities have been educated up to the Junior Secondary School or the Middle school level with 45% representing this number. The next majority with 26% were those without any formal education. Most of the households 64% have household sizes of between 1-5 people, sharing common dwelling and make '*common provision for food or other essentials for living'* by the UNDY (United Nations Demographic Yearbook, 2004; *p*.7), while the next most important household sizes of between 6 and 10 people inclusive, were responded to by 24%; these were found in both single and or multiple households with 58% and 41% respectively.

By no mean implying that farming is the occupation of the illiterate, however, a greater proportion of the respondents were formally educated only up to the JSS/middle school level. This means therefore, that they generally could not have the requisite qualification to seek employment in white-collar jobs. This explains the predominance of the major occupation in the communities, being farming with 49%.

The next most important vocations were trading, including food vending and artisanal works at 19% each of the respondents. Only 10% were employees of the public and civil service as per the samples from the various communities. This confirms the predominance of agrarian livelihoods in the district. Some of these socio-demographic data are of relevance on the respondents' disposition and bearing on the peri-urban land use change patterns. These socio-demographic characteristics have been used to cross-tabulate the responses for analyses. These have been done to establish some relationship between them and the variables on the main issues of peri-urban LULC change dynamics in the district.

4.2.2 Main Causes of Peri-Urbanization in the Bosomtwe District

According to Appiah *et al.* (2014b), the main causes of peri-urbanization in the Bosomtwe district were identified among the respondents from all the 14 communities as follows: those that are driven by population and infrastructure expansion; the availability of excess land for which reason people are moving towards the district in speculation for land, ostensibly for residential and recreational purposes; and the perceived availability of social amenities that attract people for settlement into the district. The respondents maintained these were the main drivers of periurbanization of the Bosomtwe District.

From Figure 4.1, majority of the respondent (50%) indicated that the increasing physical infrastructure in the communities, which has occurred as a result of population influx from the main urban areas of Kumasi and Atonsu townships, are the main drivers. Others were of the view that easy access to land constitutes the main driver of a pull factor attracting potential residential developers into the district to acquire land for building and commercial purposes. This was delivered with a response rate of 31%. Some respondents (19%), also indicated that the rate of peri-urbanization is caused by the presence of social amenities such as schools, clinics and potable water, among others, as the attracting medium for people to settle in the district (Appiah et al, 2014b; Appiah et al., 2015).

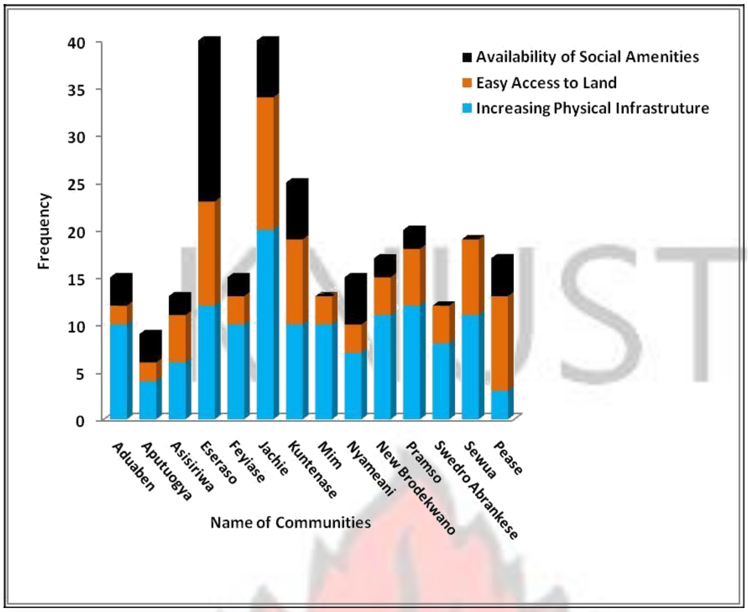


Figure 4.1: The main causes of peri-urbanization according to respondents in the district

4.2.3 Major Human Activities that mostly affect Land uses as by the Community

Results from the survey revealed that major human activities that have been affecting and determining land uses range from subsistence agriculture, residential to commercial and some recreational (predominantly the hospitality and resort) activities of land use. Communities such as *Aduaben*, *Mim*, *Nyameani*, *Jachie* and *Feyaise* with combined response rates ranging from 53% to 93%, were predominantly agrarian. Therefore their responses pointed to the increasing subsistence agriculture to which land is put in these communities (Table 4.2).

Responses obtained from *Aputuogya, Asisiriwa, Esreso, Pramso, Pease, Kuntenase* and *SwedroAbrankese* indicated that land uses for residential and commercial activities were the main dominant human activities affecting land use conversions and transformation. The relative combined response rates ranged from 50% to 89%. These responses for the two main human activities affecting land uses i.e. subsistent agriculture and residential with commercial activities were identified as highly preponderant in the specific communities indicated. Low to moderate land uses for the two activities also were identified by respondents in the other communities, with the exception of *Aputougya* where no respondent identified subsistent agriculture activities, with recreational land uses being on a very low side.

Table 4.2: Major human activities that mostly affect land uses/cover

Land Uses (LUs)	**Frequency**	**Valid Percent**
Increased Subsistence Agriculture LUs	121	44.8
Expansion in residential and commercial LUs	140	51.9
Recreation and Industrial (Small-scale)	9	3.3
Total	**270**	**100**

Source: Author's field work, 2015.

A test of association was performed on the relationship between the community location and the type of human activities that have effects on land use dynamics. This was pre-informed by the reconnaissance survey which revealed the patterns of land uses per the communities visited during the survey. From the survey it was revealed that land in some of the communities was put to particular land use types, either due to their proximity to the main city and big towns, such as *Atonsu, Kumasi* and *Esereso* or others with relative location advantages. From the 2-tailed test of association, a Pearson chi-square value of $\chi^2 = 73.546$ at a degree of freedom, *df*= 26 and a significant value of $p < .000$ at $\alpha_{0.001}$. Although the Cramer‗s V test of the strength of the association was moderate at $V = 0.37$, it was significant. This implies that depending on the location of the community in relation other factors of land use demand, human land use types are location specific. This situation does not deviate from conventional principles of hedonic tendencies of land and their relative uses to which they are put.

4.3 Peri-Urban Land Uses, Drivers and Change

4.3.1 Land Use Activities Altering Peri-Urban LULCS in the Bosomtwe District

Form the results, expansion in residential and commercial land uses were identified as the main human drivers of peri-urban land uses, constituting about 52% of the responses. The next in relevance was the increased subsistent agriculture with close to 45%. In this case, the residents are seen to wield the rudimentary forms of land cultivation. These processes and methods include the slush and burn method of tillage with its consequences of tree cover and soil quality changes. Recreational and light industrial land use activities with only 3%, was not seen as a popular land use activity in the district (Figure 4.2). Therefore the respondents did identify with this human land use activity that has the tendencies to alter the land use and land cover considerably.

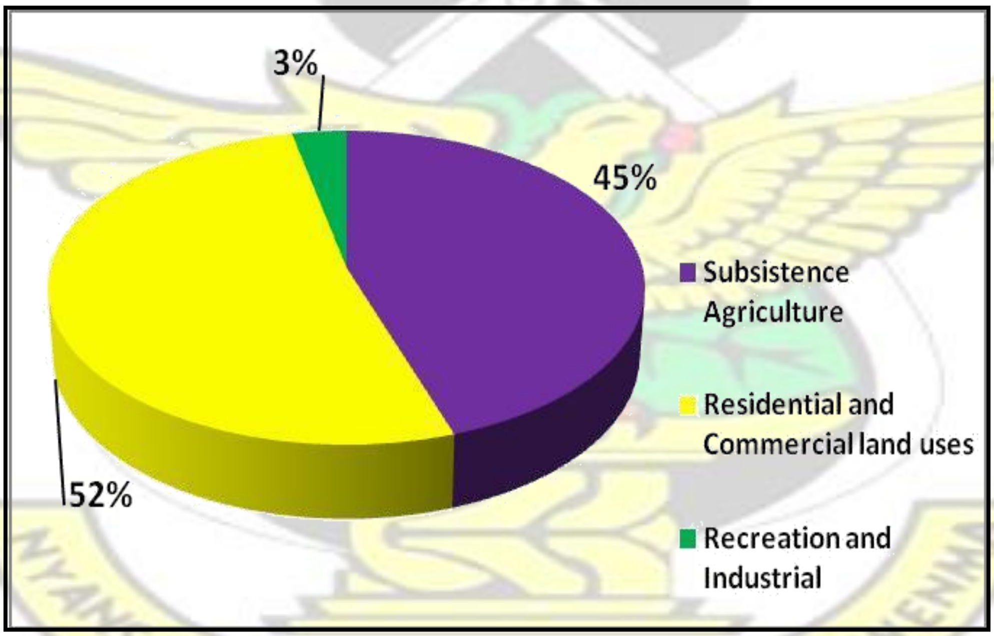


Figure 4.2: Main human activities that alter peri-urban LULCs

4.3.2 Drivers of competition for peri-urban land use in the Bosomtwe district

In the Bosomtwe district-a typical peri-urban area - these factors of land use competition drivers were identified as the easiness of the tenants to access land with 29% of the respondents indication, changing demand trend in land uses identified by 34% of respondents. This factor may have other sub-drivers by other intrinsic factors. Majority of respondents (37%) indicated that deteriorating livelihoods of land holders, owners and land lords, is the main driver which push them to yield their lands for certain land use activities for which economic incentives and motivation enticements are in return (Figure 4.3).

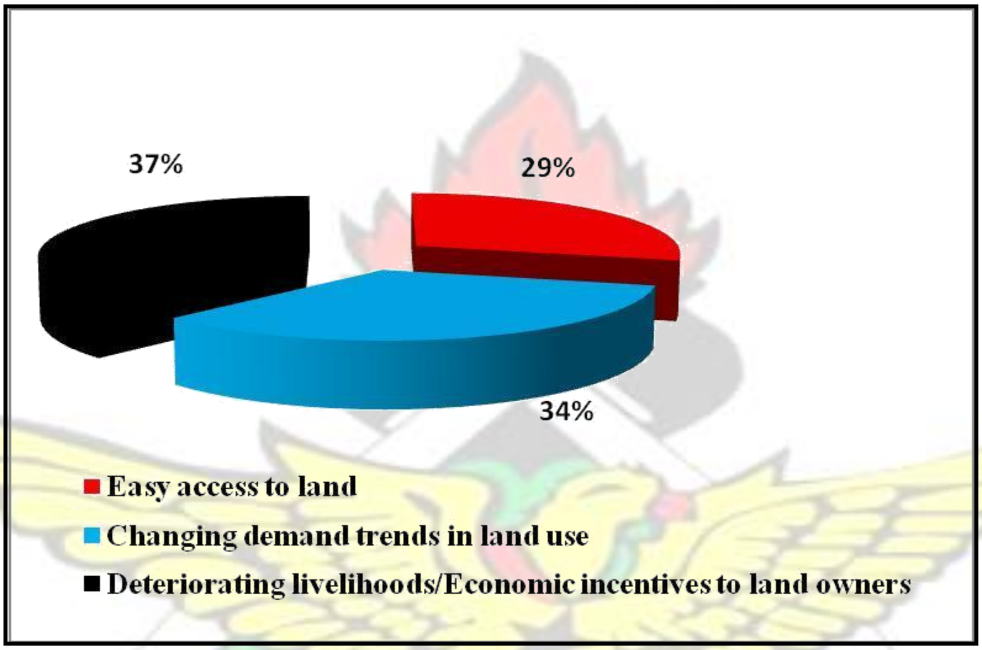


Figure 4.3: Main factors driving LULC changes

4.3.3 Peri-urbanization and Peri-urban Land use Change in the Bosomtwe district

Respondents' understanding of the concept of peri- urbanization was juxtaposed against the main causes of peri-urban land use changes in the district. From Table 4.3, increasing availability of Physical Infrastructure, correlated well with the increasing infrastructure as a description for peri-urbanization with a combined percentage response of 47%. Population increase in combination with the other causes such as availability and easy access to land and availability of social amenities yielded a combined response rate of 24%. The response rate for those whose definition entailed the combination of the two processes in association as the main causes of peri-urbanization was

29%. The results from a 2-tailed analysis showed that there is no significant association between the two concepts, as a Pearson‘s Chi-square value of 6.600 at a degree of freedom of 4 rather showed a p-value higher than α = .05 (*p*> .159) with a Cramer‘s V of.111.

Table 4.3: Main Drivers of Peri-Urbanization in the Bosomtwe District

Responses	Availability of physical infrastructure	Availability and Easy access to land	Availability of social amenities	Total
Increasing population	31	22	12	**65**
Increasing infrastructure	73	33	22	**128**
Increasing population and infrastructure	30	29	18	**77**
Total	**134**	**84**	**52**	**270**

Source: Author's field work, 2015.

The main uses of peri-urban lands in the district were identified as lands for residential, land for commercial and recreational activities and land for administrative purposes. These land uses were associated with the challenges identified as peculiar in peri-urban areas. These were identified as human and vehicular traffic congestion, social vices and problems of multiple sales of same lands to multiple buyers, with its attendant social problems of land guardsmen (*Land guardsmen in the context of Ghanaian land tenure relations, refer to hired men usually thugs by any of the contending parties over a piece of land under dispute of multiple ownership*). The results showed that there is no significant association between the two cases as a Pearson‘s chi-square value of 5.814 at a degree of freedom of 4 rather showed a p-value far higher than α= .05 (p> .213) with a Cramer‘s V of .147.

4.4 Past Peri-urban Land use Conversion and Modifications Patterns in the District A time series of peri-urban land use dynamics was undertaken using the respondents perceived and observed changes in land uses over the past10 years and their expectations of land use conversion and modification trend into the next 10 years. Over the past 10 years it was observed that residential, commercial, industrial (Low to medium) and recreational land uses, have expanded at the expense of agricultural and forest land uses (AFOLU) and cover. From the Figure 4.4, the pattern of land use changes and conversions are in the direction of Residential, Commercial and Industrial with respective response rates of 85%, 48% and 38% respectively, indicating the increasing trends of these land uses.

On the land use and cover types that were seen as decreasing, agricultural and forest land uses were identified as dwindling in extent and intensity of use with 71% and 60% respondents respectively. Other respondents were of the view that some of these land uses have remained considerably unchanged in the realms of patterns of use; in that the reduction in agriculture land use for instance is not experiencing any increment likewise the other land uses like residential which gained momentum over the past 10 years have remained continuously increasing without any signs of reduction in their intensity and use. The Figure 4.4 further depicts this seeming stability on trends with 30% and 63% of the respondents indicating that forest land use and recreational land uses have remain unchanged over the period under consideration.

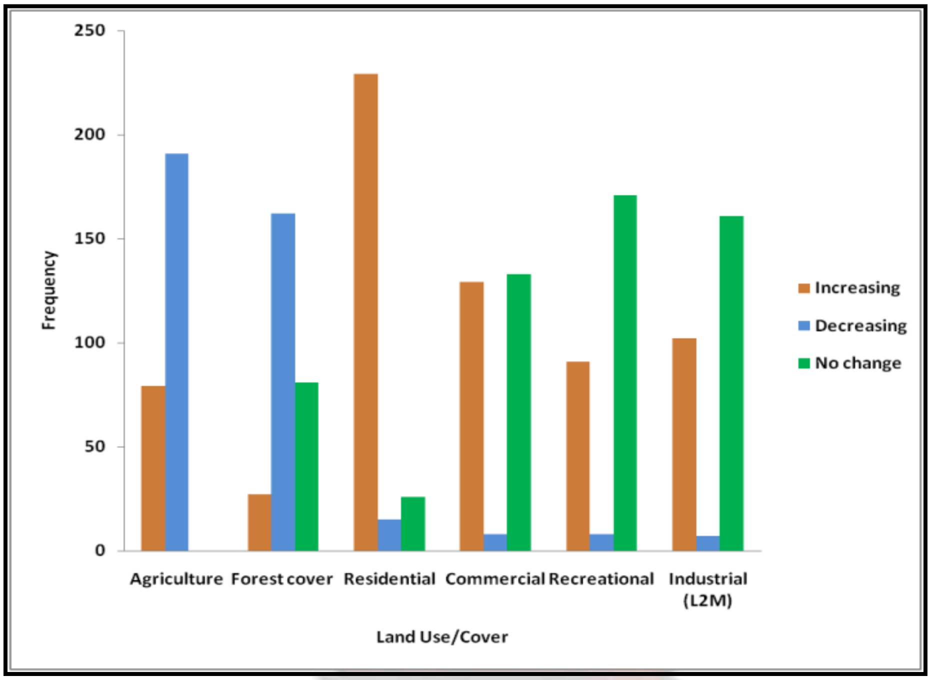


Figure 4.4: Land use activity trend over the past 10 years

In the next 10 years, the study also sought to project the land use trend from households observation considering the rates identified and perceived over the past 10 years. The responses did not deviate much from the past perceived trend of land use change in the district. From Figures 4.5 and 4.6, agriculture and forest land use/cover, according to the respondents, are expected to continue on the decreasing trend, with 62% and 59% respondents, respectively. The pattern of land use changes and conversions into the next 10 years will still be in the interest and directions of Residential, Commercial, Recreational and Industrial land uses. This is represented by their respective response rates of 80%, 66% and 38% respectively; indicating the increasing trends of these land uses into the future in the Bosomtwe district, barring any policy interventions, for the next ten years. Some of the respondents did not foresee any change in the patterns of use in the future. In fact, some respondents thought that the situation could be worse as;

> *"For over ten years of my living in this Esereso community, there has been residential housing expansion, we now have new site in this area with new*

residential buildings. The main occupation here is not farming, but trading and other commercial activities" (Interviewee, Esereso, May, 2014).

This trend of land use conversions from arable lands to residential and commercial and recreational uses have consequential implication for food security in the district as an agrarian district.

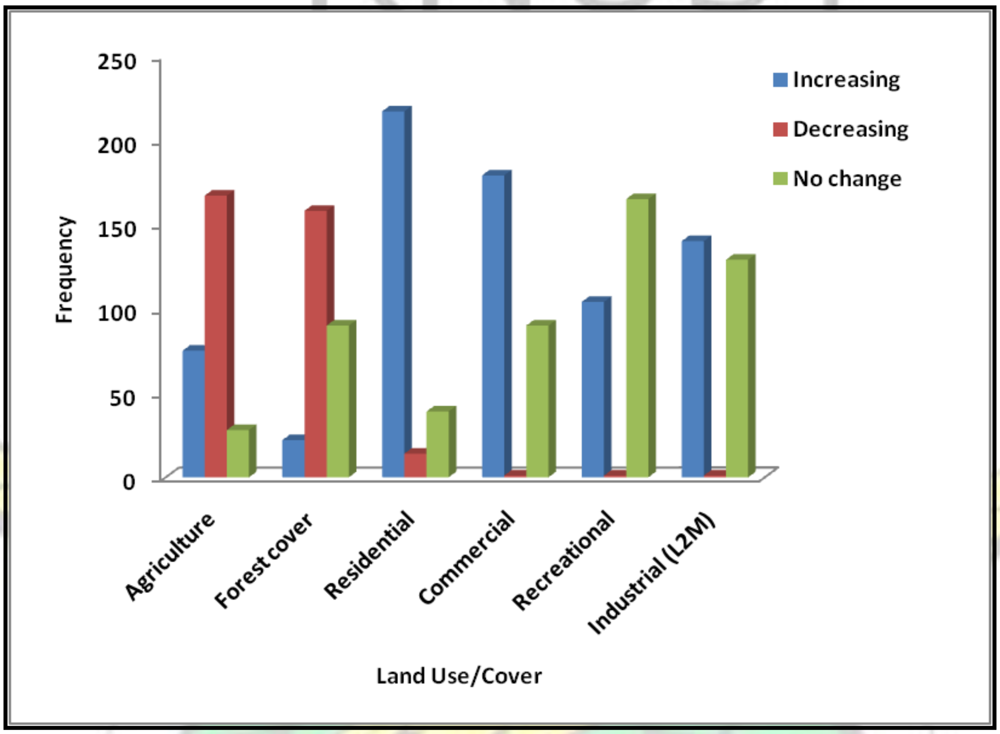


Figure 4.5: Land use trend in the next 10 years

4.5 Observed Patterns of Land use Conversion and Perceived Future Land use Trends The study identified various land use conversion permutations as from agricultural land use to residential land use and from forest land use to residential and commercial land uses and any other conversions (though not of much importance to this objective). Respondents indicated that land use conversions were in response to the major factors accounting for speculative demand for land in the district. The respondents were of the view that potential land owners/tenants were motivated to convert their land from agriculture to residential and commercial land uses because of the expected booming commercial activities in the district with 30 respondents.

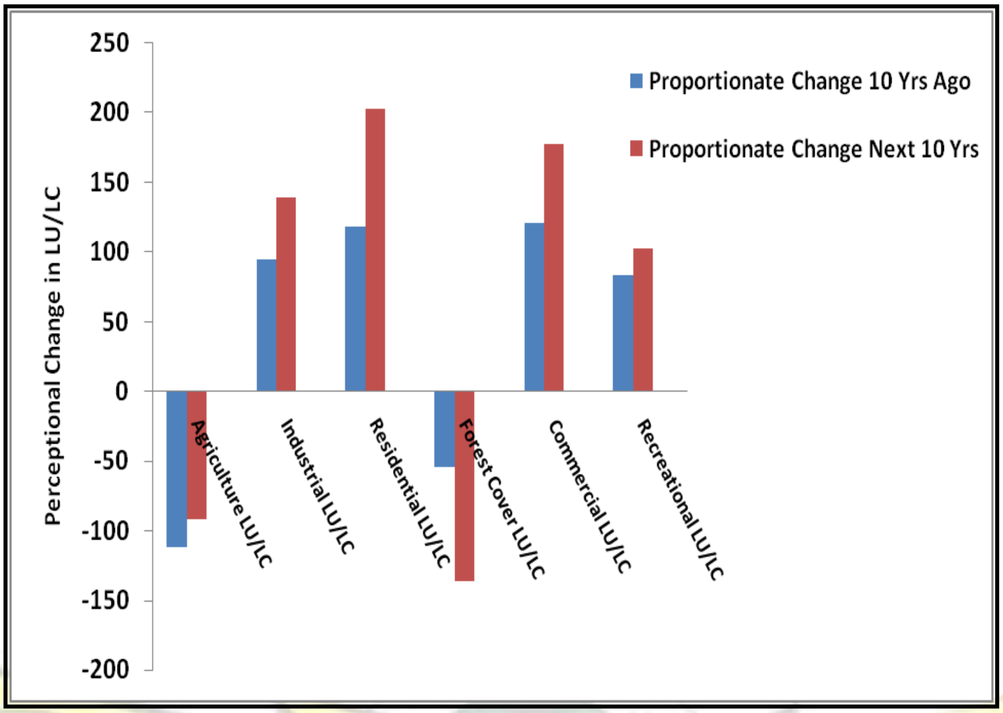


Figure 4.6: Proportional Change in LULC

The relatively cheaper grounds rent and easy access to land in the district motivated 50 and 67 respondents each for their observed patterns of conversion. In the interest of conversion from forest to residential and commercial land uses, the respondent indicated that the speculative demand due to cheaper grounds rent and easy access to land was their observation with 23 and 26 respondents respectively. On the whole, the observed patterns of land use conversion in the Bosomtwe district is motivated largely by speculative demand; where 43%, 29% and 28% respondents indicated Easy access to land, relatively cheaper grounds rent and the expected booming commercial activities as the main drivers of the conversion trends respectively.

Table 4.4: Relationship between land use conversion patterns and speculative demand for land in the district

Perceived Land Uses and Land Cover	Expected booming commercial activities	Relatively cheaper grounds rent	Easy Access to land	Total
Agric LU to Residential / Commercial LU	35(23%)	50(33%)	67(44%)	152 (100%)
Forest cover to Residential/ Recreational LU	15 (23%)	23 (36%)	26 (41%)	64 (100%)
All other conversions	26(48%)	6(11%)	22(41%)	54 (100%)
Total	**76(28%)**	**79(29%)**	**115(43)**	**270 (100)**

Source: Author's field work, 2015.

To ascertain the association between the two nominal variables, a Pearson‘s Chi-square test of association was performed. The results indicated that there is a significant relationship between the observed patterns of land use conversion and the speculative demand for land in the

2 district. At $\alpha_{.05}$ significant level,

the Chi-square value was χ = 17.516 at a degree of freedom *df* = 4. The probability value of establishing the association, *p-value* was $p < .002$. A Cramer‘s *V* test of strength of the association however indicated a weak link with a value of *V* = .180.

4.6. Household Land Use Patterns

4.6.1 Factors Influencing Selected Households' Land use Conversion Decisions

The issue of households' land use conversion probabilities was contingent on certain conditions if these are offered to the decision makers. All the communities surveyed up to 51% were of the view that deterioration of livelihoods and the economic incentives associated in converting their original lands from say agriculture to residential would influence them to make their decision.

Again, 26% of them indicated their readiness to decide to which type of land use to put their land, if speculative demand and other reasons for land acquisition have increased the changing demand trends. Finally, a proportion of 23% would decide on the fact that there is excess of land available for any future development considering their respective community population sizes (Table 4.5).

In some of the communities, there were more migrant settlers than indigenes; for instance in *Asisiriwa*, the inhabitants are occupying the land offered by the chiefs of *Mim* community. This cordial co-existence has continued for decades. In view of that leasing out their land or allowing for the conversion of their land into other uses, would not pose any future landlessness. This also

2 may explain the relatively low grounds rent per plot of land (70 x 80/90m dimension) of up to about Gh₵300.00, approximately 73 USD (*Exchange rate as at January, 2014*), in those communities.

Table 4.5: Households Decision Factors on Land Use Conversion

Communities	Excess Land	Changing Demand Trend land	Deteriorating household Livelihoods for	Total
Aduaben	6	3	6	**15**
Aputuogya	1	7	1	**9**
Asisiriwa	3	3	7	**13**
Eseraso	3	15	22	**40**
Feyiase	4	3	8	**15**
Jachie	3	9	28	**40**
Kuntenase	2	5	18	**25**
Mim	10	2	1	**13**
Nyameani	0	7	8	**15**
New Brodekwano	8	3	6	**17**
Pramso	7	5	8	**20**
Swedro-Abrankese	0	2	10	**12**

Sewua	10	4	5	**19**
Pease	6	2	9	**17**
Total	**78**	**91**	**101**	**N= 270**

Source: Author's field work, 2015

4.6.2 Gender differentials and household decisions on LULC changes

A cross tabulation between the status of the respondent in the household with the main influences on the household decisions to convert their land uses from original types, (usually agricultural and agro-forestry or forest covers to residential and commercial land uses), yielded some results. These results on the decisions to convert or modify land uses were disaggregated by gender. Among male respondents who were preponderantly the heads of households, their responses were based on all the three reasons that could influence their decisions, with deteriorating livelihoods and economic incentive as would accrue to the land owners from converting the land; being the most occurring reason with 44% response rate. The response rates of 29% and 27% corresponded to the changing land use trends and the easy access to land in the communities respectively.

Female household heads (some of whom were spouses with surviving husbands), on the other hand, were also of the view that economic incentive and changing demand trends in land use, will be their motivation to convert land uses if they have such opportunities. These femaleheaded households shared the responses with those who also doubled as the spouses of the maleheaded households with a response rate of 39% and 48% respectively.

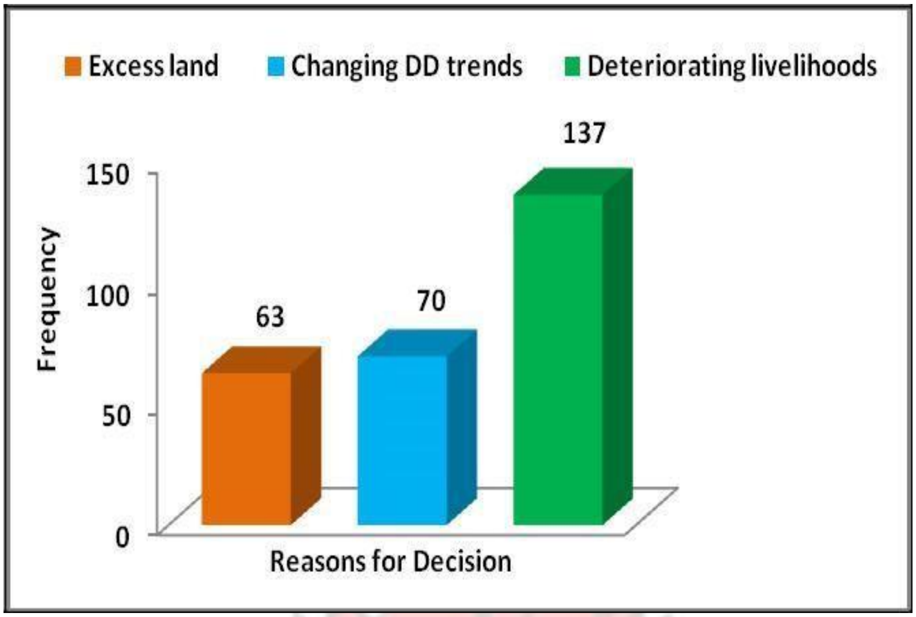


Figure 4.7: Responses of reasons to convert land use types

A Pearson Chi-square analysis for this association, showed not significant for male headed households but significant for female-headed households. From a Chi-square value $\chi^2 = 15.011$ at a degrees of freedom, *df* = 6, the probability of likely association compared with $\alpha = .05$, was $p = .022$. The Cramer's *V* test of strength of nominal by nominal association was moderate at $V = .239$.

Table 4.6: Pearson's Chi-Square tests of association between nominal variables

Gender of Respondent	***Value***	***Df***	***Asymptotic significance****	***Cramer's V***	***Total Cases***
Male	50.420	26	p < .003	.426	139
Female	49.581[b]	26	p <.004	.435	131
Total Cases					**N= 270**

*Tests were significant at α.01

The chi-square test of association between the nominal variables also yielded interesting results. This time, the analysis with association among both genders was significant. For the

2 males there was a Chi-square value of, χ = 50.420 and 49.581 at a degree of freedom *df* = 26, with a likelihood of association with p = .003 and p = .004. To test for the strength of associations, the Cramer's *V* used showed a very strong association of V = .426, and .435 respectively for males and females from all the communities (Table 4.6). The Cramer's interpretation, otherwise reported by the Cramer scale of index interpretation as quite strong association, would fit for these kinds of associations recorded.

4.6.3 Household Agents' Decision on Original Land Use Conversions

A logistic regression was also run to determine the effects of the driving responses of periurbanization as non-categories independent variables (IV) or the predictors have, to influence the dichotomous dependent variable (DV) or the response. The dichotomous responses to the dependent variables were posed, as to whether the respondents would convert their arable land from present use to a different use? They were to respond as 1= Yes, would convert and 0= No, would not convert.

These were predicted by the conditional statements of the independent variables as: what if there are changes (upward/downward adjustment) in the ground rent per standard plot of land (100m x 100m) in the district; the major human activities that affect LULC in the district; the income category of the people who predominantly settle in the peri-urban areas of the district and the criteria used in determining the price/rent of a plot of land in the district as the independent variable. The analysis was conducted using a case-wise binary logistic regression in SPSS to ascertain the likelihood of respondents taking a decisions *to convert* or *not to convert* their land to any other uses. These actions are taken in the form of the probability of the action occurring or not occurring as either 1 or 0 in binary logistic modeling (King and Zeng, 2001).

From the earlier analysis of the logistic regression model, the outcome of the data in Table 4.7 was fitted using the probabilities of conversion, given by the various independent variables. It is also to determine which of the predictor variables has the highest degree of influence in predicting the outcome of the land use conversion by the household agents. By fitting the logistic regression model to the variables, using the formula in (Eqn. 4.1), the respective odd ratio of the independent variables in predicting the outcome was calculated as follows;

$$p = \frac{\exp(a + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots)}{1 + \exp(a + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots)} \qquad 4.1$$

During the analysis, the null hypothesis stated that without the independent variables the model is a good fitting model. Alternatively, the other hypothesis was that the model is not a good fit without the inclusion of the independent variables in the model. At the case step 0, which is the beginning method the overall predicted percentage is 57.9%. This is a measure of the fitness of the model when y = the constant. The overall significant of the model without the independent variables was $p < .000$ at a $\alpha_{.001}$ significant level. However, with the inclusion of the independent variables (grounds rent per plot of land, major human activities, income category of settlers and criteria for determining rent of a plot of land), the overall significance of the model was also $p < .000$ at a chi-square value of 24.453, at a 4 degree of freedom.

The overall percentage predictive accuracy of the step 1 model is 77.6% as against the 57.9% of the null (constant only) model. Three out of the four independent variables were of much significance in predicting the outcomes of household respondents. These were the grounds rent per plot of land in the district, the major human activities that affect LULC in the district and the criteria used in determining the price/rent of a plot of land with probabilities of $p < .003$, $p < .011$ and $p < .043$ respectively, which is less than the significant level of $\alpha = .05$.

The model, however, was able to explain this prediction at only 37%., at the Nagelkerke $R^2 = 0.37$. There may, therefore, be other inherent explanations beyond the scope of the model to explain the relationship. Possible reasons could be the fact that the independent variables predicting the response variables, are not measured as categorically as the dependent variable, in a ratio and/or interval scales to yield the exact numeric predicted outcomes by each category under each response, for which the model can succinctly explain. However, a trial of the former approach, rendered most of the predictors as more than desirable confounding variables.

The confidence intervals of (CIs) of $1.358 \leq CI \leq 4.517$ and $1.039 \leq CI \leq 11.486$ for the two main predictors of the outcome, and a (EXP)β > 1, ranging between 2.477 and 3.455 means that the odds of respondents being more likely to convert their land from original uses to other uses given that the appropriate grounds rent on the land market is higher. The probability of conversion is more than 3 times, when any of the two main predictor variables increase by one unit. Also, they would convert their land on condition that demand for their land meets the criteria of prospective tenants and buyers who are looking out for some criteria upon which the grounds rent is based.

Table 4.7: Variables in the step-wise binary logistic regression Equation

	β	S.E.	Wald	df			Sig.	Exp(β)	Lower	Upper
The grounds rent/plot *(X1)*	.91	.307	8.753	1			.003**	2.477	1.358	4.517
Income category of residents *(X2)*.48				1	.227	1.614			.742	3.509
		.665	6.482	1						
Major human activities on land -1.69 *(X3)*							.011*	.184	.050	.677

Criteria determining grounds rent *(X4)*	1.24	.613	4.091	1	.043*	3.455	1.039	11.486
Constant	-1.24	1.809	.470	1	.493	.290		

**Test is significant at α.05; ** test is significant at α.01*

The assumption is that if the location of the land meets some or all of the price-fixing criteria, land owner would be in the position to convert it to other uses particularly residential uses. The probability of the case outcome of land use conversion based on the independent variables can be expressed in the general equation from Eqn. 2 as follows:

$$p = \frac{1}{1+e^{-(a+\beta_1 X_1+\beta_2 X_2+\beta_3 X_3+\ldots)}} \qquad 4.2$$

$$p = \frac{1}{1+e^{-(0.91Rg+1.24Dr+0.48I-1.24)}} \qquad 4.3$$

From the logistic regression results, with references to the odds for the likelihood of a change in any of the independent variables in predicting the dependent category can thus be determined from the odds ratio or the *logit of probability (p)* function above. The grounds rent/plot *(Rg)*; Income category of residents in peri- urban areas *(I)*; Major human activities on land uses/cover changes and the Criteria determining grounds rent *(Dr)*, have significant determining influences on the respondents to convert or not their land from agriculture land use particularly into others, such as residential land uses. The discussions of the implications of these results are detailed in chapter nine later in the thesis.

4.6.4 Implications of the Land Use Conversion Decisions

These land use conversion decision, as determined by the ground rent and associated criteria, according to Robinson *et al*. (2007), at the household level, the decision of land use conversion and modification may arise as a result of opportunities or constraints to their initial decision outcomes.

This view though, is without recourse to the customary type of land ownership arrangements that pertains in the Ashanti region and for that matter, the Bosomtwe district. The results from the communities on how households make land use decisions are *in tandem* with the views of Bajocco *et al*. (2012) that various dynamic variables interact to exert influence on land use driver-decisions to identifying the various uses to which the land could be put.

4.7 Conclusion

Such decisions may be predetermined directly or indirectly by local to regional factors, including major custodians, including traditional authorities, who invariably have the final sanctioning authority for land use and conversion at the local scale. Vejre (2008) has opined that this happens because households and other associated decision agents act to present as much as possible rational decision, pertaining to the optimization as well as maximization of gains from the use of the land resource.

CHAPTER 5: SPATIAL ANALYSES OF LAND USE AND LAND COVER AND VEGETATION COVER DYNAMICS

5.1 Introduction

Modelling LULC change in a changing environment requires dynamic analytical tools to arrive at the desired results. The chapter four presented the results from the socioeconomic sensing of respondents views and perceptions of the LULC changes in the district. These data were obtained to corroborate the LULC classification results obtained from the satellite remote sensing techniques; as presented in this chapter.

One aspect of LULC dynamics that have consequential outcomes of anthropogenic infractions on the natural environment are the changing patterns and rates of land use changes, devoted to agriculture, forestry and other land uses, particularly in peri-urban fringes.

The peri-urban areas by virtue of their complex and changing land use patterns have made themselves amenable for study within the land use science literature. The Bosomtwe district of the Ashanti region is an emerging peri-urban area, with prospects of demonstrating such complexities in its LULC patterns, at least into the next decade. This chapter espouses the results from the classification and analysis of the LULC types derived from the five satellite images covering the Bosomtwe district area.

5.1.1 Results of LULC Accuracy Assessment

The Kappa statistic is generally accepted as a measure of classification accuracy for both the model as well as user of the model of classification (Maingi and Marsh. 2002). Kappa values are characterized as <0 as indicative of no agreements and 0–0.2 as slight, 0.2–0.41 as fair, 0.41–0.60 as moderate, 0.60–0.80 as substantial and 0.81–1.0 as almost perfect agreement (Mangi and Marsh, 2002; Landis and Koch, 1977). The overall classification accuracy of the images yielded substantial high *Kappa* statistics of 80.70%, 58%, 52%, 72.41% and 82.76% for the 1986, 2002, 2007, 2010 and the 2014 images, respectively. This is an indication of classification accuracy of moderately substantial to almost perfect agreement (Tables 5.1—5.5) (Appiah *et al.*, 2016).

The high to very high accuracy of classification for three of the images (1986, 2010 & 2014), emphasize the precision of the LULC sampled points obtained via the Global Position System (GPS) survey. For the accuracy assessment of the 1986 image, the technique of land use persistency was used and juxtaposed with the current GPS points collected from current field work.

The only limiting factor in the check for LULC accuracies was the absence of reference maps or points, during the accuracy assessment process; this was, however, fixed by alternative approach. Owing to the absence of pre-existing land use maps or aerial photographs to be used as the base

th reference map, the Google map for the date of 20 April 2003 was used for the classification accuracy check for 1986, 2002 and 2007 images. Also, LULC types that remained considerably unchanged over a long period, such as old settlements, water bodies, and forest reserves, were used as reference points.

Table 5.1: Class by Class Classification Accuracy of 2014 image

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
DF	4	2	2	50.00%	100.00%
LF	3	5	1	33.33%	20.00%
BBC	37	34	34	91.89%	100.00%
RFGL	12	15	9	75.00%	60.00%
WB	2	2	2	100.00%	100.00%
Totals	**58**	**58**	**48**		

Overall Classification Accuracy = 82.76%   Overall Kappa Statistics = 0.69

DF = Dense Forest; LF = Low Forest; BBC = Build up/Bare land/Concrete; RFGL = Recent Fallows/Grasslands and WB = Water Body

Table 5.2: Class by Class Classification Accuracy of 2010 image

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
DF	4	1	1	25.00%	100.00%
LF	3	12	2	66.67%	16.67%

BBC	37	32	31	83.78%	96.88%
RFGL	12	11	6	50.00%	54.55%
WB	2	2	2	100.00%	100.00%
Totals	58	58	42		

Overall Classification Accuracy = 72.41% Overall Kappa Statistic = 0.54

Table 5.3: Class by Class Classification Accuracy of 2007 image

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
DF	7	13	5	71.43%	38.46%
LF	9	10	3	33.33%	30.00%
BBC	17	12	12	70.59%	100.00%
RFGL	9	7	1	11.11%	14.29%
WB	8	5	5	62.50%	100.00%
Totals	**50**	**50**	**26**		

Overall Classification Accuracy = 52% Overall Kappa Statistic = 0.40

Table 5.4: Class by Class Classification Accuracy of 2002 image

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
DF	11	13	5	45.45%	38.46%
LF	13	7	4	30.77%	57.14%
BBC	5	3	3	60.00%	100.00%
RFGL	9	10	6	66.67%	60.00%
WB	12	15	11	91.67%	73.33%
Totals	**50**	**50**	**29**		

Overall Classification Accuracy = 58% Overall Kappa Statistic = 0.47

Table 5.5: Class by Class Classification Accuracy of 1986 image

	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
DF	14	10	9	64.29%	90.00%
LF	9	7	6	66.67%	85.71%

BBC	11	11	10	90.91%	90.91%
RFGL	13	14	12	92.31%	85.71%
WB	10	9	9	90.00%	100.00%
Totals	**57**	**51**	**46**		

Overall Classification Accuracy = 80.70% ***Overall Kappa Statistic = 0.68***

5.1.2 The satellite images and LULC classes Analyses

This sub-section details the analyses and of the LULC classes identified from the classifications. It does so by comparing the class by class composition of the various images to ascertain the increases and decreases of the various LULC types over the periods.

5.1.3 Analysis of LULC classes for 1986 image

Results for the analysis of the 1986 image show that the LULC types at the time was a reflection of the incidence of drought and wild fires that characterized the previous year's starting from the 1983 to 1985. From Figure 5.1 & 5.2, it can be observed that the vegetation cover of the district was largely degraded temporarily (since the vegetation regenerated in subsequent years).

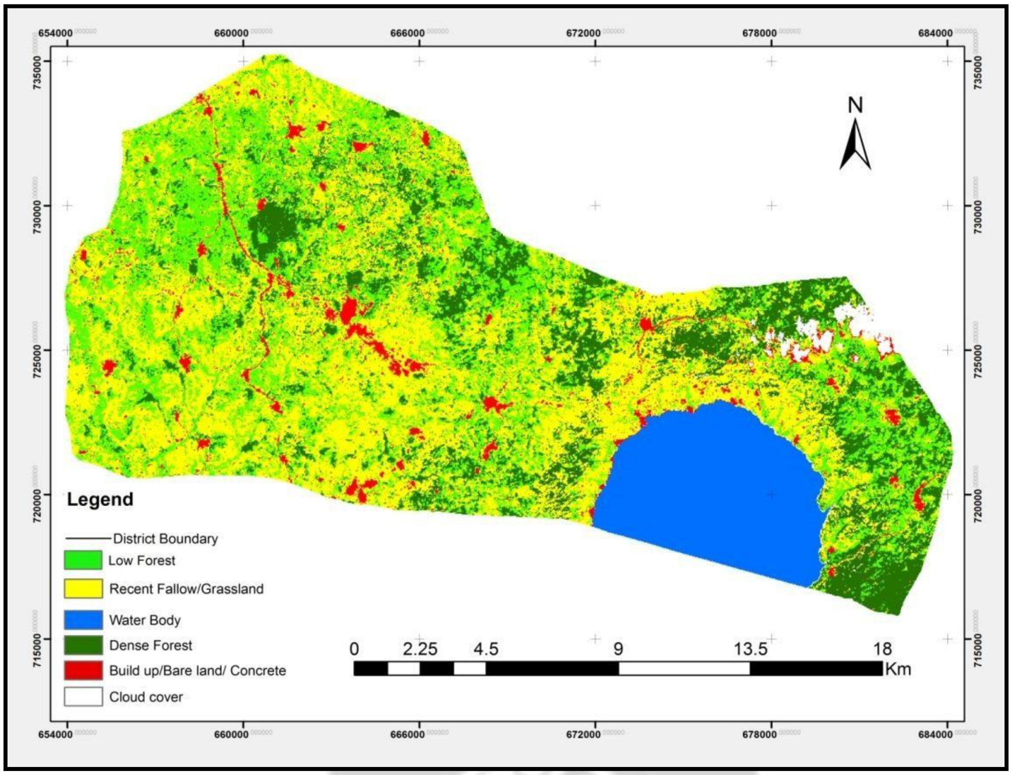


Figure 5.1 LULC Map of 1986 Landsat 5 TM image

From the classified image it was evident that recent fallows and grasslands and farm lands dominated the landscape, with 12,722 hectare (ha), representing 39% of the land area. Next in importance was the low forest, which was the newly regenerating vegetation. This covered an area of 9181 ha with percentage coverage of 28%. Patches of dense forests, that survived the drought and wild fires constituted an appreciable proportion of 5834 ha representing 18% of the total land area. Built up/Bare land and Concrete surfaces at the time was low, and occupied an area of 1201 ha, representing 3.7%. The only water body that was classified is the Lake Bosomtwe. Other water bodies were not discernible from the images for classification. The lake area was identified to be 3494 hectares.

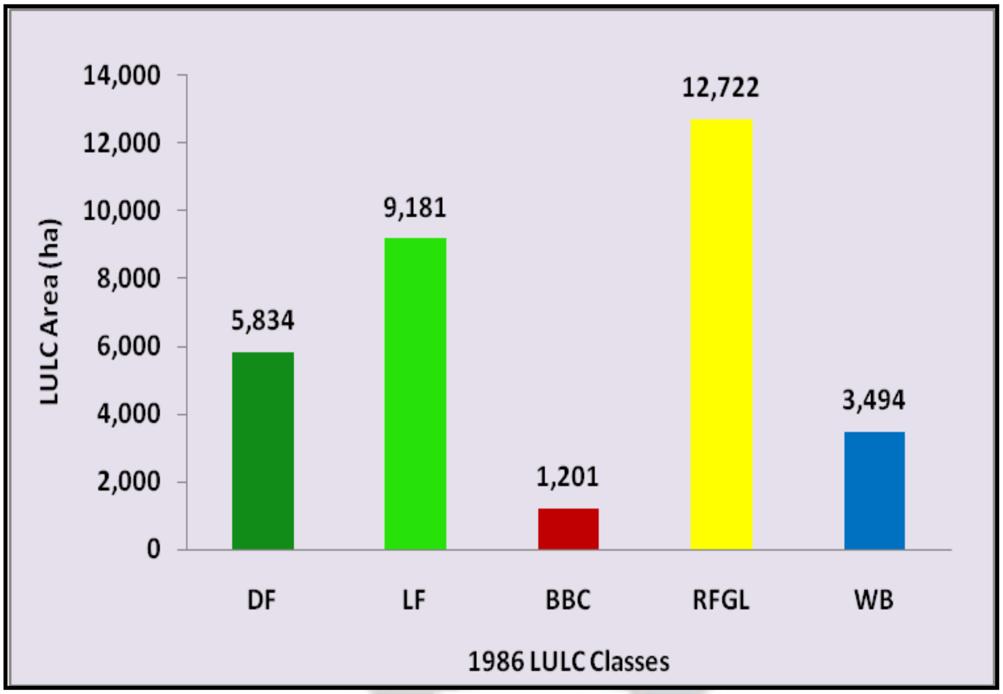


Figure 5.2: LULC classes Area (ha) for 1986

5.1.4 Analysis of LULC classes for 2002 image

The LULC classes of 2002 were an improvement over the 1986 image which served as the base year of analysis, in terms of area coverage. In 2002, dense forest cover was 8761 ha representing about 28% of the land cover. A proportion of 30% of the land area was covered by low forest vegetation with 9330 ha. Built up/Bare land and concrete surfaces also covered an area of 5664 ha representing about 18% of the total land cover. The open wood land/ and farm lands were reduced to 4423 ha at about 14% of the land area, while the lake covered an area of 3435 ha at approximately 11% of the total land area, (Figures 5.3 & 5.4).

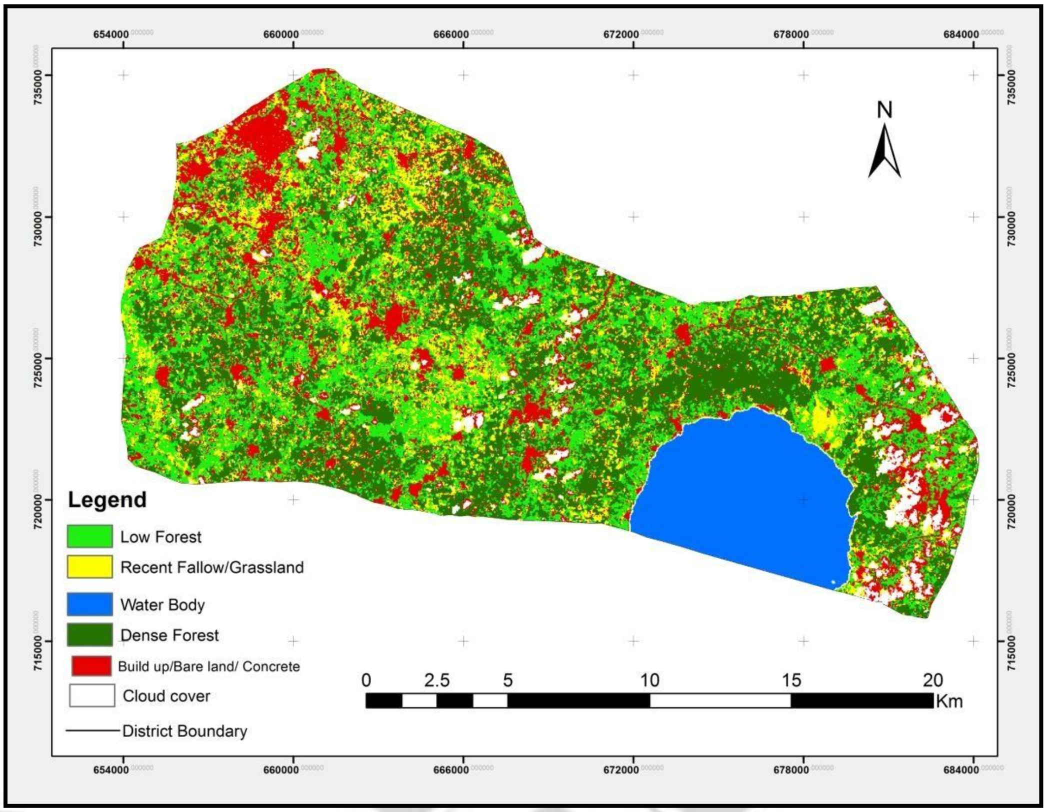


Figure 5.3 LULC Map of 2002 Landsat 7 ETM+ image

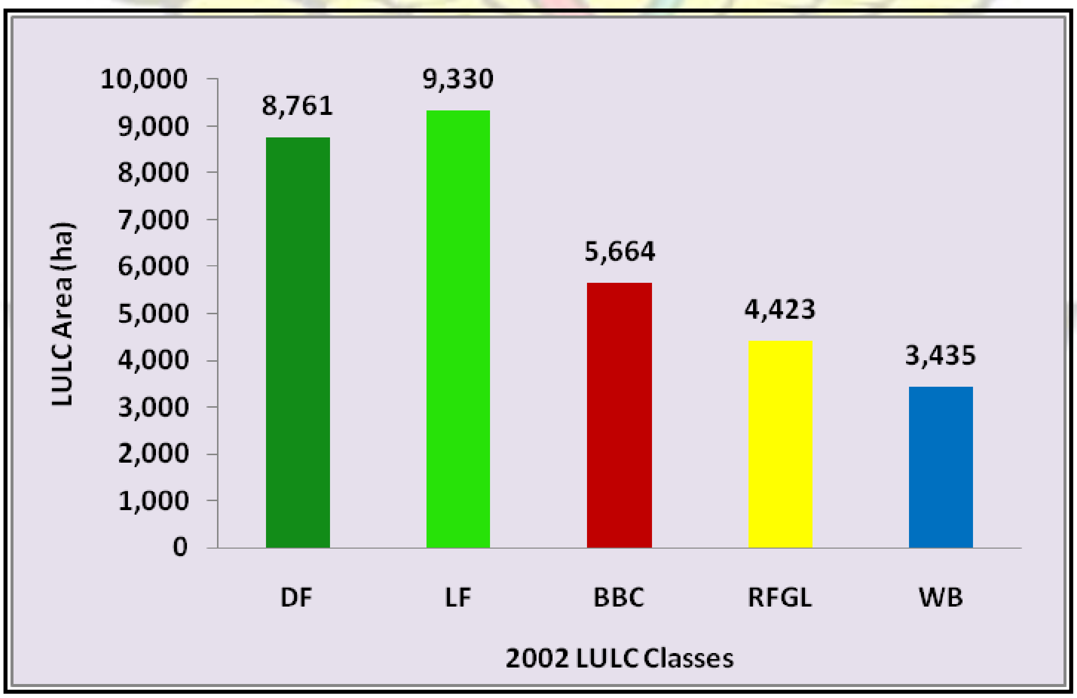


Figure 5.4: LULC classes Area (ha) for 2002

5.1.5 Analysis of LULC classes for 2007 image

The land use classes in 2007 showed considerable increase in the dense forest cover with 10,300 ha, representing 38% of the total LULC classes in the area. In order of next importance were the recent fallows, grasslands and farm lands which covered an area of 8435 ha representing 22% of the area. Low forest was ranked next in terms of coverage with 5194 ha. Built up/bare land and concrete surfaces was next in coverage of importance with 5451 ha i.e., 11% of the land area. A considerable proportion of this was as a result of the exposure of the land surfaces due to agriculture and other methods of vegetation removal around the fringes of Lake Bosomtwe (Fig 5.5 & 5.6). The lake coverage was identified as occupying 3410 ha representing 11% of the total area.

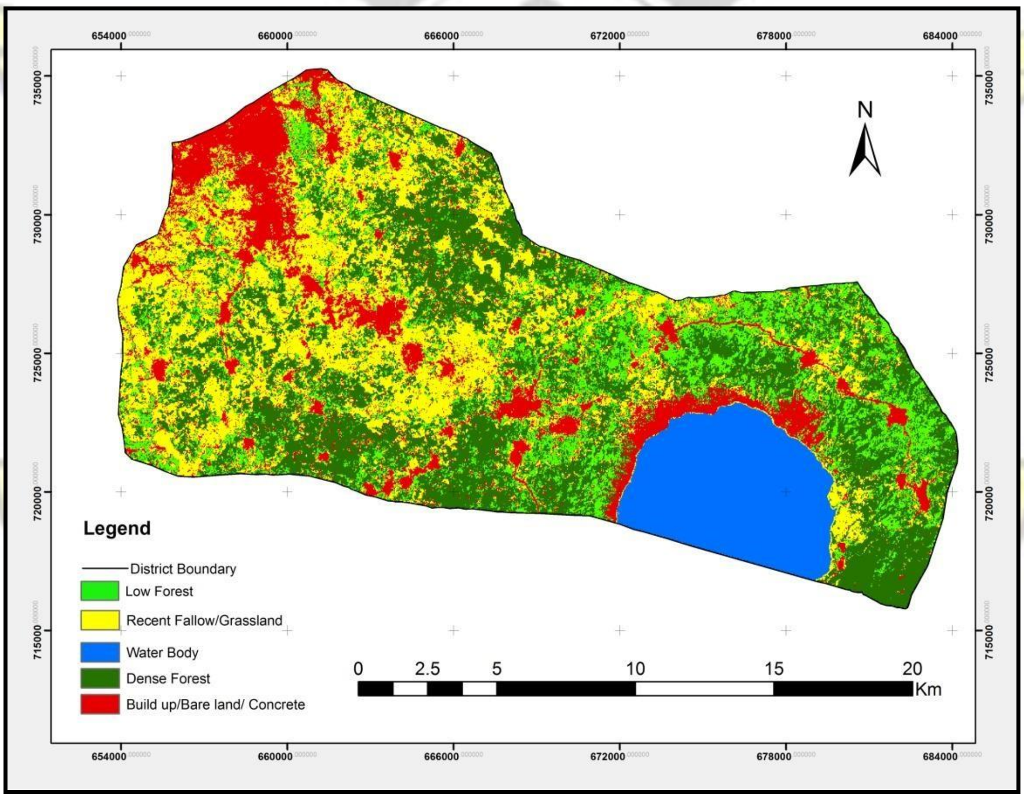


Figure 5.5 LULC Map of 2007 Landsat 7 ETM+ image

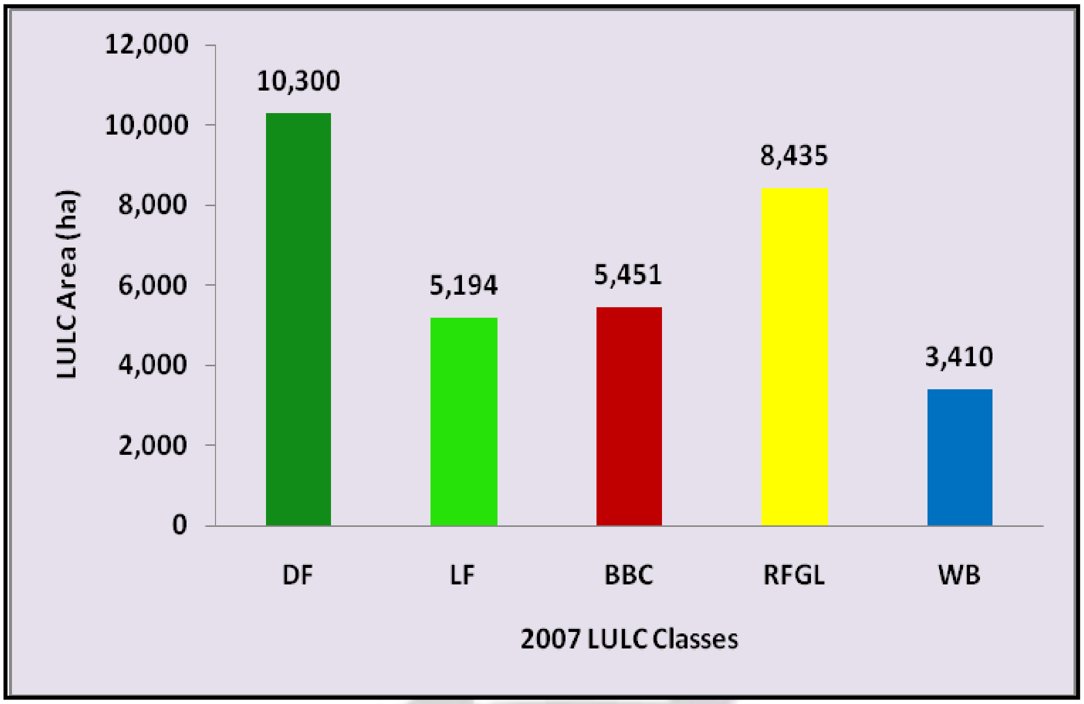


Figure 5.6: LULC classes Area (ha) for 2007

5.1.6 Analysis of LULC classes for 2010 image

By 2010, the LULC classes have shown considerable change dynamics with some profound revelations in terms of the dense forest and low forest cover (Figures 5.7 & 5.8). The total area of dense forest cover in that year was 3581 ha representing only 10% of the entire district LULC.

This deficit in coverage on the dense forest led to the appreciation in certain land areas such as Recent Fallows and Grasslands with 11,530 ha, as well as low forest, with 8138 ha, measuring up to about 36 and 25% by proportion respectively. Built up/ bare land and concrete land use and cover, were identified to be 5454 ha representing 17% of the area coverage. The lake (water body) in that year was 3420 ha representing 11% of the total area.

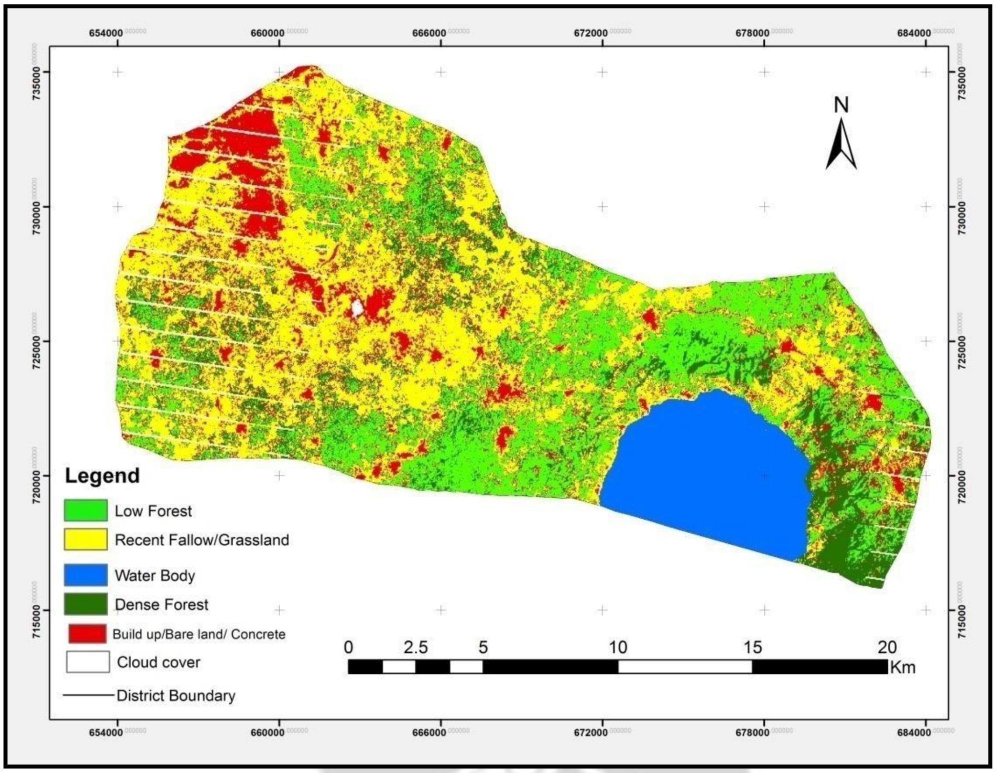


Figure 5.7 LULC Map of 2010 Landsat 7 ETM+ image

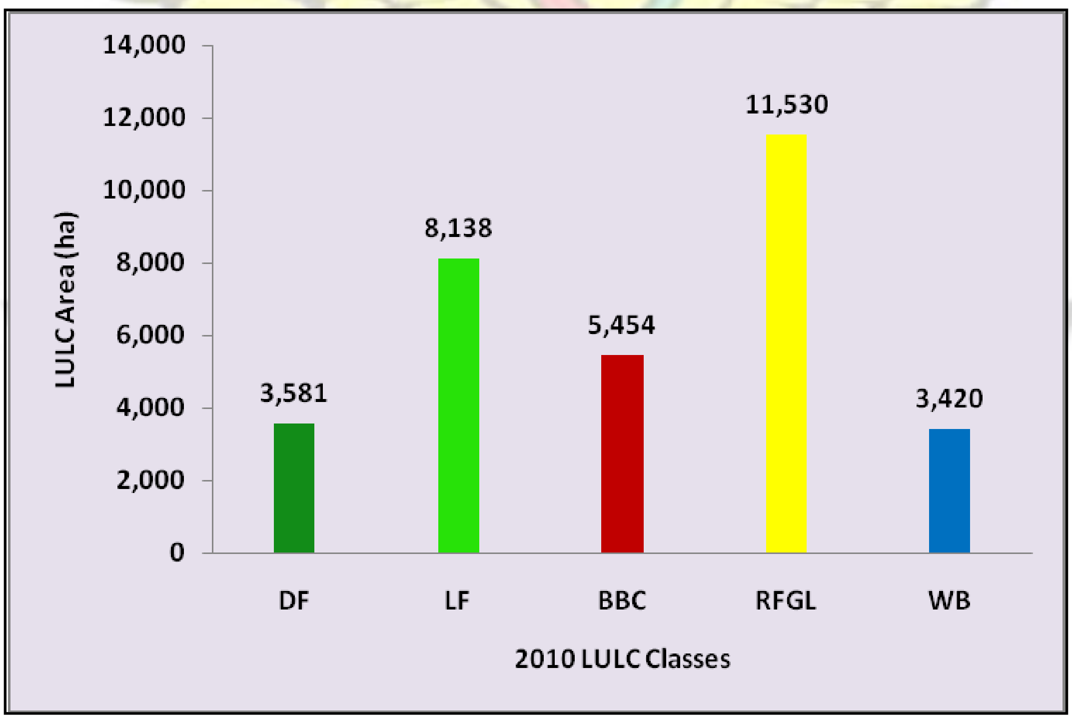


Figure 5.8: LULC classes Area (ha) for 2010

5.1.7 Analysis of LULC classes for 2014 image

The 2014 image shows that the district has experienced an appreciable level of cover changes in terms of the increasing Built up/ bare lands and concrete surfaces. The LULC (LULC) classes showed some startling revelation as far as the area coverage of the respective land uses was concerned.

Low forest cover maintained its high area of coverage with 10,947 ha, representing 33% of the total area of land use and covers. Recent Fallows and Grasslands were also next by area coverage of 9367 ha, with a proportion of 29%. Built up/bare land and concrete surfaces, although showed an increase from the visual observation, the statistics of 4597 ha by area coverage, indicated a decrease in area from the 2010 image; representing 14% of the total land area. The area covered by the lake (water body) was 3424 ha representing about 11% of the total area (Figures 5.9 & 5.10).

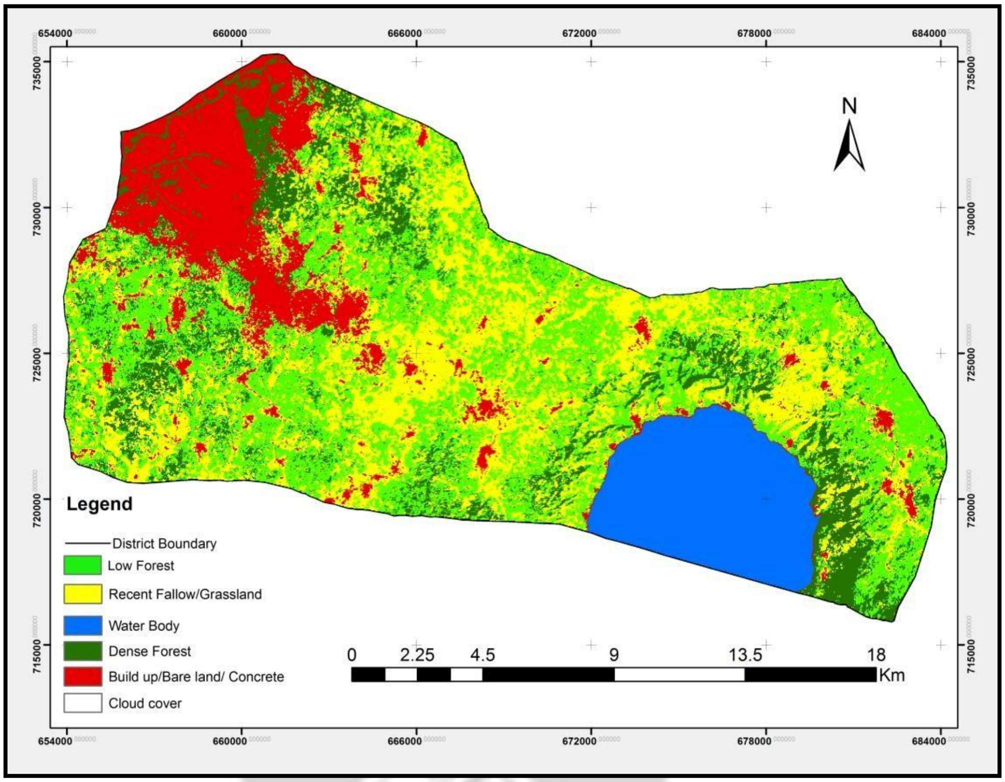


Figure 5.9: LULC Map of 2014 Landsat 8 OLI/TIS image

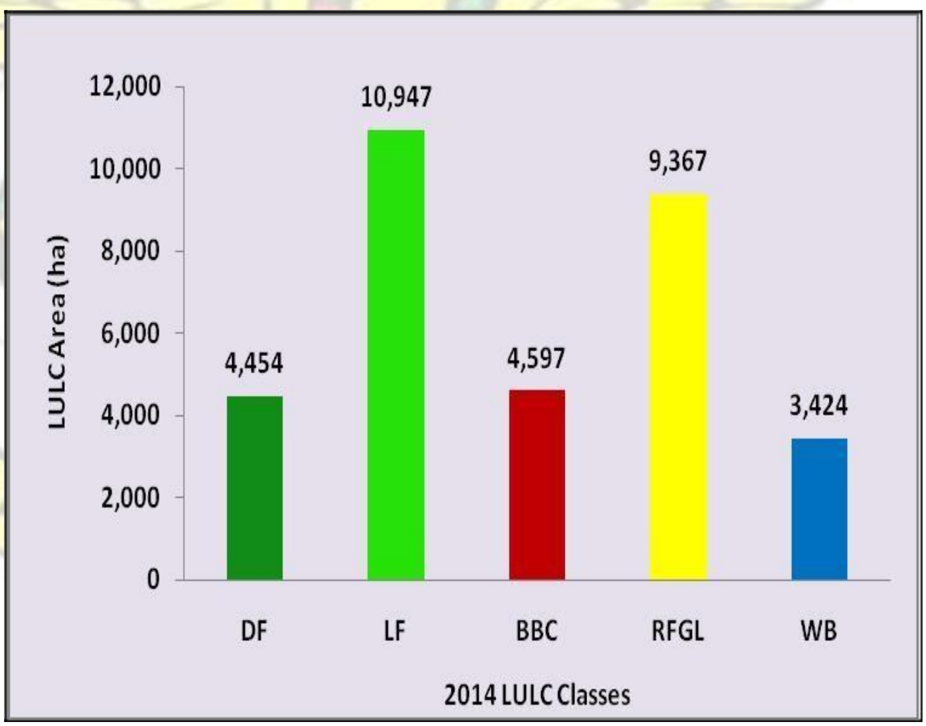


Figure 5.10: LULC classes Area (ha) for 2014

A general analysis of the LULC changes trend over the period from 1986 to 2014 does not portray the trends of peri-urbanism as the study sought to anticipate. The study proposed *ab initio* that residential and other human land use activities are increasing, with respect to other land uses such as forest cover. From the Figure 5.10, dense forest cover increased considerably until 2007, when it begun to reduce until 2010.

During this period, there was a corresponding increase in the other land uses particularly low forest cover, which also included the plantation agriculture of oil palm and citrus fruits, open wood land and farm land, mainly small holding agriculture land for food crops production as well as Built up, bare soils and concrete until 2002. The composite statistics of LULC in terms of area in hectares are displayed in Table 5.6.

Table 5.6: Composite Table of Area Statistics in Hectares

Year	1986		2002		2007		2010		2014	
LULC	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
DF	**5834.15**	**18.0**	**8760.90**	**27.7**	**10,299.87**	**37.8**	**3581.37**	**10.4**	**4454.46**	**13.6**
LF	**9180.62**	**28.3**	**9329.80**	**29.5**	**5193.63**	**18.9**	**8137.62**	**46.8**	**10,947.33**	**33.4**
BBC	**1201.00**	**3.7**	**5664.20**	**17.9**	**5451.21**	**11.0**	**5454.36**	**11.9**	**4596.93**	**14.0**
RFGL	**12,722.35**	**39.2**	**4422.90**	**14.0**	**8434.98**	**21.9**	**11530.26**	**20.1**	**9366.75**	**28.5**
WB					**3434.90**	**10.9**	**3410.10**	**10.5**	**3419.6**	
Total	**32,432.35**	**100**	**31,612.70**	**100**	**32,789.79^{x}**	**100**	**32,123.25**	**100**	**32,789.79^{x}**	**100**

x

Apart from the 2007 and 2014 images, the area statistics do not tally for the 1986, 2002 and 2010 images. This is because of the coverage of clouds and line stripes serving as noise on the images that covered portions of the total map image areas of interest.

However, between 2002 and 2007, a period of 5 years, all other land uses reduced in their area converge with the exception of recent fallows and grasslands as well as dense forest cover. Between 2002 and 2010, built up, bare soil and concrete surfaces land uses and covers, increased marginally in growth as the area figure depicts. However, by 2010, low forest and recent fallows and grasslands and farm lands have increased in area extent, while dense forest also reduced in area (Figure 5.11). This is an indication that extensive land use for agriculture and other land uses have tendencies to open up the dense forest and degraded low forest covers through subsistence fallow agricultural activities. Between 2010 and 2014, Built up bare soils and concrete surfaces reduced; while low to dense forest covers increased appreciably (see analysis of respective area changes).

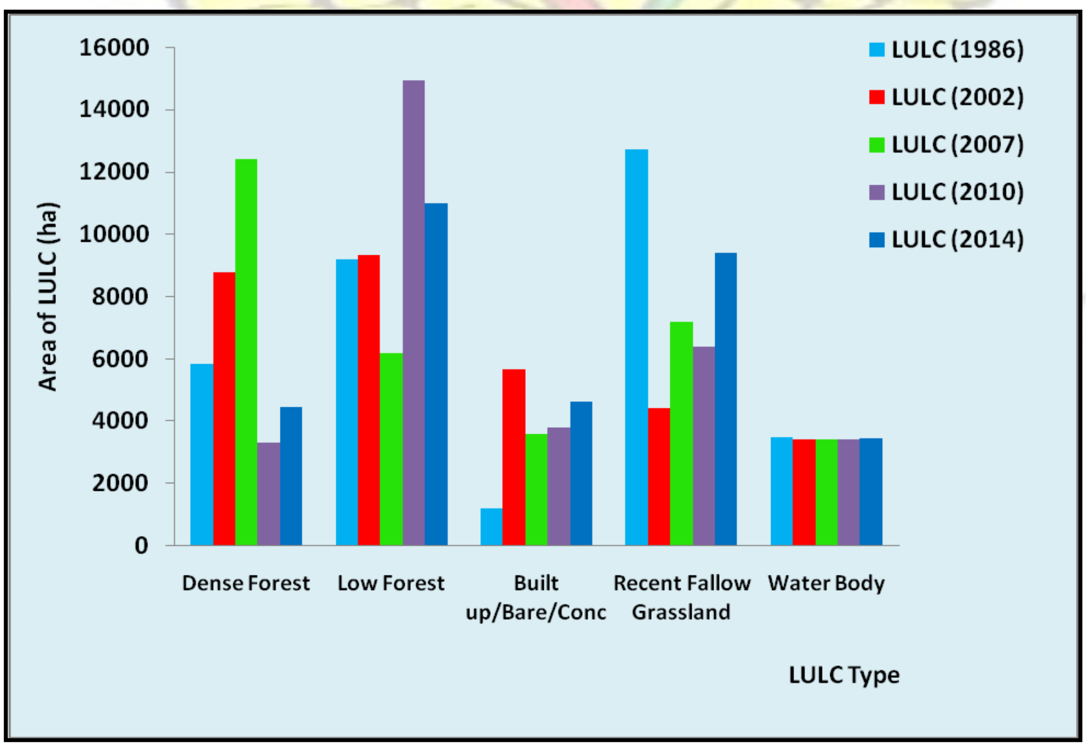


Figure 5.11: Composite LULC classes per year

5.1.8 LULC Classes Change Trends Between 1986 and 2002

The LULC class trend analysis shows the direction in which the various classes are heading using their respective initial years of comparison as the base. Between 1986 and 2002 (i.e., the 16 year-period), dense forest increased by 2927 ha. Low forest also increased by 149 ha, with Built up, bare land and concrete areas increasing by 4463 ha. Water body (i.e., the lake) also receded its shores by 59 ha. Recent fallows/Grassland was the only class that reduced substantially by 8300 ha from 12,722 ha, over the 16-year period (Table 5.7). This was the case since the district has and continues to recover from the drought and temporal degradation of the land surface, particularly vegetation cover.

Table 5.7: LULC change trend from 1986 to 2002

LULC Classes	Area (Hectares)	Percentage (%)
Dense Forest	2927	33
Low Forest	149	2
Built up/Bare/Concrete	4463	79
Recent Fallows and Grasslands	-8300	-188
Water Body	-59	-2

5.1.9 LULC Classes Change Trends Between 2002 and 2007

The LULC trends between 2002 and 2007 were indicative of human activities beginning to take a toll on the land use and cover types. Dense forest increased by 1539 ha, while Recent fallows/Grasslands also increased by 4012 ha. Low forest, Built up/bare and concrete surfaces decreased by 4136 ha and 213 ha respectively; while water body (Lake Bosomtwe) further marginally receded its shores by 25 Ha over the five-year period (Table 5.8).

Considering the predominance of negative trend in the LULC classes, it was obvious that certain land use classes especially low forest cover and built up, bare land and concrete surfaces, had transition into other uses by the year 2007. It is pertinent to note that the Built up, bare land and concrete surfaces in the previous years could be converted to other uses such as low forest and open woodland and farmland. This is because, the bare land areas included; the bare school parks (e.g. Onwe No. 2), the *galamsey* pits between Beposo and Amakom (though not part of selected study communities) and sand winning sites that dotted the district. All these bare areas have conversional abilities to other uses as indicated at a certain conversion probabilities.

Table 5.8: LULC change trend from 2002 to 2007

LULC Classes	Area (Hectares)	Percent change
Dense Forest	1539	15
Low Forest	-3146	-80
Built up/Bare/Concrete	-213	4
Recent Fallows/Grasslands (RFGL)	4012	46
Water Body	-25	-6

5.1.10 LULC Classes Change Trends Between 2007 and 2010

By 2010 from 2007, dense forest cover has reduced tremendously from the initial increasing trend since 2002, to a substantial decrease by 6719 ha. This loss was the highest decrease ever over the 24 year period from 1986 to 2010. This was at the gain of the other LULC types; where, Low forest increased in size by 2944 ha, while built up, bare land and concrete surfaces also increased marginally by 3 ha. Recent fallows and Grasslands showed an increase of 3095 ha, whiles the water body increased marginally by 10 ha over the period of three years (Table 5.9).

Table 5.9: LULC Change trend from 2007 to 2010

LULC Classes	Area (Hectares)	Percent change
Dense Forest	-6719	-188
Low Forest	2944	36.2
Built up/Bare/Concrete	3.2	5.4
Recent Fallows/Grasslands (RFGL)	3095	27
Water Body	10	0.30

5.1.11 LULC Classes Change Trends Between 2010 and 2014

The LULC classes by the year 2014 have assumed different dimensions of change from the sizes of their previous sizes in comparison to their current sizes. Contrary to the general notion that when land uses are transiting from vegetation cover to other land uses, the predominant land use and cover types happen to be built up or urban rocks and bare soils, the scenario was quite different in the Bosomtwe district.

Table 5.10: LULC change trend from 2010 to 2014

LULC Classes	Area (Hectares)	Percentage
Dense Forest	837	20
Low Forest	2810	26
Built up/Bare/Concrete	-857	19
Recent Fallows/Grasslands	-2164	-23.1
Water Body	5	0.4

What was observed, however, was that Built up bare lands and concrete surface land decreased by 857 ha (this phenomenon is attributable to possible re-vegetated bare lands included in the classes). Land cover types such as low forest, which to an extent included plantation farms increased by

2810 ha. The dense forest, however, increased by 837 ha as compared to the decreasing trend in the 2007 image. Recent fallows and Grasslands also increased by 2164 ha, with the water body gaining a rather marginal area of 5 ha (Table 5.10).

5.1.12 The Rate of LULC Change

The LULC types exhibited varying degrees of change between the successive years. According to Table 5.6, almost all the LULC classes, with exception of low forest cover between 2002 and 2007, demonstrated high rate of change from the base year in question to the next successive year. The rate of land use class change ranged from no change to very marginal changes between the successive years. This implies that between 1986 and 2002 for instance, recent fallows and grasslands changed by 2% over the 16 year period; and by this rate, the change was a reduction in the LULC class by 8299 ha. The rate of change was either positive or negative, implying a gain or loss of land use type in the following year of comparison respectively (Table 5.11).

Table 5.11: Rate of change in LULC type between the successive years

Rate of change	1986 to 2002	2002 to 2007	2007 to 2010	2010 to 2014
Dense Forest	0.043	0.012	-0.032	0.017
Low Forest	0.001	-0.023	0.051	0.026
Built up/Bare/Concrete	0.037	-0.002	0.000	-0.009
Recent Fallows/Grasslands	-0.032	0.138	0.028	-0.011
Water Body	-0.001	0.000	0.000	0.000

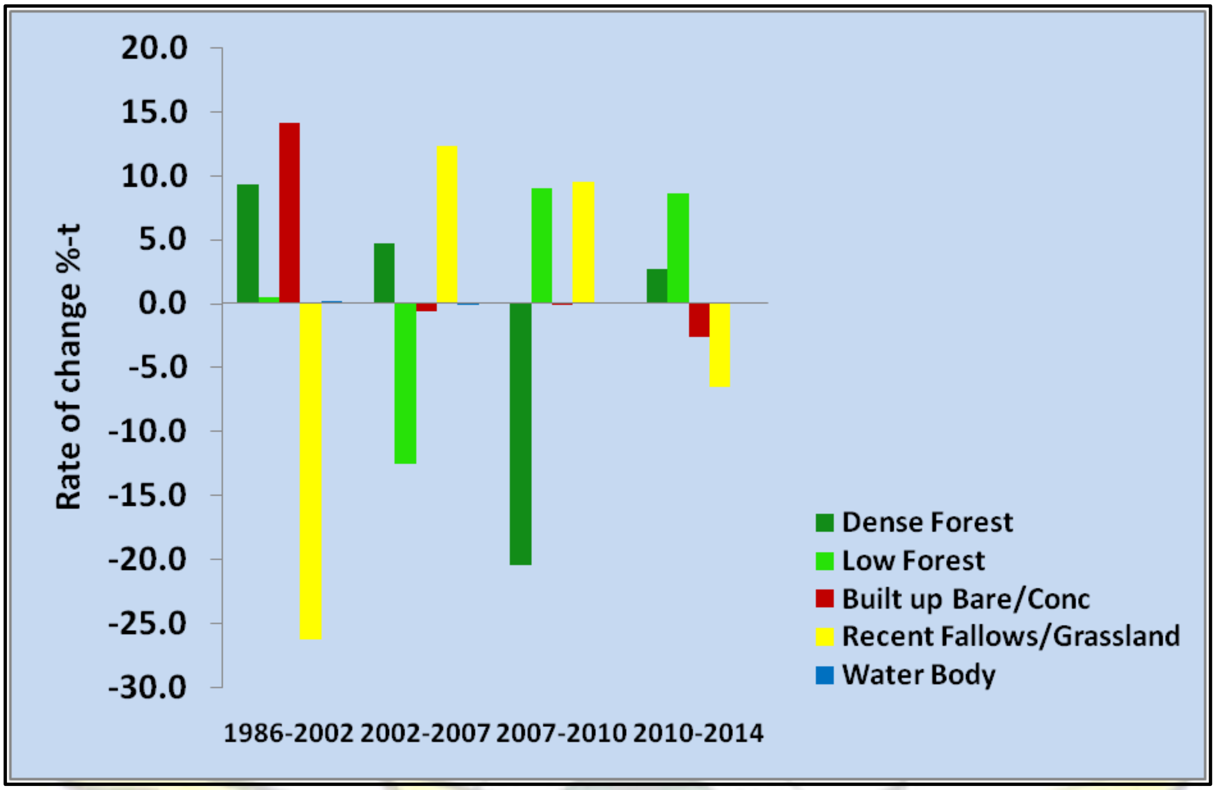


Figure 5.12: LULC change trends from 1986 to 2014

5.2 Land Use and Land Cover Change Transition Matrices

5.2.1 Introduction

A first order Markov analysis was used to derive LULC change matrices for the analysis of the rates of land use type conversions from one land use class type to another type and, between the various years' intervals of analysis. These were the co-transitions occurring between 1986 and 2002 (16yrs.); 2002 and 2007 (5yrs.); 2007 and 2010 (3yrs.) as well as between 2010 and 2014 (4yrs). Their corresponding probabilities of change were also determined, and displayed in the appropriate tables following the matrix tables. This was to measure the rate of change as well as facilitate the use of the Markov chain modelling to predict the changes in land use types into the future. The various LULC transitions have been presented in the appropriate transition matrices in tables.

5.2.2 Land use class Transition Matrix from 1986 to 2002

The analysis of the results from the image years between 1986 and 2002 LULC types as were cross-tabulated for their transitional matrix shows that the land use classes transited from one type to another according to some degree of proportions. The diagonals of the matrix, in Table 5.12, indicate the area in hectare of LULC types that remained without any conversions of class.

Between 1986 and 2002, the area of LULC retention, constituted a total of 10,359 ha representing about 37% of the total area. The most LULC conversion occurring within this period is the conversion of recent fallows and grasslands into low forest with a total conversion area of 3,900 ha. As seen in Table 5.12, there was a substantial increase in built up, bare and concrete surface land uses by 3998 ha, representing 380% change. This was gained from the conversion of recent fallows and grasslands to dense forest by 3386 ha and to built up/bare land and concrete land uses by 2043 ha. The former change was represented by an overall percentage change of -65%, during this period.

The forest cover increased tremendously by 2905 ha representing a total change of 59%. This was as a result of the regeneration of the vegetation cover from the previous years' draught and forest fires that characterized the country in the early to mid-1980s. Bare areas component of the (Built up/bare land and concrete lands) were actually re-vegetated into dense and low forest respectively with the areas of 2905 ha and 396 ha respectively. All other land use transitions did occur marginally including the Water body; which was converted to recent fallows and grasslands along its shores by agricultural activities.

On the basis of the conversion probabilities, therefore, between the 1986 and 2002, all, the land uses with the exception of the Recent fallows and Grasslands had land use probability persistence rates of more than 30% (Table 5.12 & 5.13).

Table 5.12: Land use class Transition Matrix from 1986 to 2002

LULC Classes		2002 Image DF	LF	BB/Conc.	OW/FL	WB	**1986 Total**
	Dense Forest	**2054**	1409	777	646	0	**4886**
	Low Forest	2217	**2767**	1675	1264	0	**7922**
Image	Built Bare/Conc.	132	237	**550**	127	4	**1050**
	Recent Fallows/Grasslands	3386	3900	2043	**1890**	1	**11,219**
	Water Body	3	7	3	15	**3092**	**3120**
	2002 Total	**7791**		**5048**	**3942**	**3098**	**28,197**
	Change (Ha)	+2905	**8318** +396	+3998	-7277	-22	14,662
	Change (%)	+59	+5	+380	-65	-0.7	52

Table 5.13: Land Use transition Probability Matrix 1986 to 2002

LULC Classes		**2002 Image**					
		DF	**LF**	**BB/Conc.**	**OW/FL**	**WB**	**Total**
1986 Image	Dense Forest	0.42	0.29	0.16	0.13	0.00	1.00
	Low Forest	0.28	0.35	0.21	0.16	0.00	1.00
	Built up/Bare/Concrete	0.13	0.23	0.52	0.12	0.00	1.00
	Recent Fallows/Grasslands	0.30	0.35	0.18	0.17	0.00	1.00
	Water Body	0.00	0.00	0.00	0.00	0.99	1.00

5.2.3 Land use class Transition Matrix from 2002 to 2007

By 2007, most of the land use classes have increased in terms of their area of coverage from their original marginal conversions into considerable areas of coverage. The total land use retention or persistence was 14,107 ha, representing 45% of the total land area. Most of the conversions occurred from low forest to open woodland and farmlands. This means more land was put under agricultural activities with its decreasing effect on the low forest cover. The area of covered by open woodland at the expense of low forest was 3661ha.

At the same time, most of the low forest cover was upgraded to dense cover by an area of 2358 ha. Recent fallows/Grassland and Built up and bare (mostly the bare areas) land conversions into dense forest cover was also substantial by 1211 ha and 1338 ha respectively. These dense forest areas were, however, replaced by 1470 ha of open woodland and farm lands. This means considering the former conversions into the latter respectively, there was a net loss of dense forest cover over the period in comparison to RFGL and BBC land use and covers (Table 5.14).

The land use class with the highest overall percentage change transition was Recent fallows and Grasslands with a percentage increase of 87%, while the land use class with the least change was low forest, with a percentage decrease of 47%.

Between the period, 2002 to 2007, the probability of land use conversion was very low for dense forest to built up, considering the rate of built up and bare surfaces increasing rates with less than 1% probability. At the same time there is a 55% and 40% chance that dense forest and recent fallows and grasslands would continue to retain their coverage over the period into the next reference year (Table 5.15).

Table 5.14: Land use class Transition Matrix from 2002 to 2007

	2007 Image	

	LULC Classes	DF	LF	BB/Conc.	OW/FL	WB	2002 Total
Image	Dense Forest	**4806**	1822	663	1470	0	**8761**
	Low Forest	2358	**1796**	1514	3661	0	**9330**
	Built Bare/Conc.	1338	702	**2314**	1311	0	**5664**
	Recent Fallows/Grasslands	1211	608	820	**1784**	0	**4423**
	Water Body	0	0	4	24	**3407**	**3435**
	2007 Total	**9713**		**5315**	**8250**	**3407**	**31,612**
	Change (Ha)	+952	**4929** -4401	-349	+3827	-28	
	Change (%)	+11	-47	-6	+87	-0.8	

Table 5.15: Land Use transition Probability Matrix 2002 to 2007

		2007 Image					
	LULC Classes	DF	LF	BB/Conc.	OW/FL	WB	Total
Image	Dense Forest	0.55	0.21	0.08	0.17	0.00	1.00
	Low Forest	0.25	0.19	0.16	0.39	0.00	1.00
	Built up/Bare/Concrete	0.24	0.12	0.41	0.23	0.00	1.00
	Recent Fallows/Grasslands	0.27	0.14	0.19	0.40	0.00	1.00
	Water Body	0.00	0.00	0.00	0.01	0.99	1.00

By 2007, most of the land use classes have increased in terms of their area of coverage from their original marginal conversions into considerable areas of coverage. The total land use retention or persistence was 14,107 ha, representing 45% of the total land area. Most of the conversions occurred from low forest to recent fallows and grassland. This means more land was put under agricultural activities with its decreasing effect on the low forest cover. The area covered by open woodland at the expense of low forest was 3661 ha.

At the same time, most of the low forest cover was upgraded to older fallows by an area of 2358 ha. Recent fallows and built up and bare (mostly the bare areas) land conversions into dense forest cover was also substantial by 1211 ha and 1338 ha respectively. These dense forest areas were, however, replaced by 1470 ha of open woodland and farm lands. This means considering the former conversions into the latter respectively, there was a net loss of dense forest cover over the period in comparison to RFGL and BBC land use and covers (Table 5.16). The land use class with the highest overall percentage change transition was recent fallows and grasslands with a percentage increase of 87%, while the land use class with the least change was low forest, with a percentage decrease of 47%.

5.2.4 Results of Land use class Transition Matrix from 2007 to 2010

The LULC matrix from 2007 to 2010, shows a period of similar land use conversions/transitions from one land use class to another. At this time, the various land use classes were still in transition of change after the base year‘s land use cover anomalies. These anomalies of almost recent fallows and grasslands and farm lands with patches of dense to low forest covers, have been corrected over the 24 year period (1986-2010). According to Table 5.16, between 2007 and 2010, the total LULC class persistence was 17,196 ha representing about 54% of the total land area.

In 2010, the main transition that occurred was from dense forest to low forest by an area of 4040 ha. This is a clear sign of degradation of vegetation quality. Furthermore, dense forest also transited into open woodland and farmlands with an area of 2100 ha, and from dense forest to Built up/bare lands and concrete surfaces by an area of 1364 ha.

During this same period, low forest cover gained from the transition of open woodland into low forest by 699 ha. A proportion of 2253 ha of Built up, bare and concrete lands (probably most of the bare areas), were converted into recent fallows and grasslands (probably to more farms than others). Marginal water body conversion was 1 ha and 2 ha to dense forest and recent fallows and grasslands respectively, as well as farms along the shores of the lake. There was an overall percentage increase of 60% for low forest transition by 2010. The land use class that reduced considerably was dense forest with a percentage decline by 65%.

This trend of conversions explains why the land use conversion likelihood of converting dense forest to low forest by 2010 was higher than all the other land use classes at 40%. Again, during this time, there was a lower likelihood of land use covers transiting into built up with an average probability of less than 15%, whiles the recent fallows and grasslands show highest likelihood of retention at 73% (Table 5.16 and Table 5.17).

Table 5.16: Land use class Transition Matrix from 2007 to 2010

LULC Classes		2010 Image DF	LF	BB/Conc.	RF/GL	WB	2007 Total
2007 Image	Dense Forest	**2639**	4040	1364	2100	0	**10,143**
	Low Forest	378	**2866**	629	1225	0	**5099**
	Built Bare/Conc.	146	532	**2333**	2253	0	**5264**
	Recent Fallows/Grasslands	416	699	1128	**5952**	14	**8209**
	Water Body	2	0	0	1	**3406**	**3409**
	2010 Total	**3581**	**8138**	**5454**	**11,530**	**3420**	**32,123**
	Change (Ha)	-6562	+3039	+190	+3321	+11	
	Change (%)	-65	+60	+4	+40	+0.3	

Table 5.17: Land Use transition Probability matrix 2007 to 2010

LULC Classes		2010 Image DF	LF	BB/Conc.	RF/GL	WB	Total
2007 Image	Dense Forest	0.26	0.40	0.13	0.21	0.00	1.00
	Low Forest	0.07	0.56	0.12	0.24	0.00	1.00
	Built up/Bare/Concrete	0.03	0.10	0.44	0.43	0.00	1.00
	Recent Fallows/Grasslands	0.05	0.09	0.14	0.73	0.00	1.00
	Water Body	0.00	0.00	0.00	0.00	1.00	1.00

5.2.5 Land use class Transition Matrix from 2010 to 2014

The LULC matrix from 2010 to 2014, portrayed major land use conversions/transitions from one land use class to another. At this time, the various land use class types were in real transition of change after the base year's land use cover anomalies. This was particularly so for the diagonal matrix of land uses that maintained their types in the following reference years by an increase over the previous reference year at 17,340 ha.

This was about 54% of the total land area. The highest conversions from one type to another, however, was from open woodland to low forest cover and to Built up with 3068 ha and 2027 ha respectively in 2014 (Table 5.18). Furthermore, there was a conversion of dense forest to low forest by 1518 ha; while 2006 ha of low forest were converted into open woodland and farm lands. Up to 1435 ha of Built up bare land and concrete surfaces were covered up by low forest. There were marginal conversions of the lake by an area of 5 ha to built up and bare land and concrete areas. By 2014, the proportion of dense forest has increased by a percentage gain of 21%. However, of very significant increase in land use proportion was the low forest, with an approximate percentage of 32%. The probability of land use conversion from other land uses to Built up, bare land and concrete was again less that 20%, while the probabilities for the transition from other land uses into forest and low forests were 42 and 58% respectively (Table 5.19).

Table 5.18: LULC transition matrix between 2010 and 2014

	LULC Classes	2014 Image DF	LF	BB/Conc.	RFGL	WB	2010 Total
2010 Image	Dense Forest	**1525**	1518	34	501	4	**3581**
	Low Forest	1324	**4732**	75	2006	0	**8138**
	Built Bare/Conc.	514	1435	**2218**	1288	0	**5454**
	Recent Fallows/Grasslands	981	3068	2027	**5450**	3	**11,530**
	Water Body	0	0	5	0	**3415**	**3420**
	2014 Total	**4345**	**10,753**	**4597**	**9244**	**3422**	**32,123**
	Change (Ha)	+764	+2615	-957	-2286	+2	
	Change (%)	+21	+32	-20	-20	0	

Table 5.19: Land Use transition Probability matrix from 2010 to 2014

	LULC Classes	2014 Image DF	LF	BB/Conc.	OW/FL	WB	Total
2010 Image	Dense Forest	0.43	0.42	0.01	0.14	0.00	1.00
	Low Forest	0.16	0.58	0.01	0.25	0.00	1.00
	Built up/Bare/Concrete	0.09	0.26	0.41	0.24	0.00	1.00
	Recent Fallows/Grasslands	0.09	0.27	0.18	0.47	0.00	1.00
	Water Body	0.00	0.00	0.00	0.00	1.00	1.00

5.3 The LULC Projections

LULC transitions and projections into the future have been modelled using the first order Markov transition chain (Al Bakri *et al*., 2013 and Rimal, 2011). The study used the 2010 and 2014 land use transition probability matrix with the base year initial vector as the 2014 image land use classes. This land use class map also had the best classification accuracy in terms of the overall Kappa statistic of 82.8%. The LULC types were projected by the 4-year interval duration into 2018. This is because; projecting farther into the future may result in distortions in outcomes due to certain unforeseen happenings.

Again, considering the fact that the district demonstrates predominantly rural and forest to agricultural LULC dynamics, it would be difficult to project by anticipating any drastic changes without recourse to the intrinsic parameters and factors determining LULC changes, which may change in the foreseeable future. Over the past 28 years, from 1986 to 2014, the LULC types have been largely low forest and recent agricultural fallows and grasslands in the Bosomtwe district.

Projecting the land use types into the future, two main time steps were assumed. The first time scenario is land use trend following the current (Business as usual) trends, with at least the prevailing LULC dynamics that have persisted between 2010 and 2014 being constant; and also without population characteristics changing any significantly. The second scenario is assuming increasing population size, coupled with the improvement in the income levels of the people that settle in the district. The projection in scenario two anticipates more land to be demanded for built up bare land and concrete land uses than the other purposes, in the long term (2002-2014) of a period of 12 years (Table 5.20) and (2014+12) from 2014, pitching at 2026. However, this would also depend on the Local Government institutional policy directives and how it would be complied with.

Table 5.20: LULC transition matrix between 2002 and 2014

		2014 Image				
	LULC Classes	Dense Forest	Low Forest	Built up/ Bare/Concrete	Recent Fallows/ Grasslands	Water Body	**2002 Total**
2002 Image	Dense Forest	**1,929.9**	4,283.1	323.3	2225	0	**8760.8**
	Low Forest	1,022.1	**3,303.6**	1254	3750.1	0	**9329.8**
	Built up/Bare/Concrete	619.7	1437.4	**2137.7**	1,469.4	0	**5,664.2**
	Recent		1.0				
			10,440.4				

Fallows/Grasslands	619.83	1,415.3	771.8	**1,615.9**	0	**4422.9**
Water Body	0.3		15.8	0.1	**3417.8**	**3434.9**
2014 Total	**4191.7**		**4502.6**	**9060.0**	**3417.8**	**31612.4**
Change (Ha)	-4569.1	+1110.6	-1161.6	4637.1	-17.1	
Change (%)	-52	+12	-21	+105	-0.5	

Table 5.21: Land Use transition Probability matrix 2002 to 2014

	LULC Classes	Dense Forest	Low Forest	**2014 Image** Built up/ Bare/Concrete	Recent Fallows/Grassland	Water Body	**Total**
Image	Dense Forest	0.22	0.49	0.04	0.25	0.00	1.00
	Low Forest	0.11	0.35	0.13	0.40	0.00	1.00
	Built up/Bare/Concrete	0.11	0.25	0.38	0.26	0.00	1.00
	Recent Fallows/Grasslands	0.14	0.32	0.17	0.37	0.00	1.00
	Water Body	0.00	0.00	0.00	0.00	1.00	1.00

5.3.1 Projections of LULC by 2018

The land use dynamics of Table 5.17 would not deviate any significantly under the first scenario assumption of current business as usual trends. By the year 2018, the proportion of forest cover in comparison with the 2014 proportion would have decreased, by some six hectares of the total cover. Low forest cover and water body (Lake) would reduce the same year. Built up, bare and concrete land uses and recent fallows and grasslands would increase by a proportion of about 2% and 1.6% respectively (Table 5.22).

The model validation using the index of agreement, according to Willmott *et al*. (2012), indicated that there is a little degree of variability from the observed LULC trends between the initial and the predicted. This trend implies that, the Bosomtwe district, given the current rate of LULC change dynamics would continue to remain a predominantly rural district, with periurbanism activities concentrated in limited portions of the district especially areas that are in proximity to the main urban city centre. However there is the propensity for built up and bare land and concrete surface land uses to increase considerably in the future given the transition probability matrix.

Table 5.22: Projected LULC classes Areas in Hectares by 2018

LULC Class	Area (Ha)	Percent %
Dense Forest	4478	13.6
Low Forest	9772	29.7
Built up/Bare/Concrete	10,088	30.6
Recent Fallows/Grasslands	5136	15.6
Water Body	3443	10.5
Total	**32,917**	**100.0**

A further projection was performed on the 2014 image to look at the 2026 scenario. Using the 2014 image as the initial vector, the transition probability matrix was multiplied by this initial vector, to obtain the relative land use covers in areas (ha), for each of the LULC classes by year 2026. As indicated earlier, Markovian projections into the future time steps reduces in accuracy as the number of years (t) increases (Al Bakri *et al*., 2013). This scenario is based on the arbitrary surmises that, with increasing population and improved income status of people settling in the district, (the results show that in another step of 10 years), the LULC classes would remain fairly similar to the first business as usual scenario (Table 5.23).

Table 5.23: Projected LULC classes Areas in Hectares by 2028

LULC Class	Area (Ha)	Percent %
Dense Forest	4011	12.2
Low Forest	10,255	31.2
Built up/Bare/Concrete	10,181	15.3
Recent Fallows and Grassland	5040	30.9
Water Body	3426	10.4

Total	**32,914**	**100.0**

5.4 Vegetation Cover Change Analysis in the Bosomtwe District

5.4.1 Introduction

This section presents the analyses of the vegetation cover change, using the results from the NDVI as well as the LULC classification obtained from the satellite images.

There is a direct relationship between LULC changes and vegetation cover changes. In this regard, this subsection relates the results of the LULC changes presented in the previous subsections in this very chapter, with the vegetation cover changes by comparing the normalized difference vegetation index (NDVI) derived from the landsat images.

Human interactions with the natural environment have invariably led to perpetual degradation of land and vegetation, to meet livelihood and development needs (Higginbottom and Symeonakis, 2014; Maitima *et al*., 2004). The environmental consequences of land, water and forest resource degradation in the Bosomtwe district, as identified by the study, has potential to perturb vegetation resources, with implication for inter-generational resource insufficiency (Appiah *et al*., 2014c).

The objective of this chapter, is to analyze the normalized difference vegetation index (NDVI), as a proxy for the measurement of vegetation quality, particularly, forest cover health and resilience to forest cover changes in the Bosomtwe District in the Ashanti region of Ghana.

5.4.1.1 The Underpinning Theory for NDVI

The Normalized Difference Vegetation Index (NDVI) is a numerical indicator that uses the visible red (VR) and near-infrared (NIR) bands of the electromagnetic spectrum, to analyze vegetation health (Tucker *et al*., 1991); to ascertain whether vegetation is live green or not. By transforming raw satellite images into NDVI values, resultant output image products can be analyzed to estimate vegetation type, amount, and condition of land surfaces around the world (Higginbottom and Symeonakis, 2014). NDVI is especially useful for continental to global-scale vegetation monitoring because it can compensate for changing illumination conditions, surface vegetation cover and LULC dynamics (De Jong *et al*., 2011).

NDVI does tend to saturate over dense vegetation and sensitive to underlying soil color (Nath, 2014). The NDVI values can be averaged over time to establish normal growing conditions in a region for a given time of year. By this approach, NDVI can reveal where vegetation is thriving and where it is under stress, as well as changes in vegetation due to human activities such as deforestation, natural disturbances such as wild fires, or changes in plants' phenological stages (Wessels *et al*., 2004; Kaggwa *et al*., 2008; Zhang *et al*., 2011).

It is also used to measure how in contrast, other land use types differ in reflectance in the NIR and visible red bands of the electromagnetic spectrum (Jackson and Huete, 1991). The NDVI is widely applied to vegetative studies to estimate crop yields, pasture performance, and rangeland carrying capacities. Furthermore, it is often directly related to other ground parameters such as percent of ground cover, photosynthetic activity of the plants, surface water, leaf area index (LAI) and the amount of biomass (Huete, 1988).

5.4.2 Analysis of the NDVI and LULC maps from 1986 to 2007

The images analyzed from 1986 to 2007 yielded different NDVI values for each of the land use types for the respective years. This demonstrated how vegetation had thrived and continues to thrive over the temporal periods under consideration. The NDVI values obtained for the various images corresponded to the LULC classes. Areas of vegetation and non-vegetated areas showed moderate to very low NDVI values.

The NDVI values obtained from the 1986 image showed that although the district was generally devoid of vegetation cover, remnant patches of dense and open forest had moderate to high values of between 0.343 and 0.551, and 0.270 to 0.343 respectively. Non-vegetated areas such as bare surfaces had low NDVI values of 0.150 to 0.270 (Figure 5.13a). The build up and concrete areas and water areas, as expected, were extremely low in NDVI values of between -0.378 and 0.150. This result indicates that the district at the time was dominated by low to moderate vegetations cover; and some patches of dense forest cover. Analysis of Landsat TM 1986 imagery further depicts limited closed forest cover as dense forest and extensive open forest with recent fallows, with grass lands over the area (Figure 5.13b).

5.5 Relationship between LULC and NDVI for the Study Area

This subsection describes the relationship between the LULC types and the NDVI characteristics derived from the Landsat images. These explain the effects of human land use activities on the vegetation cover abundance and resilience.

5.5.1 Estimated NDVI Values with LULC Classes of 2002 Image.

Further analysis of the 2002 imagery showed evidence of more vegetation cover in 2002 compared to 1986. This is possibly because the 2002 image was captured during the rainy season which supported rapid vegetation growth unlike the 1986 dry season image associated with stressed vegetation. Generally, the NDVI values for dense forest and cocoa cultivated lands ranged between

0.384 and 0.570. Recent fallows/grassland and bare lands had NDVI values of between 0.081 and 0.250 (Figure 5.14a). Water bodies and build up/bare surfaces had low values of -0.462 and +0.081 respectively. Image classification results for the same year 1986 showed dense forest occupied 5,834 hectares of the land, open woodland 12,722 hectares and built up/ bare areas 1201 ha. The vegetation cover types therefore, indicate that the area is covered by low to moderate forest covers by 9330 ha (Figure 5.14b).

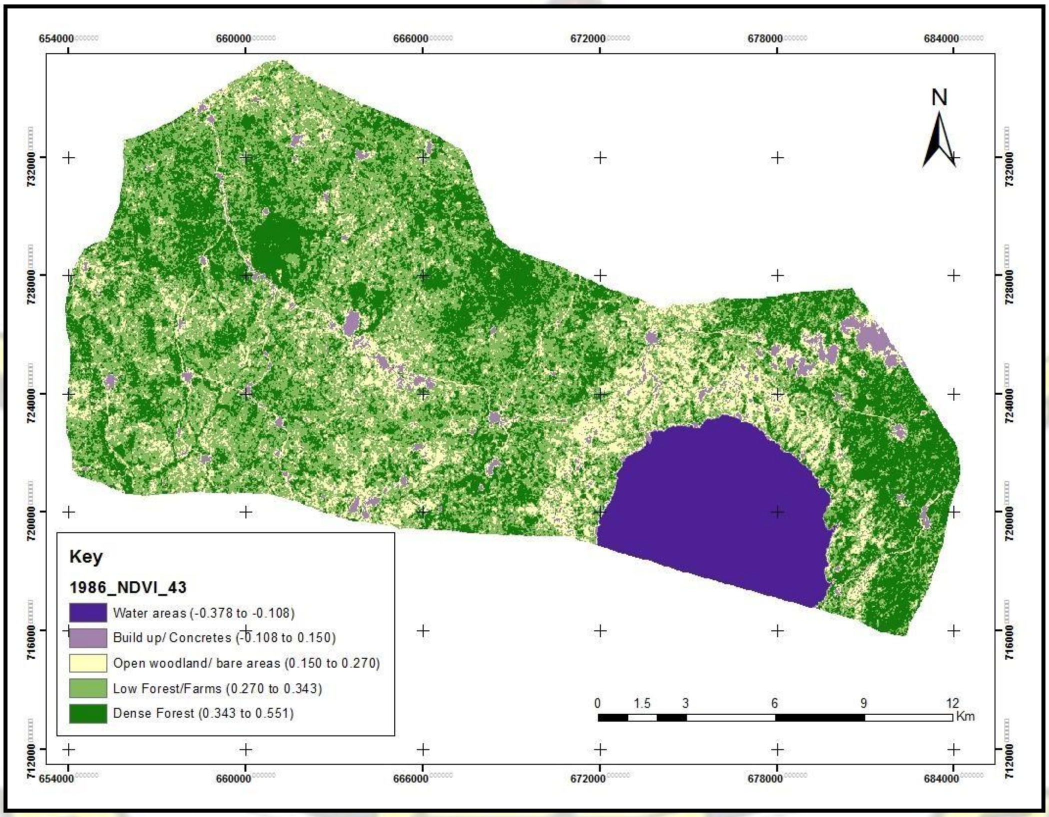


Figure 5.13a: Normalized Difference Vegetation Index (NDVI) map of 1986 image

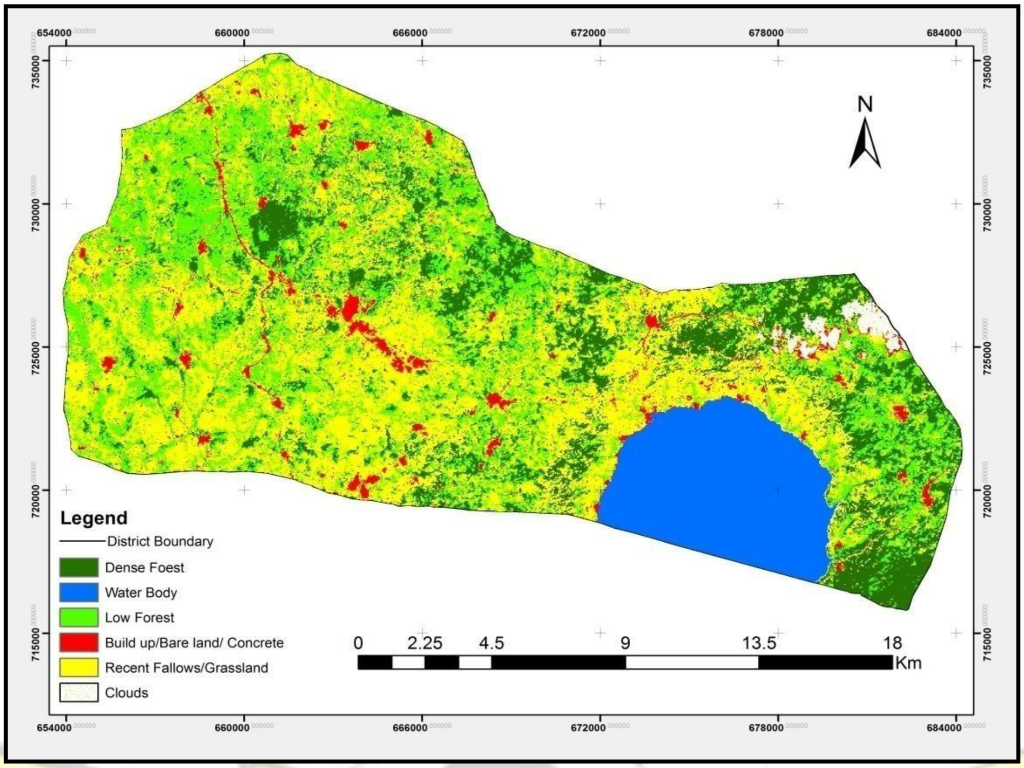


Figure 5.13b: LULC map of 1986 image

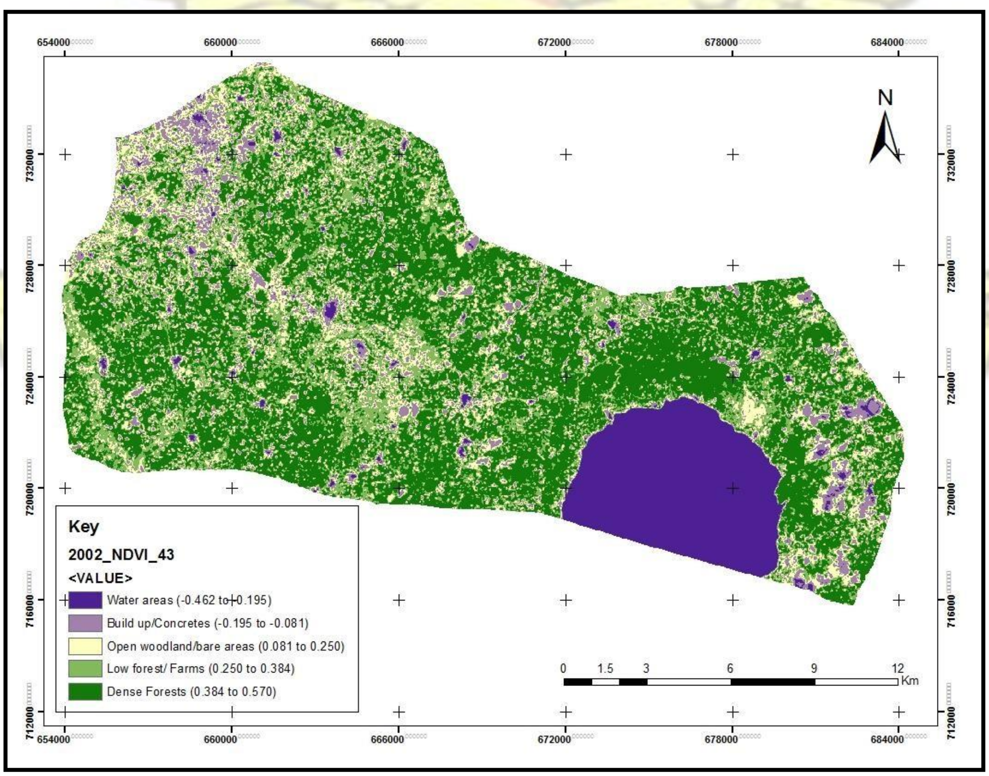


Figure 5.14a: Normalized Difference Vegetation Index (NDVI) map of 2002 Image

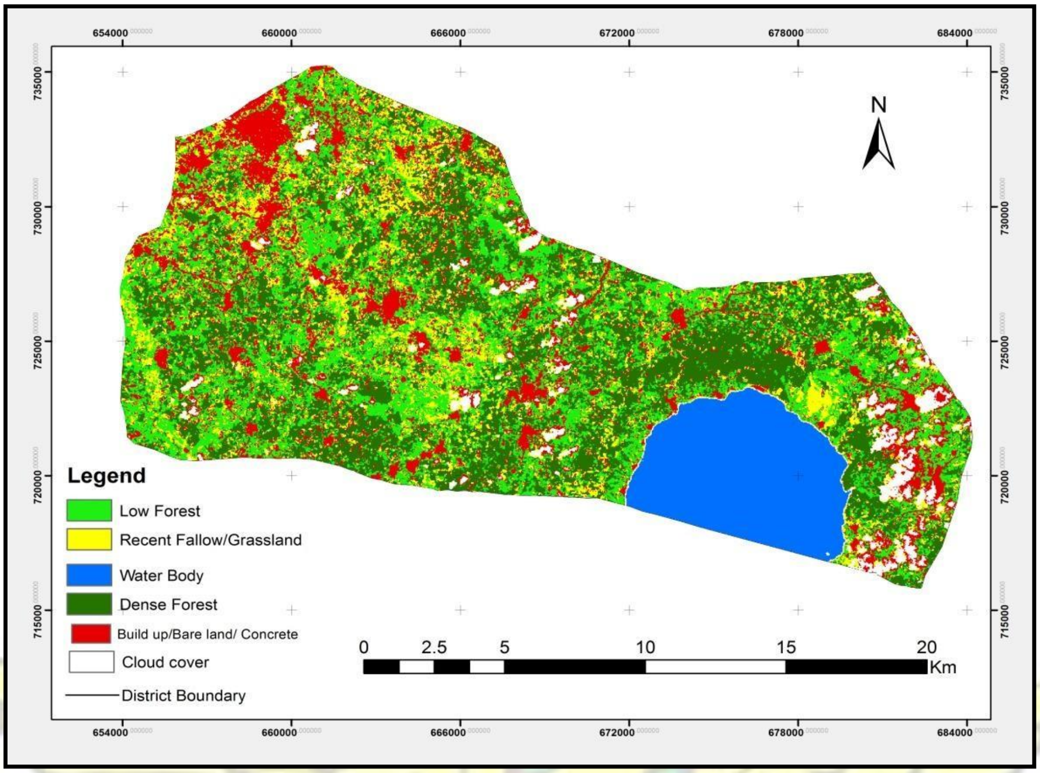


Figure 5.14b: LULC map of 2002 image

5.5.2 Estimated NDVI Values for 2007 Image

The NDVI values for the 2007 image showed vegetation health decline per the extremely low photosynthetic vegetation health indicator. From the 2007 image, the vegetation health improved from the previous year (2002) cover by 8761 hectares. NDVI values for dense and cocoa/farmlands are low, ranging from 0.056 to 0.243 and -0.014 to 0.055 respectively (Figure 5.15a). Open woodlands and bare lands had NDVI values of between -0.111 and -0.014. Water bodies, build up and concrete surfaces had very low values at -0.463 to -0.286.

The land use types classified as open woodland and build up/ bare surfaces certainly have little or no vegetation cover hence the low range values of -0.286 to +0.270 (Table 5.23). LULC categories that corresponded with the moderate vegetation and dense vegetation do not have high photosynthetically active reflectance (PAR) signatures. This means that LULC changes impact the vegetation quality negative in the district (Table 5.24a & 5.24b).

Table 5.24a: Composite table of the NDVI values from 1986 to 2007

NDVI Value Category	NDVI Value 1986	NDVI Value 2002	NDVI Value 2007
No Vegetation	-0.378 to -0.108	-0.462 to -0.196	-0.463 to -0.286
Less Vegetation	-0.108 to 0.150	-0.195 to -0.081	-0.286 to -0.111
Less-Moderate Vegetation	0.150 to 0. 270	-0.081 to 0.250	-0.111 to -0.014
Moderate Vegetation	0.270 to 0.343	0.250 to 0.384	-0.014 to 0.056
Dense Vegetation	0.343 to 0.551	0.384 to 0.570	0.056 to 0.243

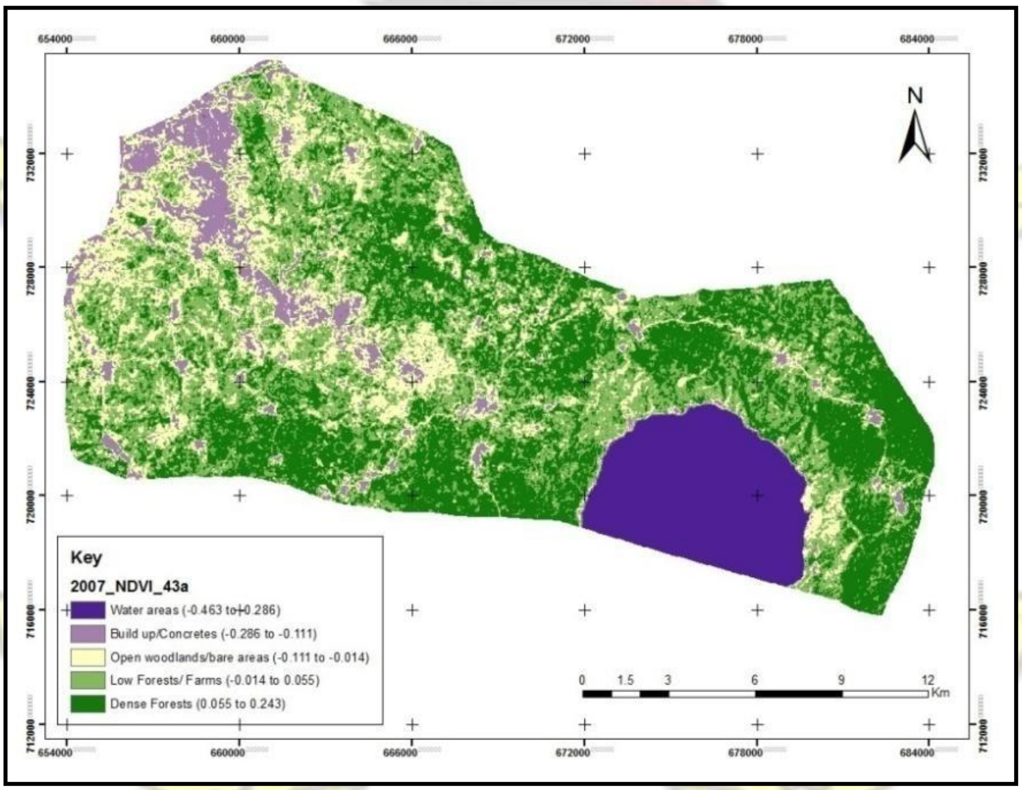


Figure 5.15a: Normalized Difference Vegetation Index (NDVI) map of 2007

Table 5.24b: Composite table of the NDVI values from 2010 and 2014

NDVI Value Category	NDVI Value 2010	NDVI Value 2014
No Vegetation	-1 to -0.278	-0.049 to 0.064

Less Vegetation	-0.278 to -0.067	0.065 to 0.184
Less-Moderate Vegetation	-0.067 to 0.043	0.185 to 0.241
Moderate Vegetation	0.043 to 0.122	0.242 to 0.283
Dense Vegetation	0.122 to 0.299	0.284 to 0.390

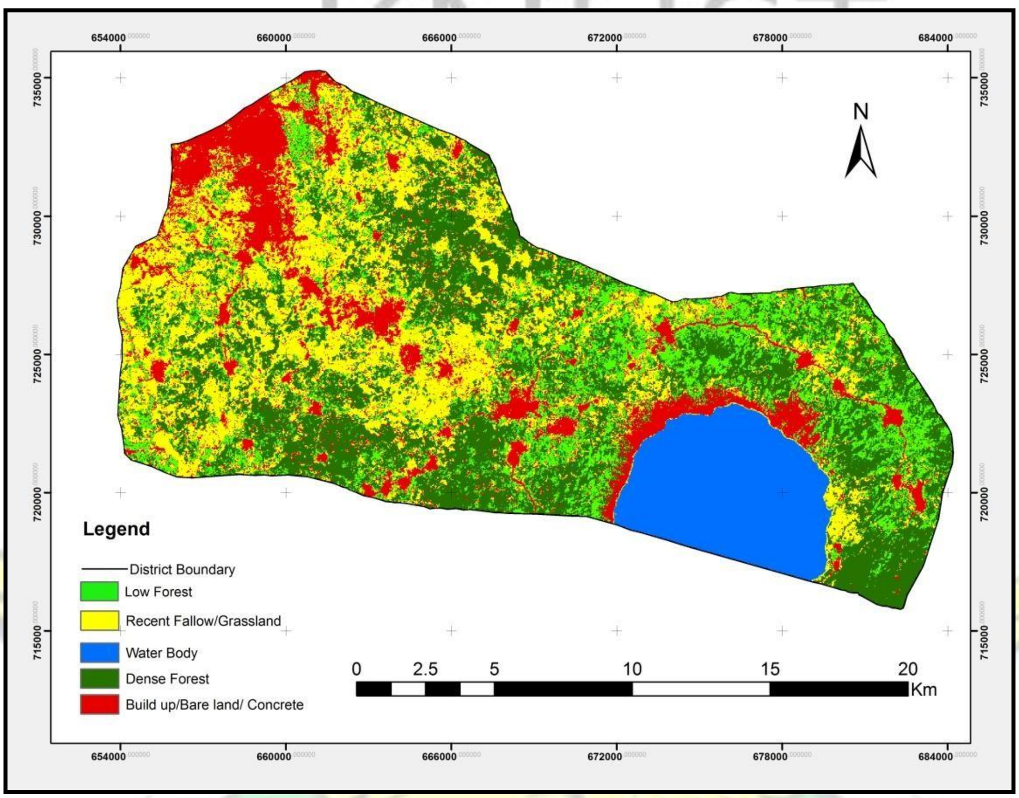


Figure 5.15b: LULC map of 2007 image

Interpretation of results in Table 6.2 shows dense forest area increased from 5834 ha in 1986 to 8760 ha in 2002. In 2007, this vegetation cover type further increased to 12,394 ha. Low forest with cocoa and farmlands changed marginally from 9,180 ha in 1986 to 9329 ha in 2002 but decreased sharply in 2007 to 6, 183 ha. Built up/bare areas increased in size as the infrastructure of the district in 1986 was 1201 ha but increased to 5664 ha in 2002. Water bodies maintained their sizes from 1986 to 2007 (Fig. 6.15b; Table 5.24).

5.6 Conclusion

Two distinct results emerged from the analysis of LULC change dynamics. First, the transition trends in the various LULC types may be conjectured that the Bosomtwe district would continue to experience the changing LULC types. The direction of change would be by the conversion from arable land use and forest land cover to residential and commercial uses. Secondly, these conversion trends are most likely to be influenced by increasing number of people moving into the district. This is because the seeming availability and easy access to land in terms of, its affordability presents the Bosomtwe district as an attractive area for resettlement; as the income statuses of re-settlers improve.

The overall condition of the vegetation cover is the decreasing quality of the vegetation expressed in terms of the low NDVI values generated from the landsat images. The maps support the results of decreasing trend of vegetation cover obtained from the LULC classification maps. Vegetation cover may be marginally increasing in terms of low forest category; however, the long-term adverse impacts of potential human LULC activities on vegetation depletion can be conjectured.

CHAPTER 6: ANALYSIS OF RAINFALL AND TEMPERATURE FOR CLIMATE VARIABILITY IN THE BOSOMTWE DISTRICT

6.1 Introduction

There is no doubt, that changing LULC and deforestation and forest lands degradation, which the study has presented in chapters five and six respectively, have implications for the variability and change of local climatic factors such as temperature, rainfall, and soil moisture. In this chapter, the results from the analysis of the climatic data, using the classical serial data and Mann-Kendal trends analyses are presented.

A trend is a significant change over time, evidenced by a random variable. These can be detected by statistical parametric and non-parametric procedures. Onoz and Bayazit (2003) indicated that the parametric *t*-test has less ability than the non-parametric Mann–Kendall test when the probability distribution is skewed. In practical applications, however, both can invariably be used interchangeably, with similar outcomes. This study, aimed at trend detection and cross verification. For this reason non-parametric statistical procedure was employed to the rainfall time series, grouped into three decadal clusters.

The rainfall time series were disaggregated in the annual time series and also into quarterly (January-March, April—June, July—September and October—December) groups, to further observe potential changes at the seasonal scale. Moreover, to quantify whether trends appear particularly severe during a particular time interval of the reference period, time series are also divided into the following three partially overlapping 31-year periods: 1981–1990, 1991–2000 and 2001–2011.

6.2 Results of the Analysis of Rainfall Data

The results of the MAKESEN‘s Solver in EXCEL revealed that apart from the three months of May, August and November, which recorded decreasing rainfall trends with a decrease of 0.4mm, 0.75mm and 0.2mm/month, all the other months recorded increasing rainfall trends. The highest of these was recorded in the month of October with an increase of 4mm/ month over the 31-year period (Table 6.1). The month of June was significant at the 95% significance level while the month of October as well as the annual total were significant at 99% significance level respectively.

Table 6.1: Result of Mann-Kendall and Sen’s Slope Statistics of Rainfall Values

Months	First year	Last Year	n	Test S	Test Z	Signific.	Q(mm/month)
January	*1981*	*2011*	*31*	*-0.5*	1.92		0.262
February	*1981*	*2011*	*31*	*-22.9*	1.22		1.000
March	*1981*	*2011*	*31*	*-247.2*	0.14		0.340
April	*1981*	*2011*	*31*	*-38.7*	1.73		2.245
May	*1981*	*2011*	*31*	*-180.3*	-0.27		-0.400
June	*1981*	*2011*	*31*	*-126.4*	2.04	*	3.427
July	*1981*	*2011*	*31*	*-188.9*	0.75		1.347
August	*1981*	*2011*	*31*	*-89.1*	-0.58		-0.750
September	*1981*	*2011*	*31*	*-188.8*	1.29		1.491
October	*1981*	*2011*	*31*	*-177.7*	2.79	**	4.358

November	*1981*	*2011*	*31*	*-64.3*	-0.17		-0.156
December	*1981*	*2011*	*31*	*-20.6*	1.61		0.733
Annual	*1981*	*2011*	*31*	*-112.1*	2.92	**	1.475

*significant at α 0.05’ **significant at α 0.01

To ascertain the degree of trend of the rainfall pattern over the 31 year period, a graphical inspection of the various intra-seasonal values, following the general linear equation Y= bX+c, was informative. The trends were indicated by the various equations of the slope (Y = QX+B) lines. These were also compared with the Sen‘s slope estimates for the individual months as well as the annual average, indicated. Although, according to the results from the MAKESEN‘S Solver, the Sen‘s slope estimate indicated that only the months of May, August and November recorded decreasing trend in the rainfall (Table 6.1), there were inherent intra-quarterly decreases in rainfall trends upon the disaggregation of the data.

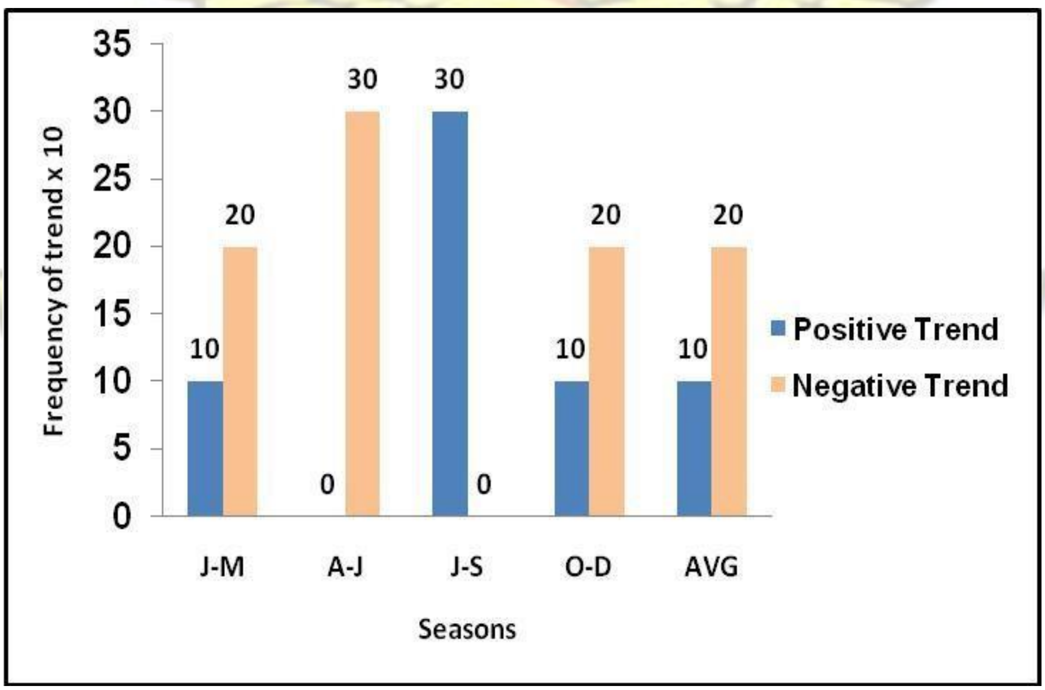


Figure 6.1: Frequency of Trend types in rainfall over the 31-year period

On the contrary, the intra and inter-seasonal (Quarterly) comparisons yielded as many as a 50% decreasing for the first and the last quarters, as well as the annual average, while the second quarter (April-June) inherently indicated a 100% decreasing trend. Only the third quarter (JulySeptember), showed a 100% increasing trend (Figure 6.1).

Table 6.2: Slope Estimate of the Inter-Seasonal Rainfall Trends (1981-2011)

Years	Jan.—Mar.	Apr.—May	July-Sept.	Oct.—Dec.	Average
1981-1990	-1.756	-0.768	0.628	-1.781	0.920
1991-2000	-2.616	-9.430	6.627	-1.655	-1.770
2001-2011	1.826	-2.634	6.923	2.661	2.194
1981-2011	0.529	2.131	1.208	1.917	1.446

A crucial case in point as observed was the decreasing trend over the last decade from 2001 to 2011. Within the major rainy season of April to June, there was a reduction in the rainfall amounts by 26mm/decade while the minor season from July to September recorded a decadal average increase of 69.2mm. In general, the rainfall trend showed an increasing trend over the last decade (2001-2011), using the annual average over the 10-year period. This implies that there is a seeming increasing trend of rainfall amounts into the future.

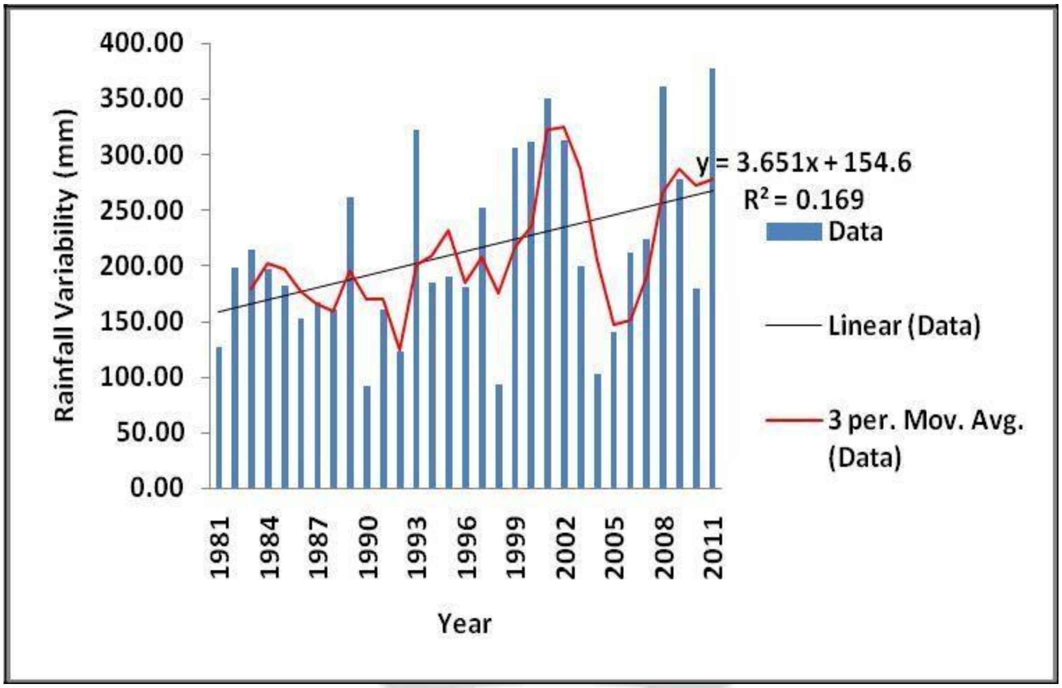


Figure 6.2: Inter-decadal rainfall variability (1981-2011)

Although the data indicate a generally increasing trend in the rainfall patterns over the 31 year period (Figure 6.2), the inter-annual trends, disaggregated by decadal comparisons showed otherwise. In these comparisons, there were more inherently decreasing rainfall trends over the years (Figures 6.3), particularly from the earlier years of 1980 to the 1990s. This therefore presents a cautious situation when predicting the pattern and trends of the rainfall into the future. It may also be misleading to anticipate that rainfall trends are increasing over the years, *pari paso*, judging from the seemingly increasing trends.

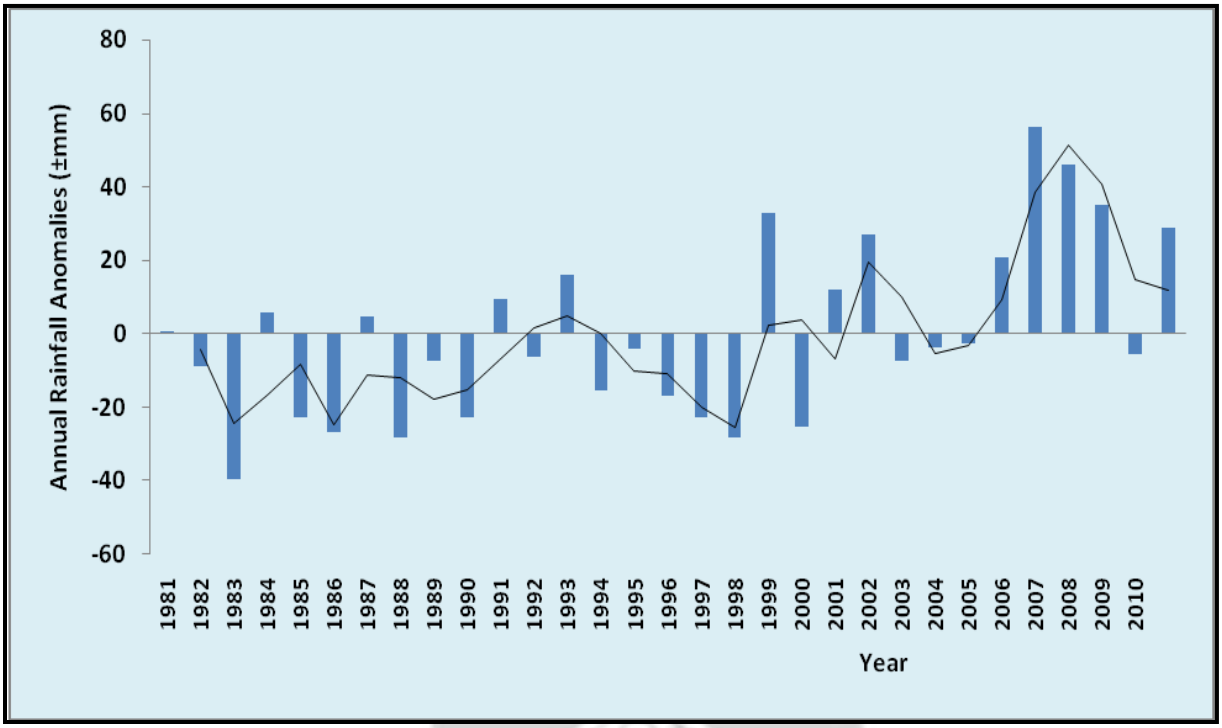


Figure 6.3: Mean Annual rainfall anomalies from 1981-2011

In the three decade period from 1981 to 2011, annual rainfall averages have to a greater extent been below the annual average baseline of 1339.8mm. Only thirteen (13) years out of the 31-year period had their average above the baseline average. These were 1981, 1984, 1987, 1991, 1993, 1999, 2001, 2002, 2006, 2007, 2008, 2009 and 2011. For the first decade of the period under study, decreasing trend seemed to prevail as only 1984 had an increase above 1339.8mm.

In the second decade period from 1991 to 2001 five years recorded averages above the baseline of 1339.8mm. The last decade, spanning from 2001 to 2011 had six years in a row, recording an increase trend in rainfall above the annual average baseline of 1339.8mm, with rainfall amount between 2006 and 2009, being significantly increasing. This suggests that rainfall trend has been oscillating (Figure 6.4). The triennial decadal average per season experienced variation with a minimum deviation of 38.7mm in 1990 and a maximum deviation of +673 in 2007; this gives an annual average surplus of rainfall of 10mm/year.

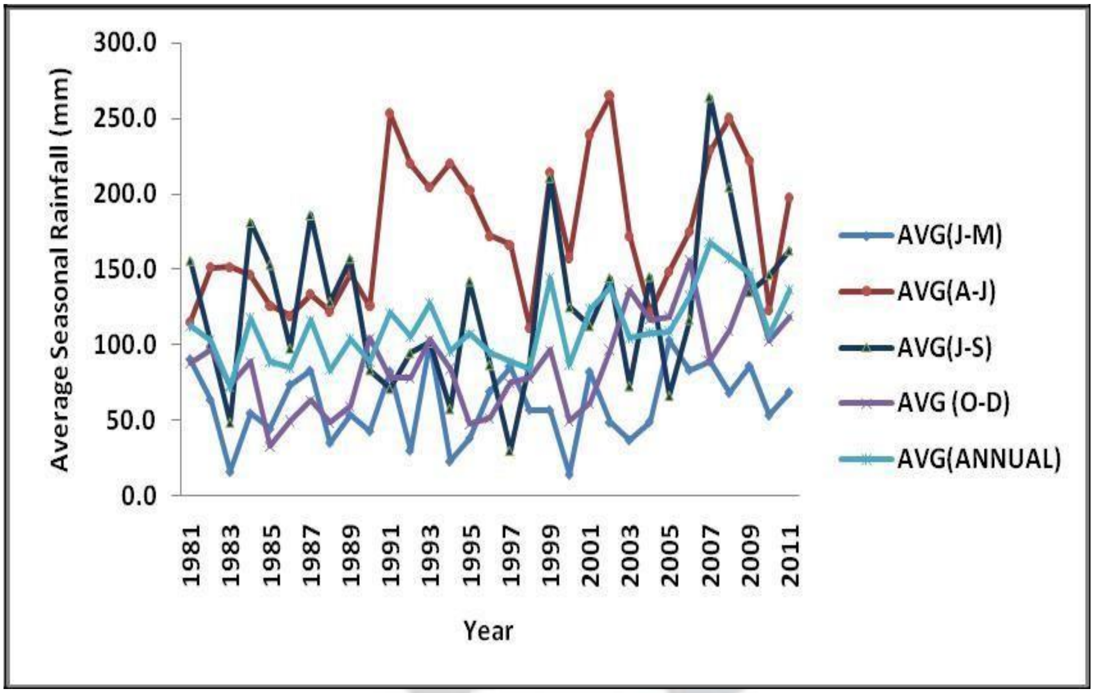


Figure 6.4: Seasonal variability from 1081-2011

6.3 Analysis of Trend in the maximum Temperature Values

The trend in the temperature was also ascertained using the Mann-Kendall and Sen‘s slope estimate in the MAKESEN‘s 1.0 solver in EXCEL. The Temperature values grouped into monthly averages over the 31 year-period (Table 7.3).

The Mann-Kendall trend and Sen’s slope analysis indicated that there was a generally increasing trend in maximum temperature values over the years. For each month, the temperature indicated an increasing slope from a low of 0.05°C/month for the months of April to as steep as 0.1°C per month for the months of May, over the 31-year period. August and September trends were significant at the 95% level of significance while the months of April, July and October were significant at the 99% level of significance. As many as four months (May, June, November and Decembers) together with the annual total trends were significant at the 99.9% level of significance.

Table 6.3: Result of Mann-Kendall and Sen’s Slope Statistics

Time series	First year	Last Year	n	Test S	Test Z	Signific.	Q

January	1981	2011	31	-33	0.78		0.011
February	1981	2011	31	-33	0.20		0.000
March	1981	2011	31	-33.1	1.23		0.020
April	1981	2011	31	-33	3.12	**	0.052
May	1981	2011	31	-30.7	5.36	***	0.110
June	1981	2011	31	-30.3	4.30	***	0.079
July	1981	2011	31	-29.5	3.17	**	0.057
August	1981	2011	31	-28.9	2.23	*	0.050
September	1981	2011	31	-30	2.35	*	0.040
October	1981	2011	31	-30.8	2.64	**	0.047
November	1981	2011	31	-31.4	3.92	***	0.067
December	1981	2011	31	-30.6	5.33	***	0.089
ANNUAL	1981	2011	31	-31.1	4.76	***	0.063

*significant at α 0.05, **significant at α0.01, ***Significant at α0.001*

6.3.1 Inter-annual Temperature Variability

This section analyses and discusses the results from the data treatment and modelling in the context of the changing dynamics of temperature values recorded over the 31 year period. These were used as the basis for the forecast into the next 4 years; to make the data fulfill complete climatic cycle. Between 1981 and 2011, only six of the 31-year mean annual temperature data analyzed (1985, 1993, 1996, 1999, 2007 and 2010) was up to 2% below the moving average, off the mean set to 0ºC. Six of the remaining years (1987, 1995, 1998, 2005, 2008 and 2009), recorded temperature values of up to 1% above the moving average, which is the baseline. There was no particular year with any extreme temperature value recorded.

6.3.2 Intra-annual Variability of Temperature

It is obvious that temperature varied from one year to another, depicting distinct variation within the major rainy season (i.e. May to July) and minor rainy season (i.e. August to October), in the context of Ghana. The temperature values were below the normal, from 1981 up to 1995. Then the temperature started increasing from 1996 up to 2008; all these years had the major rainy seasons warmer than the minor rainy seasons (August to October). March and April were the warmest months, with July and August being the coolest months, as shown in Figure 6.5. The coolest and warmest years were 1985 and 2003 with annual temperature of 30.9ºC and 32.7ºC respectively.

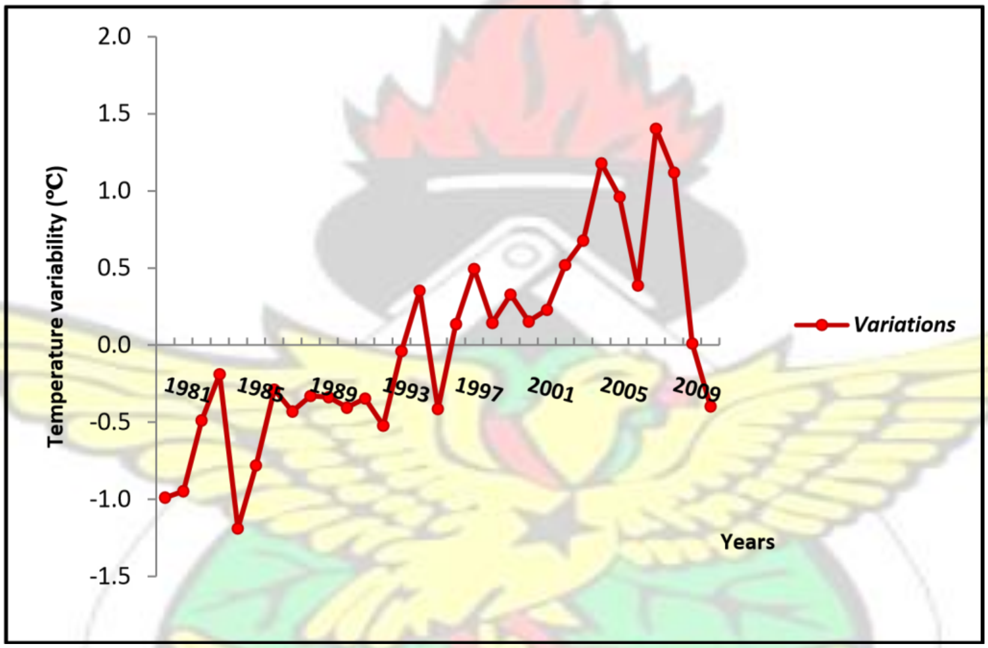


Figure 6.5: Temperature variability about the baseline temperature (1981-2011)

Regarding the temperature anomalies occurring within the various months of the years, the mean monthly temperature varied from one month to the other, especially in the major rainy season (i.e. May—July) and minor rainy season (i.e. August—October). It can be seen from Figs. 6.6— 6.9 that the major seasons were relatively warmer than the minor rainy seasons, although they received comparatively much rains than the minor seasons. Warm temperatures could imply a higher soil evapotranspiration and the drying up of land surfaces and water bodies as consequences.

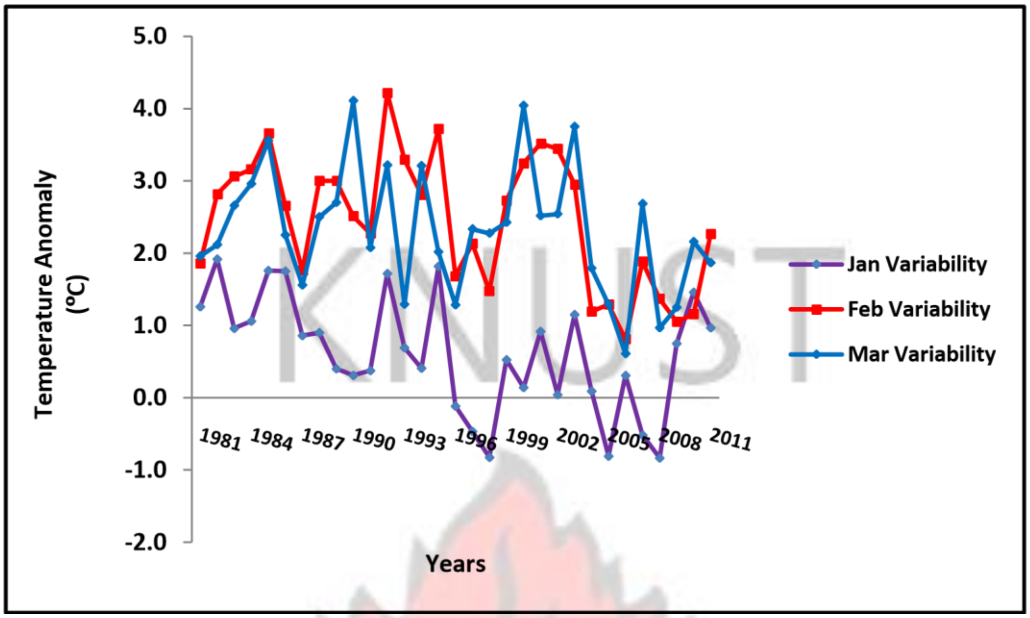


Figure 6.6: First intra-quarterly mean monthly temperature variability between 1981and 2011

It can be seen from Figure 6.6 that the mean monthly temperature for each of the 31-year period departed from the normal average baseline of 32.1 °C. Most of the average temperature for all the months over the period was higher than the district's baseline. The highest negative deviation was in 1985 (20°C– 32.1)°C, with the highest positive being 2005 and 2008, when the baseline was equal to the annual average as (33.2-32.1)°C and (33.7-32.1)°C respectively. The range of temperature from 1997 when temperature begun to increase steadily up to 2011 is 1.8 (i.e. 32.5-31.7)°C.

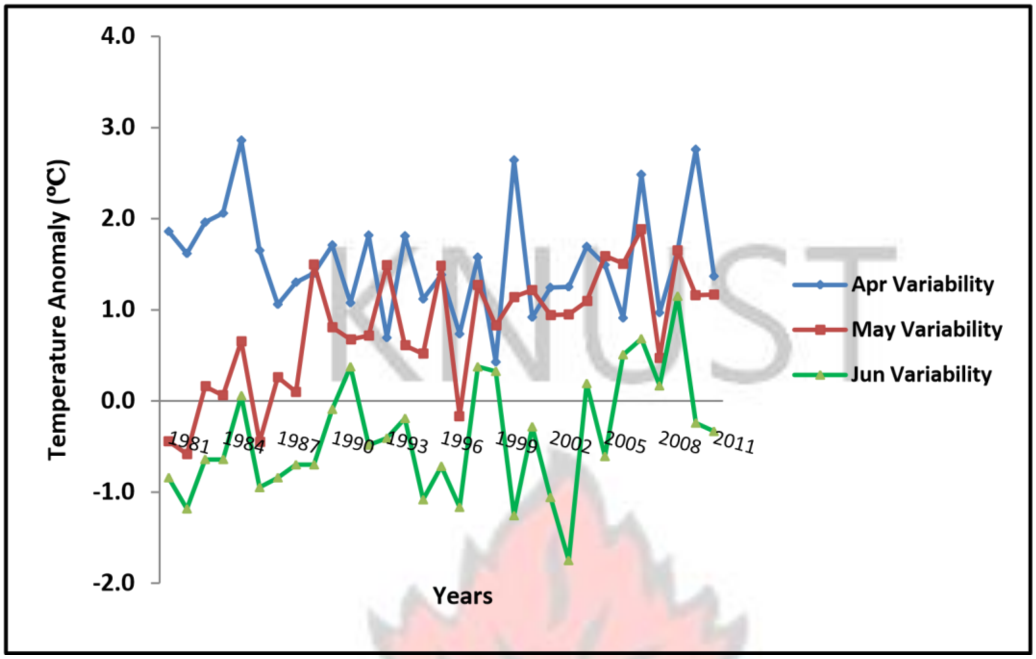


Figure 6.7: Second intra-quarterly mean monthly temperature variability between 1981 and 2011

The last two-quarters have in most cases exhibited lower temperature anomalies. However, temperature values from July to September over the years were all below the climatologic normal (Figure 6.8). The characteristics decrease in temperature from the months of April to June as shown in the previous two decades (1981 to 1990 and 1991- 2000), almost stabilized in rates of decreases over the last 10 years (2001 to 2011). At the same time the gradual increase in temperature after September towards December each year, as was observed in the two previous decades, was replaced by the sharp increase in temperature over the last 10 years (Figure 6.9). These intra-quarterly variability notwithstanding, points to an increasing trend of temperature over the past three decades, in the Bosomtwe district.

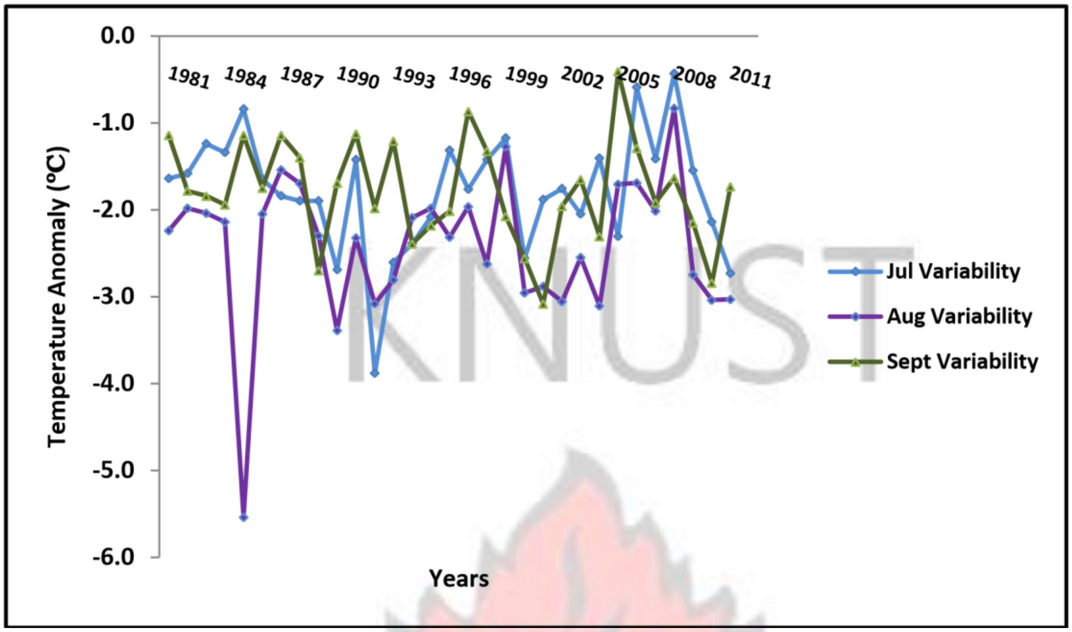


Figure 6.8: Third intra-quarterly mean monthly temperature variability between 1981 and 2011

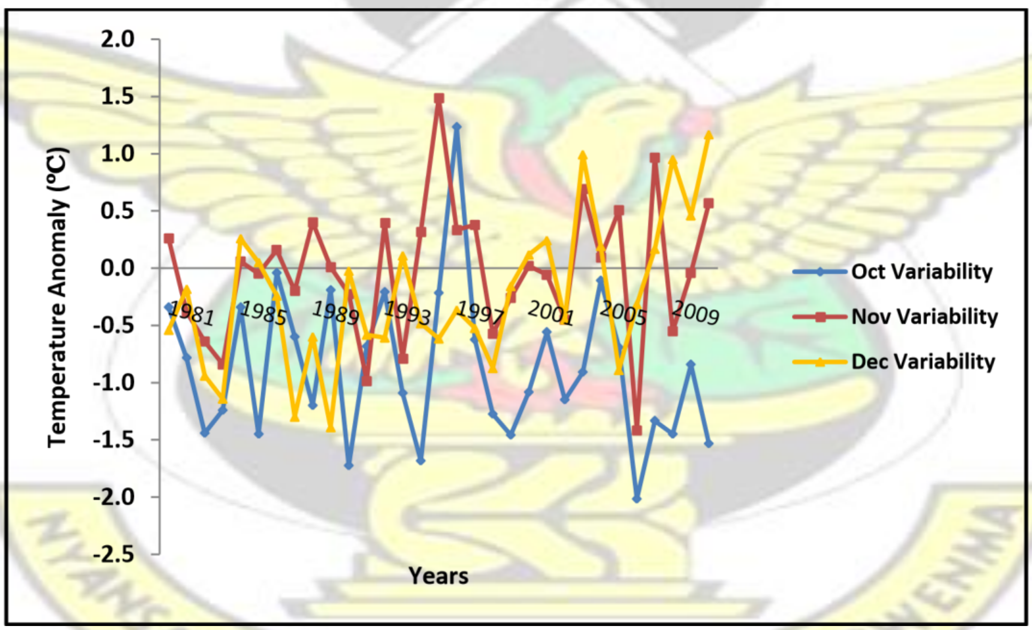


Figure 6.9: Final intra-quarterly mean monthly temperature variability between 1981 and 2011

6.4 Forecasting from the Time Serial Analysis and fitting the Regression

The summary of output of the trending which was determined by the regression model, indicated a correlation r = 0.82 and an adjusted R^2 = 0.68. which means the model is able to offer 68%

explanations to the dependent variable, temperature data Y_t as has been accounted for by the independent variable time (*t*). The analysis of variance (ANOVA) statistics also indicates a significance *F* statistic at *p*-value ($p < .000$). Further the coefficients of the independent variable t and the intercept for the regresssion (trend) line, were approx. 0.06 and 31.2ºC respectively. Both statistics were again significant at $p < .000$ at 99.9% confidence intercvals of between 30.9ºC to 31.5ºC respectively. The overall modelling output of the time series data is displayed in Figure 6.10.

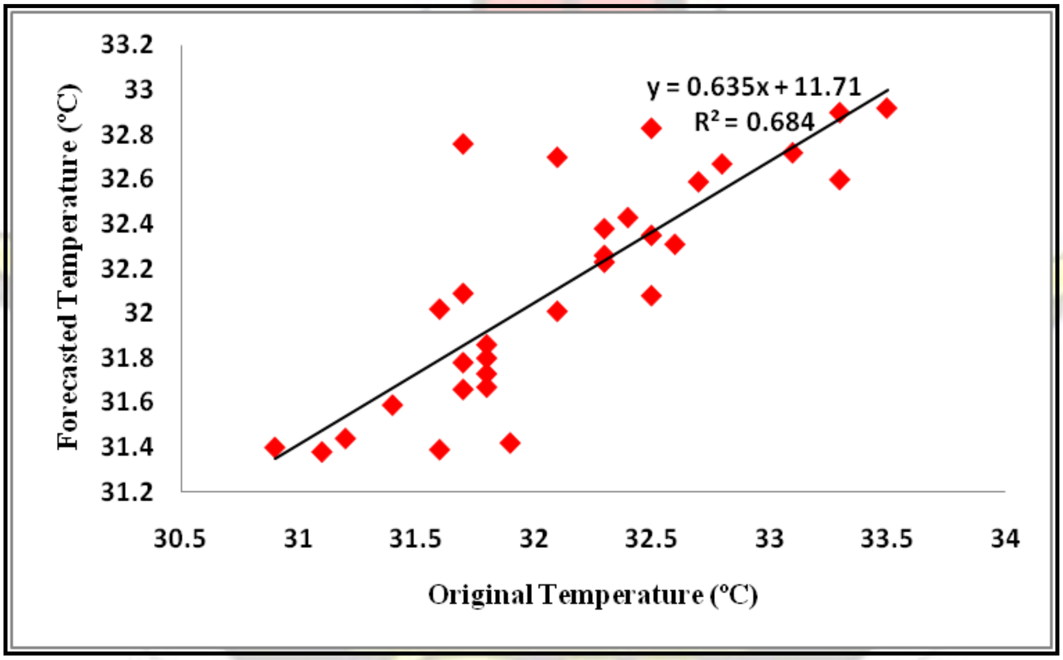


Figure 6.10: Regression of Maximum Temperature with Forecasted Maximum Temperature

The results of the time series modelling show that temperature values are increasing as the trend shows in Figure 6.11. The annual departures from the Moving Average (MA) are aggregated in the seasonality and the irregularity components. The range of departures was between the temperature range of -2 to +1% below and above the moving average respectively (Appendix 5). On the whole, however, the temperature dynamics showed an increasing trend over the three decades.

The increasing temperature as it varies around the central moving average curve indicates that, there is an inherently warming in the air temperature of the district, over the past 31 years. The forecast temperature values show an increase in temperature by about 1º C, and will continue to increase from the current annual average of 32.8ºC to about 33ºC all things being equal, and considering the trend of increase (Figure 7.11). It can be seen that for every five years of mean annual temperature records; there is an increase in temperature by 0.30ºC. This trend shows prospects of repetitions even on the forecasted years from 2012 to 2015, when a complete climate cycle would have elapsed. This, however, should be considered purely on the assumption of trend constancy.

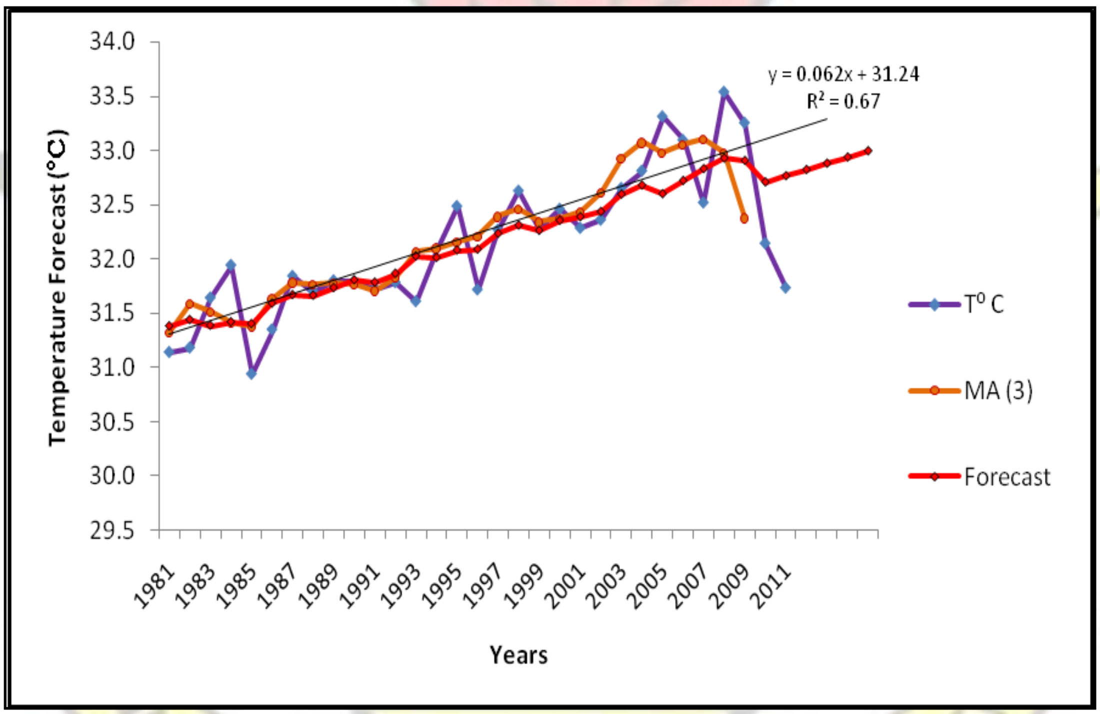


Figure 6.11: Time series forecast of mean annual temperature of the Bosomtwe District

6.5 Conclusion

The analyses of the temperature and rainfall figures over the 31-year period indicated increasing trends in both variables. The inter-quarterly temperature anomalies generated, depicted a generally increasing trends in the mean monthly temperature for the various years particularly over the last two inter-decadal periods of (1990-2000 and 2001 to 2011). Forecasted mean annual temperature values for the 4 ensuing years showed increasing trend.

Rainfall patterns according to the Mann-Kendal trend analysis showed general increasing trends. However, when the trend was disaggregated by inter decadal (1981-1990, 1991-2000 and 2001-2011) and intra seasonal (January—March, April—June, July—September and OctoberDecember) categories, the rainfall values showed a decreasing trend. This was particularly evident in the seemingly rainy season of April to June. The analysis concludes that there is the need to be conscious about the potential consequences of increasing warming and inherently decreasing rainfall pattern, which have consequences for the local climate variability and climate change in the Bosomtwe district.

CHAPTER 7: LAND SURFACE TEMPERATURE EXTRACTS

7.1 Introduction

In the previous chapter, the study analyzed climatic data, using temperature and rainfall as proxies to explain the local climate variability and climate change in the district. This chapter further related the effects of LULC changes on land surface temperature profiles as surrogate of local climatic conditions. This has been done to extract the cooling and heating profiles from the image, the rural cool and peri-urban heat troughs.

Land surface characteristics determine the amount of energy that could be absorbed and emitted. The reflectance properties of the land surface features also determine the albedo that defines the percentage reflectance of solar energy from the earth surface (Ahrens, 2005). As a proxy to determine the degree of hotness or coldness of the land surface, many researchers have used thermal infrared (TIR) satellite remote sensing methodology, to estimate the land surface reflectance properties to extract surface temperature and moisture for climatic analysis (Ramachandra *et al*., 2012; Rajeshwari and Mani, 2014; Liu and Zhang, 2011 and Srivastava *et al*., 2010). LULC dynamics give credence to the surface ability to absorb or reflect solar radiation in varying proportions.

7.1.1 The New Concepts of Peri-Urban Heat Trough (PuHT) and Rural Cool Trough (RuCT) Many studies have concentrated attention on the generation of temperature profiles to measure the urban heat islands (UHI) fluxes (Liu and Zhang, 2011 and Srivastava *et al*., 2010; Mbithi *et al., nd*; Weng *et al*., 2004 and Weng, 2001). Climate change may well modify the urban heat island and rainfall effects, but the quantitative extents are unknown at this time (Blake *et al*., 2011). Most of these studies have not considered explicitly, the potential effects of peri-urban heat trough (PuHT) systems that are potential heat islands in transition from the rural cooling troughs (RuCT), into ultimately, the so-called urban heat islands (UHIs) (Liu and Zhang, 2011).

These surface temperature profiles occur, due to the progressive increase in urbanization of the rural landscape. As a result peri-urbanization processes ensue to alter the originally rural areas towards an urban core. The land surface characteristics therefore results in the cool surface trough, moderate peri-urban thermal trough and an ultimate urban heat core. The resultant is the land surface temperature gradient that develops along the rural to urban continuum.

The various studies on land surface heating fluxes have largely focused on core urban heat islands, as surrogates of extraction urban climates (Srivastava *et al*., 2010). The literature, however, remains scanty on the conspicuous role of peri-urban areas in fuelling the ultimate heat island system. This study proposes that, considering the relatively rapidity with which rural landscapes are being modified into peri-urban land uses with different surface reflectance changing in the directions of built up and paved land uses, it is imperative to analyze the connections between the rural cooling troughs (RuCT) and the peri-urban heat trough (PuHT) systems as potentially full-fledge heat island cell areas. The object of this chapter is to analyze the lands surface temperature derived from three satellite images, as proxy for the potential creation of urban heat island, through peri-urban heat troughs (PuHT) and rural cool troughs (RuCT) continuum, in the Bosomtwe district of the Ashanti region of Ghana.

7.2 Results of LULC of Land Surface Temperature Extracts

The study has revealed that, there is a correlation between LULC classes and the surface temperature profile. This has the tendencies to support the PUHT and RuCT concepts, proposed by this study. The land surface configuration and their attending variability in terms of temperature suggest that NDVI alone may not be a sufficient metric to quantitatively study surface heat island SUHI) systems. To address this problem, Weng *et al*. (2004) earlier proposed using the vegetation fraction found within a pixel derived from a spectral mixture of other LULC fractions, instead of solely relying on NDVI as indicator. Their findings showed that vegetation fraction has a slightly stronger negative correlation with LST.

This paper discusses the omissions of the land surface temperature transitions from the rural, with preponderance of vegetation, to the urban core with high built-up and concrete surfaces. It does so by relating the LULC dynamics of the Bosomtwe peri-urban district, to determine land surface temperature fluxes; typical of peri-urban areas. The introduction of the concepts of the Rural Cool Trough (RuCT) and Peri-urban Heat Trough (PuHT), give credence to the potential LST continuum profiles between the rural cool and urban hot areas, using the peri-urban areas as the transitional zones.

7.3 Analysis of LULC classes for 2002 Image

The LULC classes of 2002, as indicated by Figure 7.1, were an improvement over the previous year's which served as the base year of analysis, in terms of vegetated land area coverage. In 2002, dense forest cover was 8761 ha of the land cover. A proportion of 30% of the land area was covered by low forest vegetation with 9330 ha. Built-up/Bare land and concrete surfaces also covered an area of 5664 ha. The open wood land/ and farm lands were reduced to 4423 ha of the land area, while the lake covered an area of approximately 3435 ha of the total land area.

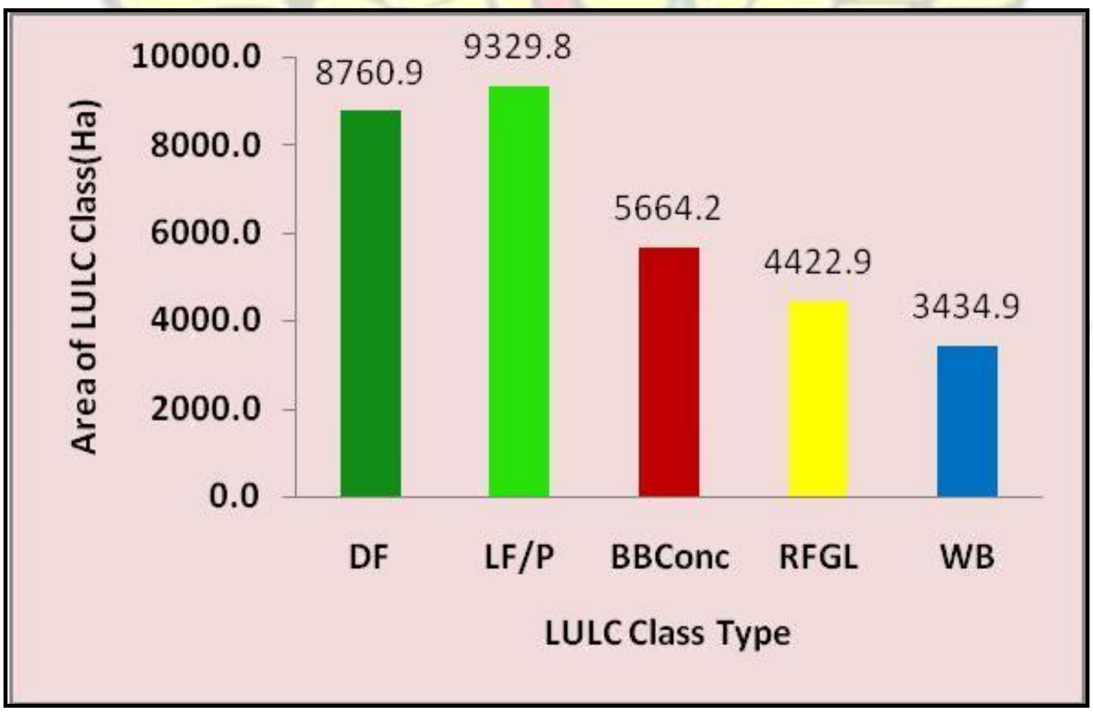
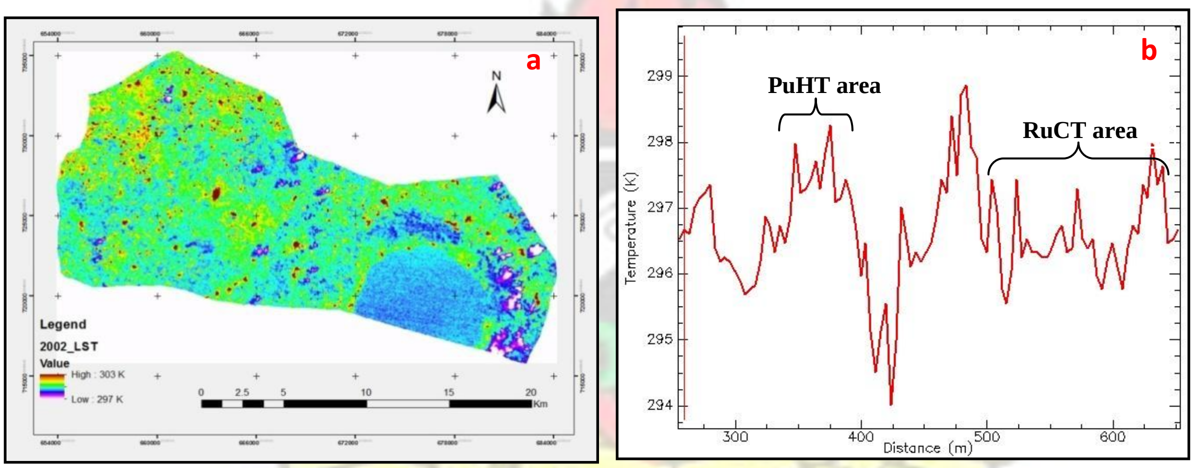


Figure 7.1: LULC classes (LULC) Area (Ha) for 2002

The corresponding surface temperature ranged from a minimum of 24°C to 30°C, with the mean and standard deviation of 36ºC and 9K respectively. The degree Kelvin is the original units of extraction of the surface temperature. This, however, is convertible to the degree Celsius. The surface temperature profile indicated an improved vegetated surface which had relatively reduced the surface heat fluxes, thereby reducing the land surface temperature (Figure 7.2a). This is *in tandem* with Baylis *et al*. (1999)'s assertion that NDVI variables usually negatively correlate with the land surface temperature.



Figures 7.2 (a & b): Land Surface Temperature extracts of the 2002 Image with corresponding surface temperature fluxes

7.4 Analysis of LULC classes for 2007 and Land Surface Temperature for 2008 Images The land use classes in 2007 showed considerable increase in the dense forest cover by 10,300 ha, representing 35% of the total LULC classes in the area. In order of next importance were the recent fallows and grasslands which covered an area of 8435 ha, being 29% of the area. Builtup/bare land and concrete surfaces was ranked next in terms of coverage with 5451 ha representing 19% of the total area. Low forest was next in coverage importance by 5194 ha, also being 18% of the land area (Figure 7.3).

A considerable proportion of this was as a result of the exposure of the land surfaces due to agriculture and other methods of vegetation removal around the fringes of Lake Bosomtwe (Figure 7.6a). A corresponding surface reflectance translated into LST values ranging between 24°C to 53°C. The mean temperature value was 38°C and a very high standard deviation of 20.5K. The rather high land surface temperature anomaly was ostensibly due to the isolated patches of burnt-up surfaces emitting a higher heat energy fluxes; in accordance of Stephan-Boltzmann law of surface emissivity.

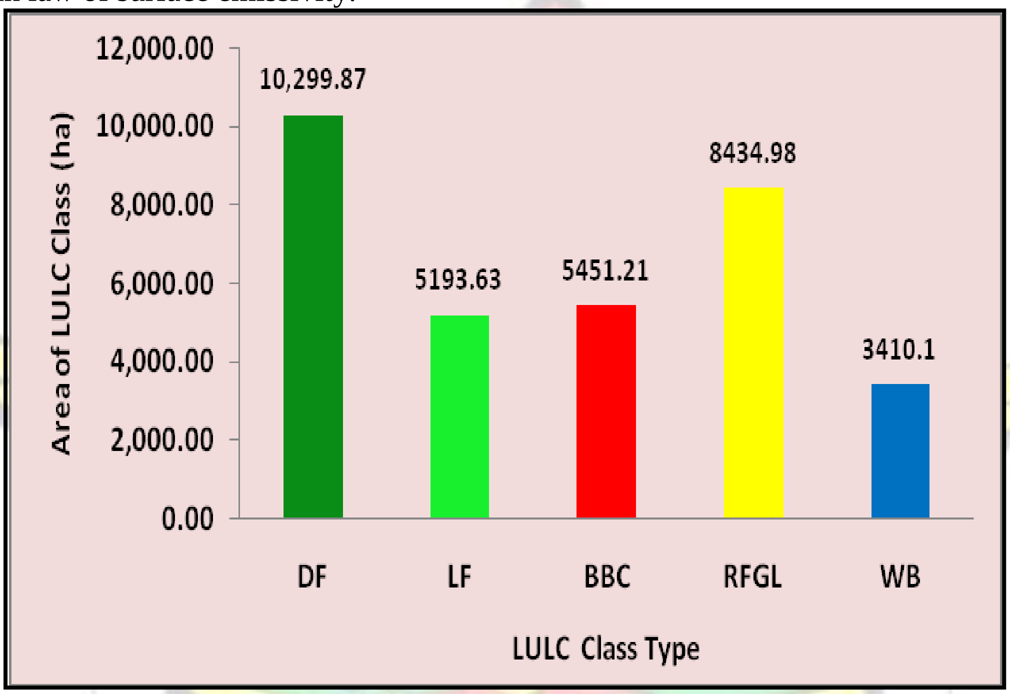
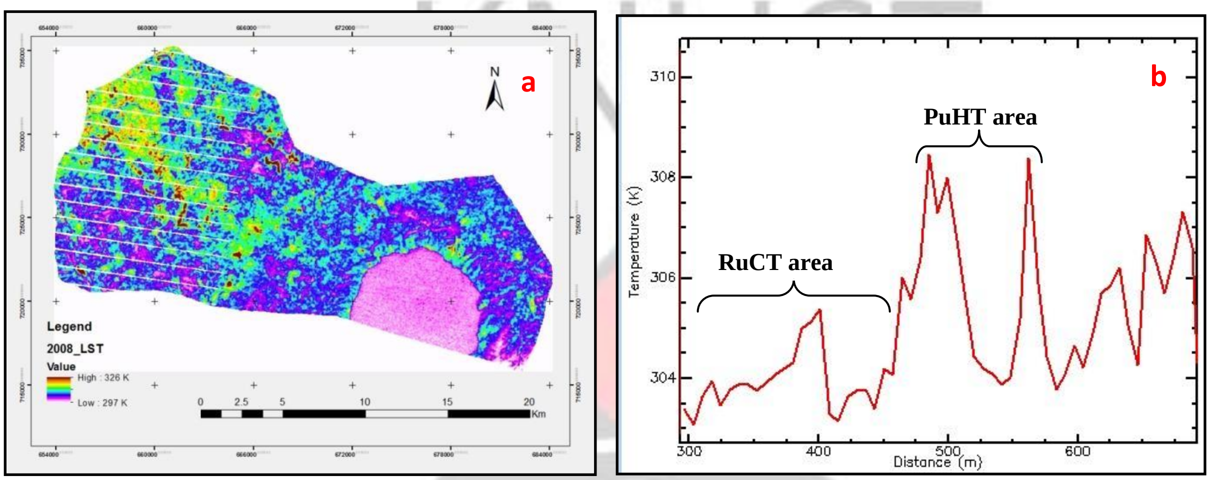


Figure 7.3: LULC classes Area (ha) for 2007

7.5 Analysis of LULC classes for 2007 and Land Surface Temperature for 2008 Images

The temperature characteristics were in response to the surface vegetation removal. As the years go by and human land use demand increases with the increasing populations, the surface becomes exposed to the various degrees of heat energy fluxes. The surface reflectance characteristics of the land use types, records the surface temperature profiles in accordance with the land surface reflective capacities (Figure 7.4a). These surface characteristics which reflected the LULC changes indicated an appreciable presence of built up/bare and concrete surfaces in the district.



Figures 7.4 (a & b): Land Surface Temperature extracts of the 2008 Image with corresponding surface temperature fluxes

7.6 Analysis of LULC classes for 2014 Image

The 2014 image shows that the Bosomtwe district has experienced an appreciable level of land cover changes in terms of the increasing built up/bare lands and concrete surfaces. The LULC classes showed that the built up areas were increasing with time, up to the year 2014.

Low forest cover maintained its high area of coverage with 10,948 ha of the total LULC. Recent fallows and Grasslands were also next by area coverage with 9367 ha. Built up/bare land and concrete surfaces, although showed an increase from observation, the statistics of 4597 ha by area coverage, indicated an apparent decrease in area from the 2010 image; representing 14% of the total land area. The area covered by the lake (water body) was 3424 ha of the total area (Figure 7.5).

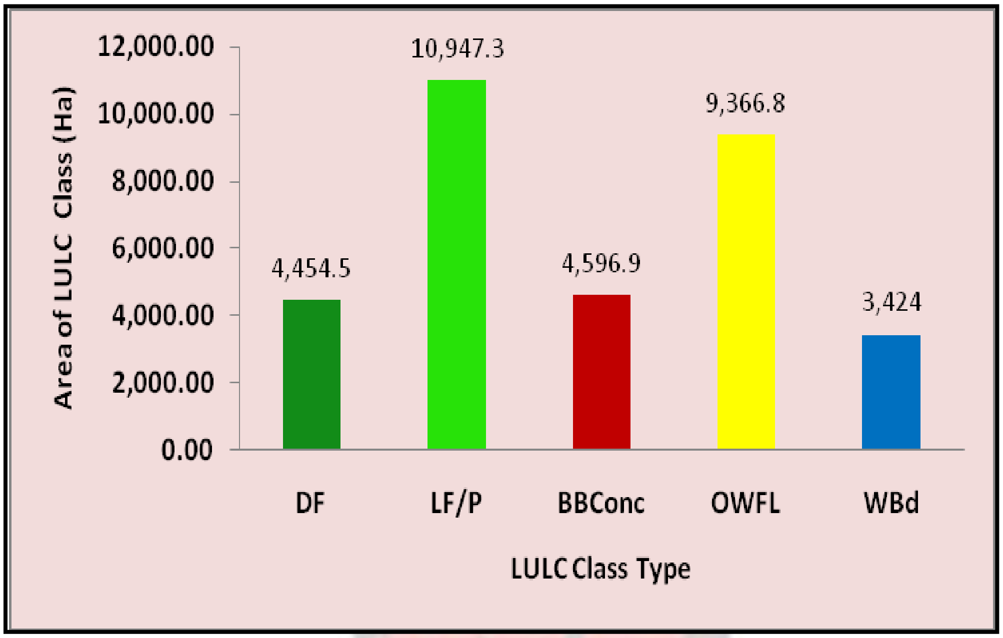
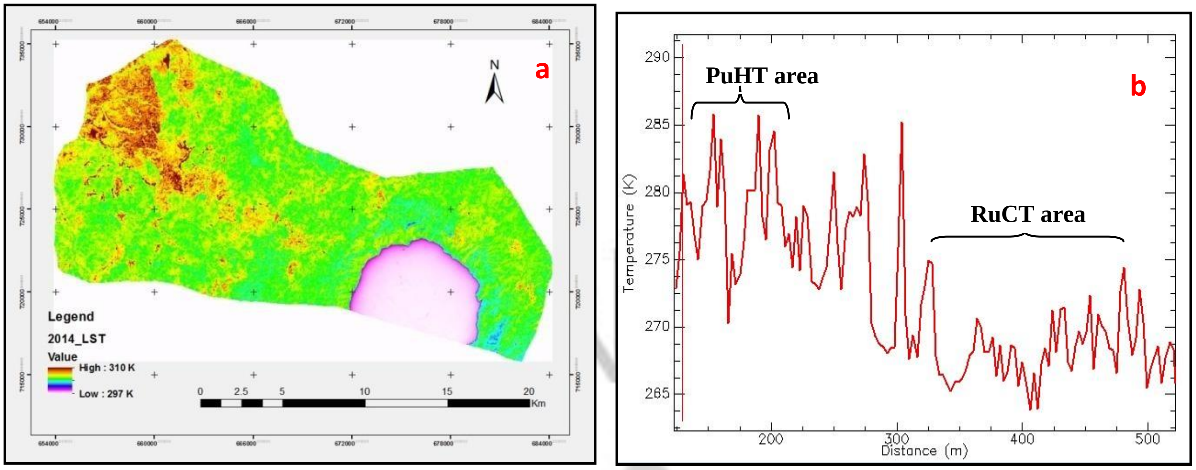


Figure 7.5: LULC classes (LULC) Area (ha) for 2014

However, by combining the built up/bare and concrete surfaces together as one class, resulted in an apparent decrease in the built up and concrete land uses in some of the transiting years. However, this land use type has been increasing consistently with time. Field observations and other auxiliary statistical data, to support this claim for instance, showed increasing trends. Data such as the number of houses recorded under the periods by the Ghana Statistical Services Population and Housing Census in 2010 has amply supported the fact that residential houses increased from 12,399 to 15,525 between the years 2000 and 2010 (GSS, 2014). This is indicative of increasing land surface temperature, associated, invariably with increasing impervious surfaces (Yuan and Bauer, 2007). This is evident by the relatively high LST of 37°C as compared to the minimum of 24°C for the RuHT and PuHT respectively (Figures 7.6a &
7.6b).



Figures 7.6 (a & b): Land Surface Temperature extracts of the 2014 image with corresponding Surface Temperature Fluxes

The aggregated temperature values from the satellite image land surface temperature extractions are displayed in Table 7.1.

Table 7.1: Extracted Maximum, Minimum, Mean and Standard Deviation of Land Surface Temperature from Images

Satellite Years	Max ºC (K)	Min ºC	Mean ºC (K)
1986	42	29	36
2002	30	24	27
2008	53	24	38
2010	41	26	34
2014	37	24	31

The 12-year duration also corresponded with an increase in the non-vegetative land uses; particularly small holding agriculture land for food crops production. Built up/bare and concrete as well as recent fallows and grasslands, compared to the vegetated covers such as the dense and low forest cover (which also included some oil palm and citrus fruits plantations), actually increased.

7.7 Conclusion

This chapter has argued that, the transition of a rural to a core urban area, also exhibits a temperature profile that traverses through a rural cool trough (RuCT) through a peri-urban Heat trough (PuHT), before achieving the ultimate urban heat island (UHI) condition. The chapter postulates further that by virtue of the constantly changing LULC dynamics in the peri-urban areas, they would serve as potential heating troughs or cells that could eventually trigger consistent increasing local LST values.

Considering the fact that the direction of change is usually in favour of build-up to concrete surfaces, the peri-urban areas have a higher propensities to produce the fueling cell effects of ultimate urban heat islands. This situation would have occurred if the peri-urban region had dynamically transformed into a complete urban core areas with fully-fledge urban land infrastructure and its associated local warming effects on the local climate. In other words, every peri-urban area is a potential urban heat island.

CHAPTER 8: DISCUSSIONS OF THE RESULTS OF SOCIOECONOMIC AND SPATIAL ANALYSES

8.1 Introduction

The previous eight chapters were devoted to the overview of the study, literature synthesis, materials and methods, including methodology for both socioeconomic and LULC and vegetation cover health as well as the climatic data analysis and land surface temperature extractions from satellite images. This chapter discusses the results in the context of the objectives set out. This is to present the interconnections between the various aspects of the results and their significance for policy and further research.

A number of factors have been identified as being responsible for peri-urbanization. Peri-urban areas result from rapid urbanization of the areas adjourning the cities and rural areas. This chapter therefore, synthesizes the implications of the socio-economic results obtained from the survey, as well as the analysis of Landsat satellite images for the extraction of the LULC types, their changes in terms of reduction, increases and persistence. This section also discusses the health of the vegetation cover, by measuring the photosynthetically active reflectance (PAR) using NDVI measure. Further, discussions of the climatic data analyzed together with the LST extracts are performed. These discussions have been done in consonance with the objectives of the study.

8.2 Peri-Urbanization in the Bosomtwe district: Drivers, Trends and Projections

The Bosomtwe district is predominantly rural; its peri-urbanization process is gaining momentum; a situation which gears toward a fully-fledged urbanized district in the future.

Accordingly, motivated by the affordability of land in peri-urban areas, Lawanson *et al.* (2012) concluded that, many people would want to resettle from the big cities to the rural to peri-urban fringes. One of the manifestations of peri-urban land-use change is the dynamic physical and environmental modifications (Cobbinah and Amoako, 2014).

The Bosomtwe district in the Ashanti region, like any other peri-urban area, is experiencing a number of determining factors that are contributing to land use and land cover changes. These are in the form of either land use conversions and/or land use modifications (Lambin *et al.*, 2000). There were a number of factors that determined the preponderance of the different responses to the changing patterns of land use and land cover (LULC). According to Appiah *et al.* (2014) sometimes, some of the factors were just extremely significant in determining the land use change patterns in the study area. As the fast developing peri-urban areas such as *Atonsu, Esereso* and Kumasi are becoming seemingly congested, the spill-over effect of urban population's relocation is affecting the Bosomtwe district to also grow in response to the pulling–up effect scenario, reported by Acheampong and Anokye (2013).

This scenario was the driver behind people in the district, to engage in speculative demand for land in the district for the purpose of residential, hospitality (hotels/guest houses) and commercial land uses. It is obvious that potential settlers are taking advantage of the fast growing surrounding bigger towns to secure their place in the district in anticipations for the future urban status of the district. Consequently, the works of Ravetz *et al.* (2013), Dutta (2012) and Kombe (2005) seem to have confirmed from the study that, there is evidence why some of the respondents indicated their motivation to acquire land in the district because of their optimism of a future economic boom in the district.

It is of no surprise that among the various reasons given for causes of peri-urbanization in the district, the respondents indicated that increasing physical infrastructure and easy access due to relatively cheaper rent on land are their motivations (Cobbinah and Amoako, 2014; Lawanson, *et al.*, 2012). They also indicated that with some level of availability of social amenities there is the tendency for population movements toward the district for settlement. These, in combination, drive the peri-urbanization processes and land use change dynamics in the Bosomtwe district.

8.3 Land use Conversion Patterns in the Bosomtwe District

Land use and land cover dynamics are the current defining features of the peri-urban morphologic picturesque of every naturally or human-organized space, particularly in the Bosomtwe district of the Ashanti region of Ghana. The changing land uses in the peri-urban areas have considerable impact on the local environmental changes in the Bosomtwe district. Using appropriate policy instruments, Dutta (2012) suggests that urbanization and for that matter peri-urbanization becomes synonymous with frequent land use changes that have varying impacts on the rural environment. Supporting this assertion further, Vejre (2008) submits that land use in urban and peri-urban areas in particular, have become extremely important objects for planning and management. This is as a result of increasing conflicting interests for their uses.

However, the demand for land in the Bosomtwe district was predominantly in favour of residential purposes. In addressing the issues of sustainability, Busck *et al*. (2006) suggested that the peri-urban interface comprises a heterogeneous mosaic of environmental and productive ecosystems working in combination with socioeconomic lifestyles of land owners' peculiar relationships with the immediate urban areas.

The above reasoning supports the facts that land owners would begin to earmark their original lands with original use type ready for conversion to a new type, based on the availability of certain positive externalities that would accelerate the decisions. These would take effects within appropriate prevailing land tenure regimes. These include improved infrastructure, which connotes improved welfare and ease of land and rent manipulations by owners in the urban fringes.

This implies that there may be other unknown reason that could affect the land use conversion trend observation or the speculative demand for land in the Bosomtwe district. It can be conjectured that land could be acquired not for their use sake, but for the satisfaction of holding them for future gains. This situational viewpoint is akin to large-scale land acquisition. Accordingly, Gurara and Birhanu (2012) have pointed out that expectations in the rising land value in Africa, in anticipation of favourable investments policies, is one of the key drivers of large scale land acquisition.

8.4 Household Decision on Land use Conversion and Modification

According to Robinson *et al*. (2007), at the household level, the decision of land use conversion and modification may arise as a result of opportunities or constraints to their initial decision outcomes. This view though, is without recourse to the customary type of land ownership arrangements that pertains in the Ashanti region and for that matter, the Bosomtwe district. The results from the communities on how households make land use decisions are *in tandem* with the views of Bajocco *et al*. (2012) that various dynamic variables interact to exert influence on land use driver-decisions to identifying the various uses to which the land could be put.

Such decisions may be predetermined directly or indirectly by local to regional factors, including major custodians, including traditional authorities, who invariably have the final sanctioning authority for land use and conversion at the local scale. Vejre (2008) has opined that this happens because households and other associated decision agents act to present as rational decision as possible, pertaining to the optimized use of the land resource.

8.4.1 Gender Differentials and Household Decisions on LULC Changes

The survey revealed and as explained earlier, the household decisions to convert their original land uses to others in response to the changing demand trends, the deteriorating livelihoods and easy accessibility to land had some relationship with certain variables such as, the location in terms of the community in question. Also of relevance was the gender of the respondent as well as the status of the respondent as being the head of household, spouse or other member in the family.

To the female heads of households, the other reasons may not be crucial; this is because women in recent times, particularly in the urban to peri-urban areas also bear a greater part of current household economic burdens with their spouses (Mandere *et al.* 2010). This situation is in congruence with the current household split-roles and decisions between males and females that are becoming synonymous with the urban lifestyle. While in purely rural setting major household decisions are taken by the male counterpart, the peri-urban setting exhibits an admixture of the extremes; as the results portray. Other respondents as sons and daughters who were interviewed during the survey clearly showed how insignificant their status could influence any household land use decisions.

According to Tsai *et al.* (2015), when households face substantial financial stress during a specific year, farmers are expected to act rationally by seeking alternative land use patterns or conversions. In this case if the decision lies with the female heads, who are mostly farmers in the

Bosomtwe district, they are bound to respond to the momentary economic hardship by changing their land use types accordingly. Sometimes a temporal dispossession of the land ensues, when the land is used as collateral for other forms of financial relief.

Similarly, the results run as per the community responses to the questions of their motivations, which are the attractors or opportunities to better their lot, to convert their original land use to others, produced a similar trend of responses. From all the 14 communities, the reason of deteriorating livelihoods and the economic incentives were the driving motive to change their LULC types in the district. This has been asserted by Afriyie *et al.* (2013) that peri-urban land use changes are in response to the derived increasing economic benefits. This asserting was affirmed by respondents' view that it is a good idea to convert one's land in response to the changing demand trends in land use (Table 4.4). This is an absolute expression of respondent‘s rationality in maximizing their welfare from their assets, being land resources. In using this approach, the underlying spatial and temporal dynamic process associated with a rational economic agent can be made explicit (Irwin and Georghegan, 2001).

8.5 Relevance and Implications of Drivers of Peri-Urban Land Use

The Bosomtwe district in the Ashanti region, like any other peri-urban area, is experiencing a number of determining factors that are contributing to LULC changes. These are in the form of either land use conversions and/or land use modifications (Lambin, *et al*., 2000). There were a number of factors that determined the preponderance of the different responses to the changing patterns of LULC. Sometimes, some of the factors were just extremely significant in determining the land use change patterns in the study area.

Although the Bosomtwe district is predominantly rural, its peri-urbanization process is gaining momentum; a situation gearing toward a fully-fledged urbanized district in the future.
Accordingly, motivated by the affordability of land in the peri-urban areas, Lawanson *et al*. (2012) concluded that many people would want to resettle from the big cities to the rural and peri-urban fringes. One of the manifestations of peri-urban land-use changes is the dynamic physical and environmental modifications (Cobbinah and Amoako, 2014).

Generally, changes in land cover during the last fifteen years included cropland reduction and forest recovery due to land abandonment in mountainous areas, in favor of dispersed urban land use expansion in lowlands (Aubrya *et al.,* 2012; Bajocco *et al.,* 2012; Salvati *et al.,* 2012). Contrary to this trend in the District, the expansion in peri-urban land uses in lieu of forest covers and crop lands, do defy topographic barriers, as higher elevations up to about 800m experienced forest fragmentation.

This LULC trend has potential climate change implications in the peri-urban landscapes that are transforming in a serial continuum from a rural landscape to an urbanized landscape. This, according to Pongratz and Caldeira (2012), is caused by the emission of greenhouse gases from degraded lands, including forest lands as well as the production and use from combustion of fossil fuels, by small to light industrial productions. The adverse implications of these on the local climate can be conjectured to an appreciable degree of certainty.

8.6 Synthesis of LULC Results from Satellite Data Analysis

This section is devoted to the synthesis of the results of the LULC types and their effects on the NDVI of the vegetation in the district.

8.6.1 Effects of LULC Dynamics on NDVI values as Proxies to Vegetation Health

The results of the NDVI values indicate that, although dense forest cover increased from 1986 to 2002 it decreased further in 2007 given the lower NDVI values. Other land use types characterized by intense human activities, such as infrastructure development expanded with possible effects on the vegetation abundance and resilience.

Bosomtwe district falls within the tropical forest zone, as such it is expected to have high positive values of between +0.5 and +0.9 (Vlek *et al*., 2010). Land use classes such as recent fallows and grasslands increased from 1986 to 2007 owing to land surface exposures through clearing of vegetation for farming; logging and illegal mining activities as the major drivers of land degradation (Kusimi, 2008), the density and health of vegetation were affected. A similar result is presented in the NDVI image such as the LULC maps classified for the area (Appiah *et al*., 2015).

The built-up, bare lands and concrete surfaces increased from 2002 to 2007. Although the rate of increase was not rapid, the result showed expansion of residential and commercial land uses (Kissinger *et al.*, 2012). The expansion may be explained by endogenous and exogenous factors such as, population growth through in-migration into the districts. The Bosomtwe district may urbanize faster regardless of the reduction in built up area, bare and concrete land uses from 5664 ha in 2002 to 3587 ha in 2007. This reduction could be due to re-growth of vegetation on bare lands. Apparently, it was in the 2007 NDVI image that the dense forest cover decreased given the lower value of between 0.056 and 0.243.

The fact that vegetation, particularly forest covers are dwindling, using the evidence of the LULC classes, indicates that, the future changing trends pose a depleting threat to the overall forest cover in the Bosomtwe district. Although there is a seemingly moderate growth rate of built-up, bare land and concrete land use activities, efforts must be made to enhance vegetation cover in the district. It is identified from the LULC maps that forest covers both dense and low forest classes, are not rapidly being replaced by built-up, bare land and concrete; rather, by recent fallows and grassland.

However, the same cannot be said for the recent fallows/grassland that dominated the land use and covers over the years, when low to moderately vegetated land were compared with the moderate to dense vegetation coverage. These areas of recent fallows have potential tendencies to be converted into other land uses that would lead to the complete removal of the vegetation cover, more rapidly than the rate at which natural forest re-growth could pace.

From the north-western part of the district map, it is evident that residential activities are spreading in what this study describes as the *funnel-shape growth* of urbanization that result in rural areas expanding into the urban core, along major and minor arterial road routes; obviously, being non-vegetation land uses (Maitima *et al*., 2009).

The analysis of LULC classes *in tandem* with the vegetation characteristics in terms of the normalized vegetation index (NDVI), offer a better methods of comparing and estimating the impact of non-vegetation land uses on the vegetation land use and cover (Firl and Carter, 2011). This methodology usually carried out in Software such as ArcGIS and ERDAS Imagine to generate interactive maps (USGS, 2011), offer a useful approach for comparing the categories of land uses and land cover changes and their corresponding impacts on the NDVI as measure of vegetation abundance and resilience.

The overall condition of the forest cover is decreasing in abundance and resilience. This is shown by the decreasing NDVI values generated from the maps. These values support the results of increasing trend of LULC transitions from vegetation to other land uses, particularly the built up and bare to concrete and recent fallows and grasslands. Vegetation cover may be marginally increasing in terms of low forest category. That notwithstanding, forest cover *per se* are also dwindling in abundance and health, in the District.

The slower rate of built up, bare and concrete surfaces notwithstanding, there is considerable reduction and transition from dense forest cover into low forest which in itself also contains some human land use i.e. plantation agriculture. Again, the fact that recent fallows and grasslands are increasing, indicate that the level of agriculture-based and other vegetation reduction-based activities dominate the LULC activities. These may lead to emissions of carbon dioxide, which could consequently increase the local greenhouse gas loading. The increasing concentrations can have implications for local warming with variable impacts on the local climate, especially temperature and rainfall patterns.

The results obtained and analyzed, thus far from the land use classes for the various years indicated that the district is not experiencing urbanization as the study conjectures and to a large extent corroborated by the socio-economic survey. Areas that exhibited peri-urban to urban land uses were restricted to the north-western part of the district. Communities occupying this subsection of the district include; *Esereso, Sawua, Jachie, Pranso* and *Aputuogya.* The remaining communities in the district remain predominantly rural. The expansion in the growth of built up bare land and concrete surfaces are slower than anticipated. The trending of this growth is seen in the typical funnel-shaped pattern growing along the main arterial road networks from the main city center towards *Kuntenase*, the district capital of the Bosomtwe district.

Although the dense forest increased appreciably by 2014, the low forest cover continued to increase consistently. In classifying the LULC, some other land use types were identified from ground truth to have been embedded in the low forest vegetation cover. These were the oil palm plantation and some citrus fruits that dominated some areas in the district. These points to the fact that forest cover, in terms of the dense forest is still dwindling in proportion to the other land uses, comparably (Appiah *et al.,* 2015; Jackson *et al.,* 2012). In addition to this, considering the expansion of recent fallows /grassland, resulting from farmland preparation and abandonment, the presence of vegetation cover as a sink to carbon dioxide could be reduced. This may exposed the district to LULC-based emission and concentration of carbon dioxide (Virgilio and Marshall, 2009). The consequences of these on local climate variability and change could be imminent in the district.

The fact that built up/bare and concrete surfaces in the district are increasing, shows that the LULC types would remain largely recent fallows/grassland as well as the low forest. However, considering the expansion in the built up and bare and concrete surface trending from the northwestern part of the district from the main urban peripheries of Kumasi, *Atonsu* and *Esereso*, into the rural areas, the projection of built up/bare land and concrete surfaces would increase consistently in the near future. This would transition to overtake most of the land use types, particularly the recent fallows/grassland and low forest.

The probability of the other land use types transiting into other LULC types in a Markovian chain reaction of proportions, could also lead to the general reduction in the vegetation cover in the district. In comparing the vegetation and non-vegetation maps of the district, it can be observed that land uses and land covers (LULCs) other than forest covers are generally increasing at the expense of forest covers. As low forest and dense forests reduce in sizes, it is an indicative of the reduction in agriculture, forest and other land uses (AFOLU) activities in the

district.

8.6.2 Changing Patterns of LULC with Respect of Vegetation Cover

The results have some far-reaching implication on the forest cover change, as perceived by the respondents in the Bosomtwe district. LULC changes are dynamic human activities which require conscious streamlining. There is need to attribute the underlying causes of LULC dynamics to the specific human drivers or activities, responsible for deforestation and degradation processes (Appiah *et al*., 2014b).

From a perceptual perspectives, forest cover is depleting in the interest of other land uses and land covers (LULC); particularly residential and commercial activities. Peri-urbanization as the name suggest, is the development of urban periphery into urban areas. Once people become integral part of this setting, their household decisions become aligned with the most immediate rational reactions, all things being equal, to convert land into other uses from their original, in most cases, agriculture, forest and other land uses (AFOLUs).

As speculative demand for land in the wider Kumasi Metropolis is oriented toward the district, vegetation cover changes are expected to be rapid. The rapidity of LULC change has been better determined from the spatial modelling of the vegetation change detection scenarios in a time serial analysis. However, the fact that the local people, most of whom have been in the community for decades have observed the depletion of their vegetation cover, give credence to the fact that human land use activities that have the potential to alter original vegetation covers are on the ascendency in the district. The business as usual situation and the seeming scramble for land for residential developments (in most cases, for lateral expansion), would definitely have consequential degrading effect on the vegetation cover.

Another cause of forest degradation is the clandestine operations of illegal logging activities through chain saw milling of timber in the district. The district assembly contends that this problem is indeed a challenge worth dealing with, in safeguarding the forests. This is especially so, when the only natural lake, Lake Bosomtwe radial streams that feed into the depression take their head waters from the forested highland zones. Illegal gold mining and Sand winning, is also identified as another rampant land degradation activity practiced in some parts of the district. In the absence of adequate jobs for the youth in the district, the activity of sand mining and illegal gold mining have become lucrative livelihood activities, supporting household incomes, in both on and off-farming periods. This result, led to the rejection of the null hypothesis that; there is not relationship between LULC and vegetation cover health.

8.7 Juxtaposition of the Perceptual and Actual Outcomes of the Analyses

Certainly, land use and cover trends are not consistently in favour of built up/ bare land and concrete surfaces, to any appreciable extent. This finding is unlike the general trend that areas of perceived urbanization tend to demonstrate rapid growth in residential and built up land uses (Ravetz *et al.,* 2013). The trends identified are seemingly non-characteristic of peri-urbanization to a possible urbanization.

In any case, the general observations from the field work, and coupled with the classified images show that plantation agriculture and food crop subsistent farming dominate the landscape in terms of use and cover in the district. These results therefore, seem to contradict some aspects of the perceived responses delivered by the respondents on the causes and rates of vegetation cover change, in the direction of losses. These perceptions are not infallible from errors of observation.

The actual LULC classification showed an increasing built-up, though, at a decreasing rate.

The analysis of the result shows that LULC transition in the district has been in the direction of more of agriculture lands, recent fallow land and grassland land use and covers rather than built up/bare areas and concrete, explicitly. There may be other extraneous factors responsible for this trend. This is because while low forest decrease in one year in subsequent years there is transition from bare lands (a component of the built up/bare/concrete surface land use class) into low and recent fallow/grassland covers. These fluctuating trends in land use is more in favour of recent fallows and build up implicitly, before the low forest LULC types over the entire periods under analysis.

The LULC trend from the satellite image classification does not seem consistent with perceptual observation of the socio-economic survey responses. The trends that are usually characteristic of peri-urbanization and a possible urbanization, was not clearly identified. This result largely implies that the Bosomtwe district is peri-urbanizing, but at a moderate rate, as far as residential and commercial built up land uses trends is concerned. At the same rate however, dense forest covers are rapidly reducing and degraded in terms of quantities and quality. In any case, the general observations from the field work, and coupled with the classified images show that open wood lands and plantation agriculture dominate the landscape in terms of land use and cover in the District.

The pointers show that land is more put to the use of subsistent farming and plantation agriculture for food and cash crops respectively. Agriculture, forestry and other land uses (AFOLU) such as urban built up, concrete, rocks and soils comprise the complex mixture of LULC, though at differing proportions and rates of transition. This is arguably an encouraging land use trend that needs to be promoted in order to reduce forest degradation and agriculture and forest depleting-based carbon dioxide emissions. This is because changes in land use, land cover, disturbance regimes, and land management have considerable influence on carbon and greenhouse gas (GHG) fluxes within ecosystems (Sohl *et al*., 2012). The consequential effects on local warming and climate variability and climate change in the District could be devastating.

8.8 The Implications of Rainfall and Temperature Variability on Local Climate

This subsection discusses the implications the climatic data analyzed have for the local climate variability and change.

8.8.1 Discussions of Rainfall Variability

The rainfall trend of variability makes the future of rain-fed agriculture bleak, unless appropriate adaptation and mitigation measures are put in place to ensure sustainability. This trend analysis reveals that dealing with the current trend lies with the development and introduction of improved technology such as irrigation, and crop varieties. These could be done among others, through effective dissemination of ideas and innovations by the appropriate government agencies to smallholder farmers, who rely heavily on the rainfall for cropping. It also behooves on farmers as well to embrace these and vary their farming practices and systems to adapt to the current changing rainfall patterns.

This study is underpinned by the need for further research, from varied spheres and sectors of development due to the risk posed by climate change to global food security. Ching (2010), for example advocates for research on climate change mitigation in agriculture; whiles Foli *et al* (2011) emphasized the need to advance mitigation action on evidence-based research. This hinges on an informed understanding of local climate trends which this study sought to provide.

8.8.2 Discussions of Temperature Variability

The forecasting climatic variables as proximate conduit for climate change, using temperature variability in an increasing trend, give credence to fact that climate change can no longer be discounted in the human development arguments (Yaro, 2013). It is now evident that the climate has been changing and this climate change is caused by human activities in relations to the biosphere (Pongratz and Caldeira, 2012).

Considering the rate of peri-urbanization of the Bosomtwe district, evidenced by the level of peri-urbanization process driven largely by residential expansion, agriculture and forest lands are increasingly depleting, giving way to residential and hospitality/recreational (Hotels and Guest Houses). These are the very conduits of peri-urban heat built-up that could translate into urban heat island in the district.

The foregone results and discussions imply that the last 15 years or so have experienced considerable increasing trend in both temperature and warming, as evidenced from the increasing trends in the air temperature values recorded. This trend is a confirmation of a study by Minia *et al*. (2004) and Yaro (2012), in which they estimate that temperature will continue to rise, while rainfall is also predicted to decrease in all agro-ecological zones in Ghana. This means the intraquarterly variability of temperature above the district's average confirms the findings of Maddison (2007) that temperature in Africa is becoming warmer in recent years.

This implies that the temperature pattern shows an increasing trend with time. For the months of April, May and June, which correspond to the rainy season in the district to have steeper trending in temperatures over the period poses concerns for the local climate. This is particularly the case considering the inverse correlation between rainfall and temperature patterns. The evidence that urbanization and precipitation are positively correlated, that notwithstanding, a consensus on the relationship has, however, not yet been reached (Blake *et al*., 2011).

8.9 Implications of LULC Change on Rural and Peri-Urban LST Regime

The land surface temperature invariably corresponds to the land use and cover types classified from the five satellite images. Areas of bare and build up areas show high reflectance and hence high temperature profiles. These areas according to Joshi and Bhatt (2012) are the causes of urban islands in high densely built urban environments. In rural environments, the temperature characteristics are observed to be low in comparison to the urban areas. This was evident in the study of Ambinakudige (2011) in India, that the anthropogenic activities that alter the land cover and exposes it to intense heating is the cause of the differential temperature regimes between the urban core and the rural outgrowth areas.

The Bosomtwe district also demonstrates similar urban to rural temperature profile. By implication, as rural land uses and replaced by the peri urban build up and bare areas, which eventually become the peri-urban heat trough (PuHT), with potentials for urban heat island conditions. These sensible heat fluxes result from the modification and conversion of vegetative and rural land use and cover types to considerable built-up land use types (Carnahan and Larson, 1990). These exhibited moderate to extreme LULC characteristics of the peri-urban and urban landscape, with varying LST configuration (Srivastava *et al.*, 2010). The PuHT could be described as the incipient stages of urban heat islands; however, the former has a relatively wider geo-spatial dimension in comparison to the latter.

In the context of the Bosomtwe district, this PuHT conditions have higher likelihood to occur in the fast-growing peri-urban towns in the district. Areas such as *Esereso, Jachie*, *Aputuogya*, *Kuntenase and Pramso* as shown in Figures 3.1 & 8.3a, are likely to be influenced by their local micro-climates, and likely to be a function of the land use change dynamics. In the context of this study, an operational and postulated temperature threshold for the PuHT and RuCT in a tropical semi-deciduous climate zone, such as the Bosomtwe district were averaged at 31°C.

The resultant effect would be expressed in terms of reduced rainfall and high temperature regimes (Voogt and Oke, 2003). If the trend of land use and cover change continues into the future, a drastic near to full urban heat island is imminent in such areas, considering the business as usual scenarios. These temperature threshold values could be calibrated based on the type of climate regions under consideration. The associated reflectance of the LULC types yielded considerably high land surface temperatures. This phenomenon, presents the opportunity for the formation of peri-urban heat troughs (PuHT). When juxtaposed with the rural cool troughs (RuCT), there is the tendency for surface energy fluxes dissipation from the rural areas with high vegetation cover, which serves as carbon sinks to regulate local warming effects (LWE) (Bhatt *et al.,* 2013).

8.10 Conclusions

There are a number of factors that influenced peri-urban LULC dynamics in the Bosomtwe District. Conversion of lands to other uses, including forested lands was influenced by different socioeconomic biophysical drivers as outlined. In all these, the connotations of peri-urbanization involve a transformation of the rural landscape through demographic pressures on rural and urban periphery.

These land use change dynamics, the study has shown, may have considerable potentials to alter the district's vegetation cover and increase the rate of peri-urbanization. These outcomes have implications for the local greenhouse gas emissions, particularly from degraded forests and increased built-up/bare/concrete surfaces that serve as sources rather than sinks for the sequestration of carbon dioxide. Furthermore, the associated LST extracts corresponding with the LULC types defined the surface heat profile of the districts in the RuCT and the PuHT systems as thermal cells trending from the rural to the peri-urban areas as the potential urban heat island system.

CHAPTER 9: SUMMARIES OF KEY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

9.1 Introduction

This is the final chapter that offers the summaries of key findings, conclusions and recommendations obtained from the previews of results and discussions chapters.

In recent decade, issues relating to land use and climate variability and climate change have come to the forefront of the environmental and development literature. Equally, specialized scientists and international organizations have realized that LULC dynamics have largely influenced local climatic patterns. In response to this, institutions have been established at subregional and national levels to research into land use and climate change, predict likely changes and assess likely impacts and the mitigation and adaptation pathways to adopt.

In Ghana, large scale anthropogenic forces are being superimposed onto the natural dynamic systems with independent ecological influences and consequences. Nonetheless, it is crucial to comprehend the relationship between peri-urban land use and climate changes as well as the various land management decisions that specifically drive the area into different landscapes. With this, the study integrated the socioeconomic survey and remote sensing methodologies in modelling the LULC dynamics of the Bosomtwe district of the Ashanti region. This was to proffer possible specific management options that might help the district assembly in its land use plans enforcement and management practices.

This chapter, therefore, is a summary of the key findings of the study obtained, the conclusions and recommendations as well as the contributions to the body of knowledge and the literature.

9.2 The Problem Setting with Objectives

The Bosomtwe district is one of the fast expanding peri-urban settings in the Kumasi Metropolis. It has one of fastest growing rates of private land acquisition and residential sprawl in response to the choice of the changing human populations of relocating away from the city centre. The increasing concentration of residential and commercial activities, have implications for the agricultural, vegetation and other LULC dynamics. The paucity of scientific knowledge and data for the predominantly agrarian populations living in the Bosomtwe district, justifies the need to undertake the study.

The main objective of this study is to analyze the peri-urban LULC dynamics in the Bosomtwe district of the Asante region, using the combined methodologies of socioeconomic and satellite remote sensing techniques.

9.3 Key Findings from the Study

This section summarizes the key finding of the entire procedures and results obtained and analyzed for the study. A triangulation of qualitative and quantitative design was used through structured questionnaires in 14 communities on the basis of population, in the Bosomtwe district. This was done in a socioeconomic survey from which the data was analyzed in the Statistical Package for Social Sciences (SPSS) v.16 for Windows applications.

Further, the use of six Landsat satellite data of Thematic Mapper and Enhanced Thematic Mapper+ (TM/ETM+) images, as well as Landsat 8 Operational Land Imager and Thermal Infrared Sensor (OLI/TIRS) images, were analyzed in ENVI, ERDAS Imagine and ArcMap Remote Sensing and Geographic Information System software respectively.

9.3.1 Socioeconomic Drivers of Land Use and Land Cover Change

The increasing rate of peri-urbanization in the district is as a result of increasing demand for residential and commercial land uses at the expense of agricultural land uses. This has resulted in substantial conversion of prime agricultural lands into other land uses particularly residential and commercial. These outcomes have perceived negative implications on food security in the district.

Easy access to land and the gradual deterioration of economic livelihoods are some key determinants of agricultural land use conversions in the District. Therefore, the economic incentives expected from the conversion of agricultural land into residential and commercial land uses are the motivating factors for change. Agriculture as an economic activity is gradually losing its profitability among peasant households.

9.3.2 Land Use and Land Cover Dynamics and Trends

The probability of other land use types changing into other LULC types is highly in favour of built up and concrete land uses. According to the Markov chain transition reaction of proportions, the land use activities could lead to the general reduction in the vegetation cover in the district consequently over the next 24 years projected into the future.

By comparing the vegetation and non-vegetation covers of the district, it can be observed that LULCs other than built up areas (which rapidly increased in some years, due to built-up, bare and concrete class composition), are slightly increasing at the expense of forest covers. As low forest and dense forests reduce in size, particularly from 1986 to 2010, it is an indication of the reduction in agriculture and forest land use activities in the district.

9.3.3 Vegetation Cover Change Trends

Results of the image classification of LULC and NDVI analysis showed considerable expansion of infrastructure, extension of agricultural lands and bare land surfaces that contributed to reduction in forest cover and loss of the woody vegetation. LULC classes for build up, bare lands and concrete surfaces increased. The expansion may be explained by endogenous and exogenous factors such as, population growth through in-migration into the districts.

The overall condition of the forest cover is that it is decreasing in abundance and resilience, as the NDVI values generated from the maps do not support results of increasing trend from the land use and land cover classification maps. Vegetation cover may be marginally increasing in terms of low forest category. That notwithstanding, forest cover per se may also be dwindling in density and health, in the District. The Bosomtwe district may urbanize faster regardless of the reduction in build up area, bare and concrete land uses.

9.3.4 Rainfall and Temperature Analyses for Climate Variability and Climate Change

Rainfall pattern indicated a generally increasing trend over the 31 year period. However, the inter-annual trends, disaggregated by decadal comparisons showed otherwise. This therefore presents a cautious situation when predicting the future pattern and trends of rainfall in the district. It could further be misleading to anticipate an increasing rainfall trend over the years, *pari paso*, judging from the seemingly fluctuating inter-quarterly trends.

The results clearly points to the inherent truth that the temperatures have been changing and in the increasing directions as the time series and Mann-Kendall trend analyses of temperature data have shown. Forecasted mean annual temperature values for the 4 ensuing years showed probable increasing trend. The analysis concludes that there is the need to be conscious about the potential consequences of increased warming on rainfall pattern and soil moisture to sustain subsistence agriculture in the district.

9.3.5 Land Surface Temperature for RuCT and PuHT Regimes

Considering the fact that the direction of change is usually in the favour of build-up to concrete surfaces, the peri-urban areas have a higher propensities to produce the fueling cell effects of ultimate urban heat islands. This situation would have occurred when the peri-urban region has dynamically transformed into a complete urban core areas with fully-fledge urban land infrastructure and its associated local warming effects on the local climate. In other words, every peri-urban area is a potential urban heat island.

9.4 Conclusions

As agriculture, forest and other land uses (AFOLU) are gradually losing their prominence with time, demand for other land uses are soaring considerably. In the event that households would have to make decisions as to what use to put their land, given the reasons of, for instance, deterioration of livelihoods from subsistent agriculture, and the social complacency of professing excess land available and the changing demand for land uses, the decision-maker (i.e. household heads) would not hesitate to convert their land to other land uses.

In most cases, the probability (odds) of converting from one land use to another will be high, as have explicitly been reported by the logistic regressing model. According to the respondents, many landowners would change the use of their lands with some high certainty, if factors that determine their land use preferences change. Their claim was that unprofitability of agriculture and alternatively high prices offered for land meant for other uses (residential, recreational and commercial) in recent times, compelled the majority of farmers to decide to convert their arable lands from agriculture to other uses.

In view of this, arable land availability would be threatened as long as there is demand for land and landowners' criteria to dispose of their lands are met. This could have dire implications on food security, considering the predominantly agrarian nature of the Bosomtwe district.

Household decision making on patterns of land use change on the basis of gender in the Bosomtwe district of the Ashanti region, is based on the social and economic conditions prevailing as well as the status of the household head in the family. In female headedhouseholds, the results have shown a gradual paradigm shift in explicit decisions regarding the land use at the household level, in most of the communities surveyed.

Although male headed households maintained the *status quo*, this situation in the peri-urban Bosomtwe seems threatened. This is because, modernizations and its co-jointed consequences of urbanization and enlightenment, has empowered females adequately to begin to assert and exert some levels of ownership rights. In view of this, the decisions to apply these lands to whatever uses they deem rational is no longer the preserve of the male counterparts. Particularly of interest is the assertive roles of women in taking vital rational decisions on their land use and modifications; a privilege they hitherto did not enjoy. Other socioeconomic factors such as the land tenure regime, status and gender of the household head, also have tendencies to influence their land use decisions.

The study findings have shown important changes in the land use and land cover patterns in the district. After an urbanization process, coupled with farmland abandonment between 1986 and 2010, substantial increments in peri-urban to urban land uses and clear increments in farmland coverage were found between 2010 and 2014. This suggests that major changes in the socioecological driving forces affecting landscape dynamics have occurred in the last two decades. The LULC trends from 1986 through to the years 2010 and 2014 are consistently in favour of built up/bare land and concrete surfaces, as well as the open woodland and farmlands, to an appreciable extent. These trends are certainly the characteristics of peri-urbanization and consequently a possible urbanization. This result largely implies that the Bosomtwe district is rapidly peri-urbanizing as the study conjectured, based on the earlier increasing urbanizing trend from the 1980s to the early 2000s.

In any case, the general observations from the field work, coupled with the classified images, show that agriculture plantation and subsistent crop farming, dominate the landscape in terms of land use and cover in the District from 1986 to 2014. However, the pointers show that the land is put more to the use of residential and commercial purposes than agriculture and forest land uses (AFOLU).

Considering the intricate relationship between temperature and rainfall, it stands to conclude that, the Bosomtwe district is experiencing conditions of appreciable changing ecological and anthropogenic process. These processes working *in tandem* would have deleterious effects on local climates and its consequences on human livelihood activities in the district.

Finally, this study has shown the relevance of the use of land surface temperature extraction algorithm, as empirical efforts of simulating local climatic conditions. It has done so by juxtaposing the corresponding LULC characteristics and their respective reflectance properties as additional inputs for the simulation of a local warming or cooling effects, depending on the land use and land cover types. The study concludes that the LULC categories corresponded well with the LST extracts obtained. This result, led to the rejection of the null hypothesis that; there is not relationship between LULC and LST extracts.

9.5 Recommendations

9.5.1 Recommendations for Policy

This study in line with the objectives and conclusions recommend that following for policy and institutional actions.

First, in the area of peri-urban land use and land cover changes driven by human land use activities, the Planning Unit of the Bosomtwe District Assembly should strictly enforce the laid down Land Use Plans (LUP). In this regard, it is further proffered that periodic stakeholder engagement on land tenure issues, access, use and conversion should be organized by the District Assembly.

Second, continuous monitoring and protection of forest cover and judicious land uses are recommended. Following from this, vegetation cover degrading land use activities that affect the forest density and health need to be curtailed by the District Forest Service Division to pursue vigorous forest protection laws.

Next, Ghana meteorological agency should liaise with the Bosomtwe District assembly, especially the Department of Food and Agriculture, to offer periodic climatic information, particularly to farmers in the district. These campaigns could be in the form of early warning systems on climatic events, particularly rainfall patterns alterations and other climate smart production methods.

Finally, the District Assembly through the Department of Town and Country Planning (DTCP) should enforce land use regulations towards the protection and sustenance of prime agricultural and forest land covers, as physical development cannot be avoided entirely. The removal of the vegetal cover exposes the land surface to insolation expressed in reflectance that signifies the heating or cooling surface systems. Vegetation cover should be protected to reduce potential future urban heat islands as the district transits through a peri-urban heating system.

9.5.2 Issues for Further Studies

A study using high resolution image classification is recommended to reduce the errors of misclassification. This could be hypothesized that, there is no significant difference in the classification accuracies of moderate resolution image and high resolution image classification.

Relationship between digital elevation model (DEM) and LULC in a mountainous landscape as the Bosomtwe district should be explored along-side policy mechanisms. It could be hypothesized that: there is no significant compliance difference between the topographic restrictions and regulatory restrictions to land uses in the District.

There is the need to validate the normalized difference vegetation index (NDVI). It could be hypothesized that: there is no significant difference between the NDVI of the district and a reliably downscaled NDVI reference data.

A further investigation and the determination of an average temperature values as the threshold for the measure of the rural cool trough (RuCT) and peri-urban heat trough (PuHT) in tropical climatic zones is proffered for further research. It could be hypothesized that: there is no significant difference between the temperature values of urban heat islands and peri-urban heat trough areas.

9.5.3 Contributions to Knowledge and Literature

9.5.3.1 Contribution to Knowledge

The hybrid of analyses that juxtaposed spatial correlation between the socioeconomic sensing of land use and land cover with the satellite remote sensing of the drivers and dynamics of LULC in the Bosomtwe district, is an addition of a layer of knowledge and a methodological contribution.

The study has demonstrated that it is possible to study peri-urban areas using the theories of urban evolution and ecological evolution with its intricate sub-processes and structures and forms part of peri-urban ecological systems (PUES) studies. This is a theoretical contribution from a Ghanaian perspective.

Further, the introduction of the new concepts of Peri-urban heat trough (PUHT) and Rural Cooling troughs (RuCT) into the land surface temperature studies as surrogates of urban heat island (UHI) analyses is novel and hence, an addition and theoretical contribution to the existing knowledge.

9.5.3.2 Contribution to the Literature from the Thesis

Empirically, through this study, the following six peer-reviewed papers have been published with additional two submitted for review and possible publication. This is quite an ample contribution to the literature. The following papers emanated from the thesis:

- **Appiah, D.O**., Bugri, J.T and Forkuo E.K. 2016. Land use conversion probability in a Periurban District of Ghana. *Chinese Journal of Urban and Environmental Studies* Vol. (3):1-21.

- **Appiah, D.O**., Schroeder, D., Forkuo E.K and Bugri, J.T. 2015. Application of GeoInformation Techniques in Land Use and Land Cover Change Analysis in a Peri-Urban District of Ghana. *International Journal of Geo-Information*, Vol. 4:1265-1289.
- **Appiah, D.O.,** Bugri, J.T and Forkuo E.K. 2015. Modelling the Perspective of Agricultural Land Use Trajectories in a Peri-Urban District of Ghana. *Journal of Scientific Research & Reports,* Vol. 5(1): 16-31.

- **Appiah, D.O.,** Adanu, S.K., Forkuo E.K and Bugri, J.T 2015. Normalized Difference Vegetation Index Analysis of the Vegetation Cover in Bosomtwe Peri-Urban Settlement, Ghana. *Journal of Basic and Applied Research International,* Vol. 5 (3): 146-156.

- **Appiah, D.O.,** Bugri, J.T., Forkuo E.K and Boateng, K.P. 2014. Determinants of PeriUrbanization and Land Use Change Patterns in Peri-Urban Ghana. *Journal of Sustainable Development;* Vol. 7(6): 95-109.

- **Appiah D. O**. and Boafo J. 2015. Analysis of Temperature Anomalies as proxy to Climate Variability and Change in a Peri-urban District, Ghana. *Advanced Journal of Environmental Management* Vol. 1(3): 20-33.

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APPENDICES **Appendix 1: A sample Questionnaire Used in the Household Survey**

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI
DEPARTMENT OF CIVIL ENGINEERING
WASCAL GRADUATE PROGRAMME IN CLIMATE CHANGE AND LAND USE

THESIS TOPIC: GEOINFORMATION MODELLING OF PERI-URBAN LAND USE/LAND COVER AND VARIABILITY CLIMATE CHANGE IN THE BOSOMTWE DISTRICT, ASHANTI REGION, GHANA

Dear Respondents
This questionnaire is administered to solicit your response on the peri-urban land use and its dynamic relationship to climate change in the Bosomtwe District. Your responses will go a long way in enabling the researcher acquire the requisite data to write a thesis for a purely an academic exercise. Your candid answers and opinions are therefore solicited. Be assured that your responses would be treated with the utmost confidentiality and the anonymity of your personality is assured. Thank you.
*Name of Community*___________________________________
*Category of respondent*____________________________

DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

1.Position of respondent in the household	1.Head	
	2.Spouse	
	3.Daughter/son	
	4.Parents	
	5.Other (specify)	

2. Gender of household head	1.Male [ ] 2. Female [ ]
3. Age of household's head	1. 20-35 years [ ] 2. 36-45 years [ ] 3. 46-55 years [ ] 4. 56-65 years [ ] 5. 66-75 years [ ] 6. 76+ years [ ]
5. Head of Household's educational level	1. No formal education [ ] 2. Primary [ ] 3. JHS/Middle Sch. [ ] 4. SHS/Tec/voc [ ] 5. Tertiary [ ] 6. Other, (specify)
6.Marital Status of head of household	1. Married [ ] 2. Single [ ] 3. Widow/widower [ ] 4. Divorced
7. Size of Household ***(A household is a person living alone or a group of people who eat from the same pot) GLSS, 2005/06.***	1. 1-5 people [ ] 2. 6-10 people [ ] 3. 11-15 people [ ] 4. 16-20 people [ ] 5. 20+ people [ ]
8. Type of Household	1. Single Household [ ] 2. Multiple Household 1.Couple only [ ]
If multiple household, which of these members constitute your household?	2.Parents with children [ ] 3.Couple and other relatives [ ] 4.Parents, children and other relatives [ ]

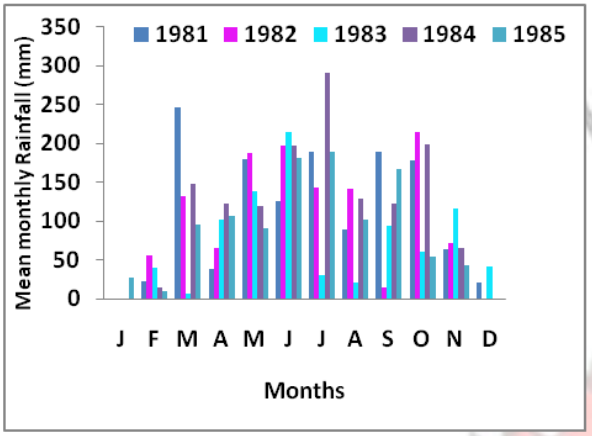
DRIVERS OF PERI-URBANISATION AND LAND USE

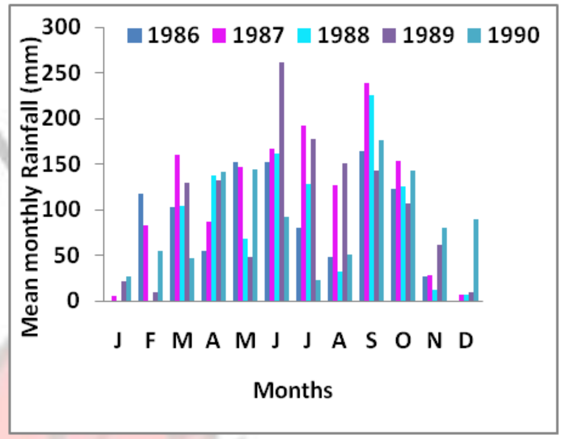
17. in your opinion which of these describe periurbanisation?	1.Increasing population [ ] 2.Increasing infrastructure [ ] 4.Increasing population and infrastructure [ ] 5. Increasing residential activities [ ]

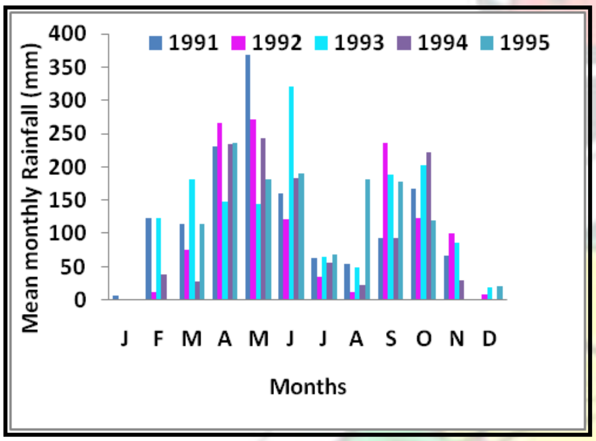
	6. Other	
	Give reason (s) ……………………………………………………. ……………………………………………………. …………………………………………………….	
18. What use can peri-urban land be put to?	1.Land for residential activities	
	2. Land for commercial activities	
	3. Land for recreational activities	
	4. Land for administrative activities	
	5. A mixture of all land uses	
19. What are the causes of peri-urbanisation in this district?	1.Availability of Physical infrastructure	
	2.Avaialability of land	
	3.Availability of social amenities	
	4.Easy Access to land	
	5.Availability of new markets	
	6. Congestion in the urban centres	
	8. A combination of the factors above 7. Other (please specify)…………………………………………… ……………………………………………………	……..
20. What are the challenges associated with the peri-urban land use plans in the Bosomtwe area?	1..Rapid population growth	
	2. Unplanned settlements	
	3. Unauthorized Physical structures	
	4. Land use for administrative activities	
	5. Land encroachments onto public spaces	
	6. Other	
21. What are the challenges associated with the peri-urban in the Bosomtwe area?		
	1. Human and vehicular traffic congestion	
	2.Social vices	
	3.Multiple sales of land	
	4.Land guardism	
	5. Other	

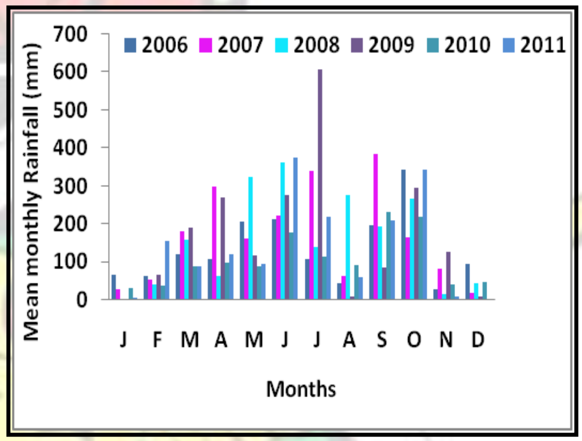
22. What human activities affect land uses and cover in the Bosomtwe district?	1.Subsistence agriculture 2.Residential expansion 3.Booming Commercial activities 4.Recreation and Hospitality 5.Industrial (small to medium) Others specify…………………………………… …………………………………………………… ………………………………………………………………… ……………………………………….
23. What are the factors determining the land use and land cover changes in the Bosomtwe peri-urban areas?	1..Easy access to land 2. Changing demand trends in land use 3. Deteriorating livelihoods of land owners 4. Economic incentives for land use conversion 5. Others specify………………… …………………………………………………… ……………………………………
24. What influence the household decision in conversion of land to other uses in the peri-urban setting?	1..Excess land sizes 2. Changing demand trends in land use 3. Deteriorating livelihoods of household 4. Economic incentives for land use conversion 5. Others specify………………… …………………………………………………… …………………………………………………… …………………………………………………… …………
25. What factors account for speculative demand for rural and peri-urban land in the community?	1..Relaxed tenure arrangement 2.Easy access to land 3.Relatively cheaper grounds rent 4. Other
26. What income categories of people are predominantly settling in the peri-urban areas?	1.High income category (owner occupiers 3 bedrooms +) 2.Middle income category (owner occupiers 2 bedrooms) 3.Low income category (tenants up to 2 bedrooms) 4. Mixed income categories (all rentals)
27. How do you respond to the conversion of agrarian/arable to residential?	1. Leased part for such activities 2. Relocate farmland to a farther place 3. Restrict the conversions

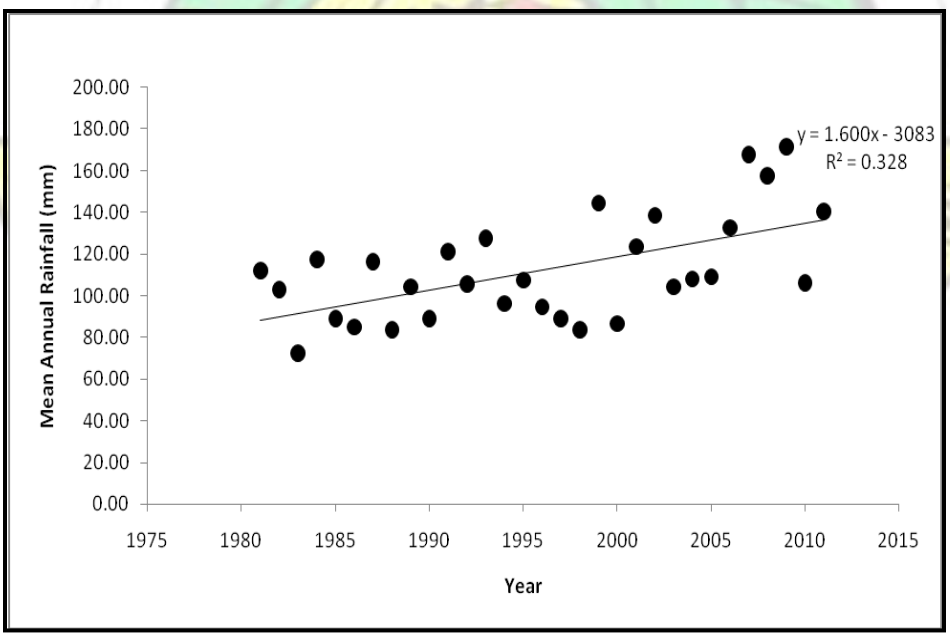
	4. All the three	
	5.Other	



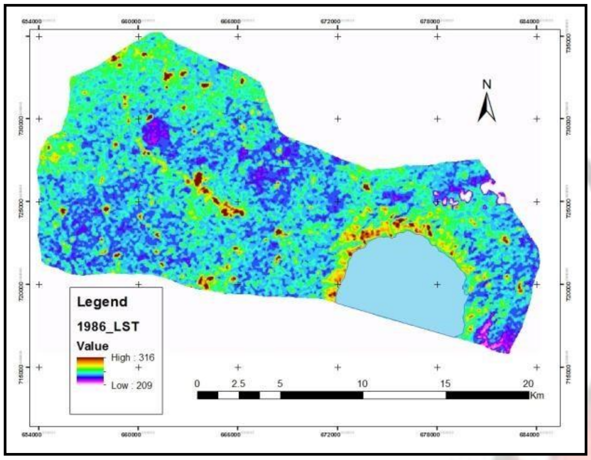


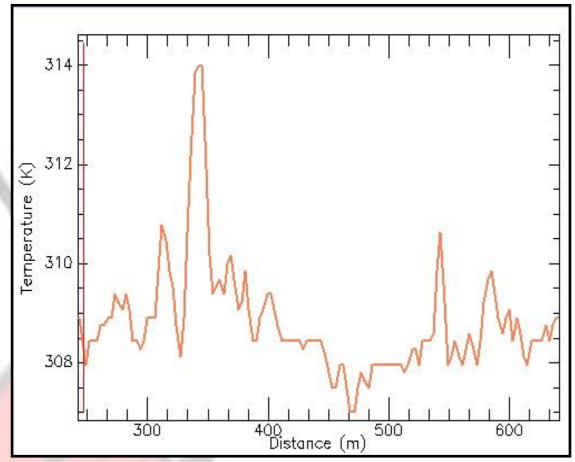




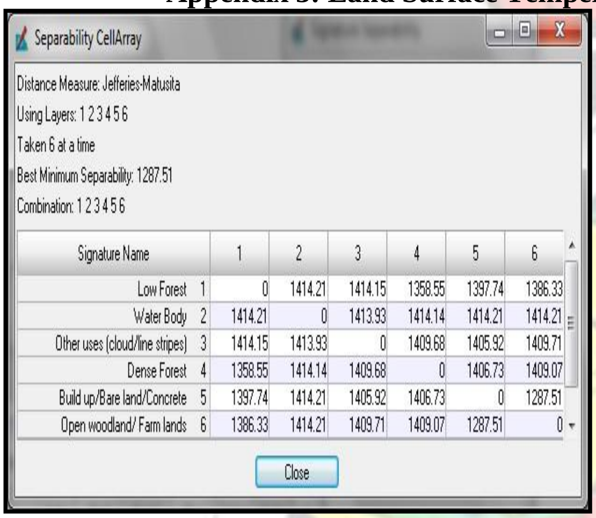


Appendix 2: Samples of Mean Monthly Rainfall figures for the 30 year period

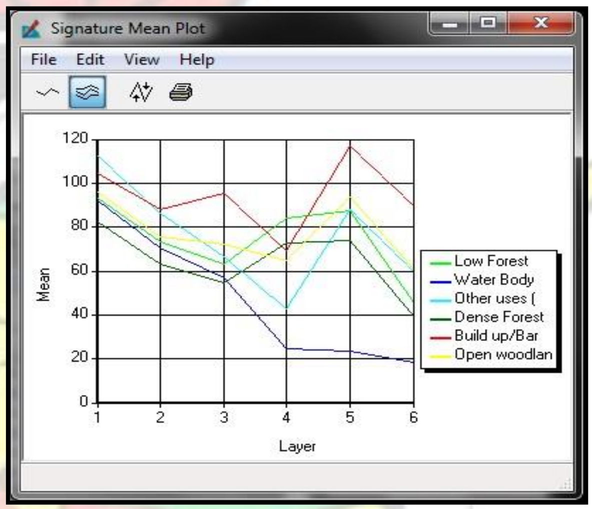




Appendix 3: Land Surface Temperature Profile of the District in 1986



Signature Name		1	2	3	4	5	6
Low Forest	1	0	1414.21	1414.15	1358.55	1397.74	1386.33
Water Body	2	1414.21	0	1413.93	1414.14	1414.21	1414.21
Other uses (cloud/line stripes)	3	1414.15	1413.93	0	1409.68	1405.92	1409.71
Dense Forest	4	1358.55	1414.14	1409.68	0	1406.73	1409.07
Build up/Bare land/Concrete	5	1397.74	1414.21	1405.92	1406.73	0	1287.51
Open woodland/ Farm lands	6	1386.33	1414.21	1409.71	1409.07	1287.51	0



Appendix 4: Jeffries-Matusita Separability Distance for the 2010 Landsat ETM+

Appendix 5: Data Table for Classical Time Series Analysis of Temperature

Year	Series	T° C	MA (3)	S_t, I_t	S_t	Deseasonalized	Trend (T°C)	Forecast (T°C)
1981	1	31.1			1	31	31.26	31.38
1982	2	31.2	31.3	1	1	31.1	31.32	31.44
1983	3	31.6	31.6	1	1	31.6	31.38	31.39
1984	4	31.9	31.5	1.01	1	32	31.44	31.42
1985	5	30.9	31.4	0.99	1	31	31.5	31.4
1986	6	31.4	31.4	1	1	31.3	31.55	31.59
1987	7	31.8	31.6	1.01	1	31.8	31.61	31.67
1988	8	31.7	31.8	1	1	31.7	31.67	31.66

1989	**9**	31.8	31.8	1	1	31.8	31.73	31.73
1990	**10**	31.8	31.8	1	1	31.8	31.79	31.8
1991	**11**	31.7	31.8	1	1	31.8	31.84	31.78
1992	**12**	31.8	31.7	1	1	31.8	31.9	31.86
1993	**13**	31.6	31.8	0.99	1	31.5	31.96	32.02
1994	**14**	32.1	32.1	1	1	32.1	32.02	32.01
1995	**15**	32.5	32.1	1.01	1	32.5	32.07	32.08
1996	**16**	31.7	32.2	0.99	1	31.8	32.13	32.09
1997	**17**	32.3	32.2	1	1	32.2	32.19	32.23
1998	**18**	32.6	32.4	1.01	1	32.6	32.25	32.31
1999	**19**	32.3	32.5	0.99	1	32.3	32.31	32.26
2000	**20**	32.5	32.3	1	1	32.5	32.36	32.35
2001	**21**	32.3	32.4	1	1	32.3	32.42	32.38
2002	**22**	32.4	32.4	1	1	32.4	32.48	32.43
2003	**23**	32.7	32.6	1	1	32.6	32.54	32.59
2004	**24**	32.8	32.9	1	1	32.7	32.59	32.67
2005	**25**	33.3	33.1	1.01	1	33.4	32.65	32.6
2006	**26**	33.1	33	1	1	33.1	32.71	32.72
2007	**27**	32.5	33	0.98	1	32.5	32.77	32.83
2008	**28**	33.5	33.1	1.01	1	33.4	32.77	32.92
2009	**29**	33.3	33	1.01	1	33.2	32.88	32.9
2010	**30**	32.1	32.4	0.99	1	32.4	32.94	32.7
2011	**31**	31.7			1	32	33	32.76
2012	**32**				1		33.06	32.82
2013	**33**				1		33.11	32.88
2014	**34**				1		33.17	32.93
2015	**35**				1		33.23	32.99