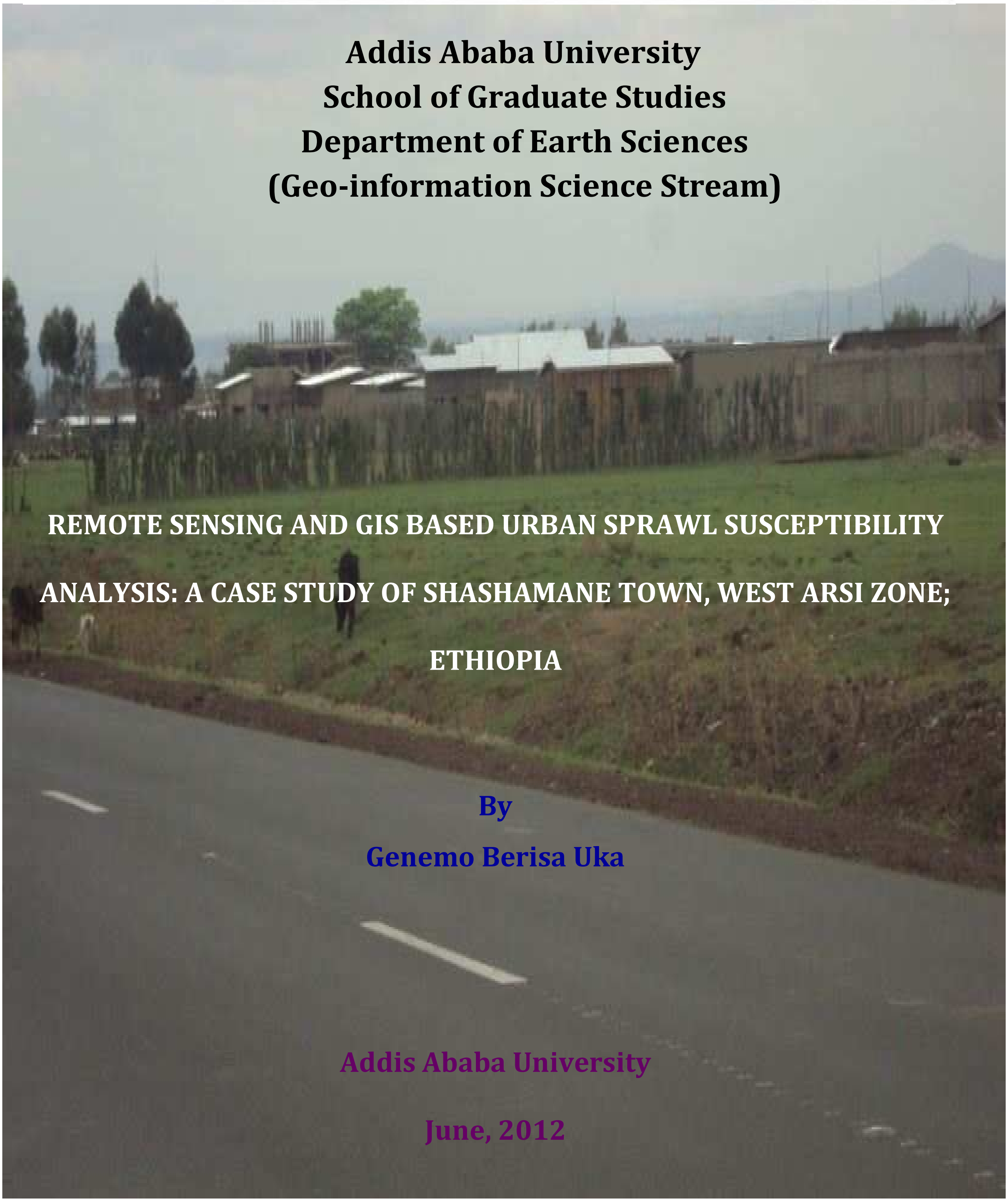

Addis Ababa University
School of Graduate Studies
Department of Earth Sciences
(Geo-information Science Stream)

REMOTE SENSING AND GIS BASED URBAN SPRAWL SUSCEPTIBILITY ANALYSIS: A CASE STUDY OF SHASHAMANE TOWN, WEST ARSI ZONE; ETHIOPIA

By

Genemo Berisa Uka

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN GEO-INFORMATION SCIENCE.

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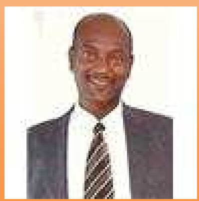

The late Professor MIESO DENKO, the scientific hero whose untimely death is the great loss not only for his family, relatives and friends but also for the scientific community at large. He was passed away on 25th April 2010, in the University of Guelph, Canada while he was only forty.

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ACRONYMS

AHP	Analytical Hierarchy Process
CR	Consistency Ratio
CSA	Central Statistical Agency of Ethiopia
DEM	Digital Elevation Model
EIA	Environmental Impact Assessment
EMA	Ethiopian Mapping Agency
EPA	Environmental Protection Agency of the United States
ERDAS	Earth Resources Data Analysis
ETM	Enhanced Thematic Mapper
FCC	False Color Composite
FAO	Food and Agricultural Organization of the United Nations
GIS	Geographic Information System
GLCF	Global Land Cover Facilities
GPS	Global Positioning System
IDW	Inverse Distance Weighted
ITCZ	Inter Tropical Convergence Zone
LU/LC	Land use / Land cover
MCE	Multi-Criteria Evaluation
MLC	Maximum Likelihood Classifier
OUPI	Oromia Urban Planning Institute
PA	Peasant Administration
PCM	Pairwise Comparison Matrix
SRTM	Shuttle Radar Topographic Mission
TCC	True Color Composite
TM	Thematic Mapper
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WGS	World Geodetic System
WLC	Weighted Linear Combination

Abstract

In this paper, analysis was made on the urban sprawl susceptibility of the town of Shashamanne using remote sensing and GIS techniques. To quantify and measure the urban sprawl, an assessment was made on the extent and rate of land use/land cover (lulc) change using multi-temporal landsat images during 1986, 2000 and 2011 and Shannon's entropy index. The supervised classification algorithm was employed to identify the major land use/land cover types in the study area and they were categorized into 4 types: agricultural lands, urban/built up areas, vegetated lands and bare fields. Being the focus was on the spatial extent of built up areas; the LULC maps were further simplified into built up and non-built up areas. With Shannon's Entropy approach the degree of dispersion or concentration of built up area's development or sprawl was described. Finally, to predict urban sprawl susceptibility of the study area the parameters such as land use/land cover during 2011, slope, population density and distances from major road axis and rivers were integrated using MCE function in ArcGIS. Results indicated that the study area has undergone a tremendous change in urban growth and pattern during the study period. Predominantly at the expense of agricultural lands and vegetated areas in the hinterlands, built-up area was increased from 1977 ha (in 1986) to 2677 ha (in 2000) and further rose to 4329 ha (in 2011). Shashamanne town was expected to have sprawl pattern types of ether linear/strip along highways, or expansion/cluster, or leapfrog as common to other urban centers in the world. However, in reality, the town has rather had irregular sprawl pattern type that is termed here as amoeboid shape. This is to mean that sprawl phenomenon in the study areas was of a variable irregular pattern showing the combination of the three sprawl patterns: linear/strip along highways, expansion/cluster and leapfrog. The analysis made on urban sprawl susceptibility revealed that, of the total area of the study site 1023 ha (8%), 5279 ha (41%) and 394 ha (3%) were respectively, highly, moderately and marginally susceptible to sprawling. This implies that large areas that are currently reserved as informal green spaces, fertile farming lands and other natural resources have been threatened.

Keywords: Urban Sprawl susceptibility, GIS and Remote Sensing tools, LULC Change, Urban Sprawl Measurement, Shashamanne Town.

1. INTRODUCTION

1.1 Study Background

The history of urban growth indicates that urban areas are the most dynamic places on the Earth's surface. Despite their regional economic importance, urban growth has a considerable impact on the surrounding ecosystem (Yuan *et al*., 2005). Most often the trend of urban growth is towards the urban-rural-fringe where there are less built-up areas, irrigation and other water management systems. In the last few decades, tremendous urban growth has occurred in the world, and demographic growth is one of the major factors responsible for the changes. By 1900 only 14% of the world's population was residing in urban areas and this figure had increased to 47% by 2000 (Brockerhoff, 2000).

The world, especially the developing ones, has shown an unprecedented expansion of urban areas and growth of urban population at such a great pace resulting in the immigration of over 60% of the world's population to live in urban areas by 2030; and it is expected that most of the urban growth will occur in less developed countries (Aldershot and Ashgate, 2003 cited in Routledge, 2007).

The rapid population growth of the world in general, and in urban areas in particular, has resulted in uncontrolled haphazard growth in the fringes of urban areas without the knowledge and consent of both concerned cities' and bordering rural administrative bodies. This illegal growth which often appears in a dispersed manner along highways, or around the city centers has pervasively been affecting rural arable land in the outskirts has in turn been threatening the livelihood of inhabitants in the vicinity. The phenomenon has further been creating amorphous suburban centers here and there hampering authorized growth of the cities. Such prohibited settlement needs immediate solution to be controlled. To this end, scholars such as Theobald and Bugliarello, have explicitly termed such destructive and illegitimate urban expansion towards neighboring rural villages as "urban sprawl" (Theobald, 2001; Bugliarello, 2000). Because of the steep numbers, the civic bodies have already been wavering; they cannot manage the fast growth of the population and therefore, urban centers are expanding in an unplanned way. It has been noted in various literature that urban sprawl, the main focus of this study, is a complex phenomenon, which not only has environmental impacts, but also social impacts (Barnes *et al*., 2001). For instance, it has been witnessed that urban sprawl has resulted in the loss of productive agricultural land, open green spaces, loss of surface water bodies and depletion of ground water, besides causing water, air, noise, and solid waste pollution.

Even though it is quite difficult to discern urban sprawl in totality, good ways of understanding its complexity are land use/land cover change analyses and urban growth pattern recognition (Sudhira *et al.*, 2004). Throughout the literature, there is ambiguity on the distinction between urban growth and urban sprawl except to suggest that urban sprawl is a type of urban growth. On top of this, a linked phenomenon of urban sprawl outside the actual agglomeration boundaries is described as leapfrog development and is observed in more and more major cities across the world (Gordon and Richardson, 1997). Due to its complexity, there is no specific, measurable, and generally accepted definition of urban sprawl (Sutton, 2003).

However, until recently, the problem of urban sprawl was restricted to the developed world; it also exists in developing countries although in a different form. For developing countries sprawl is largely a result of necessity- people move to the city in search of better employment opportunity (Menon, 2004). This necessity led immigration of the people from countryside to the cities and commit illegal settlement within and around the jurisdictional boundary of urban areas stretching the size well beyond the limits of the city. In contrast, sprawl in developed countries is the results of high incomes that pushes out the rich from the center of cities where people live in very congested manner; therefore, it is possible to say that sprawl in developed countries is the results of wealthy people's preference to live in the outskirts of the city, where open spaces are found at reasonable distances from cities. Even though the causes and patterns of sprawl are different depending on the context in which they occur, solutions proposed are similar with some modifications. Prior needs and economic viability should be taken into consideration for best results. 'Concentrating growth' is what many planners recommend as a measure against sprawl for a sustainable city.

The transformation of rural land into urban land uses leads to increase in impervious surfaces. The major impact of urban sprawl is felt on the productive agricultural lands, surface water bodies, changing urban hydrology and creating new hydrological environment (Alberti *et al*., 2000, Banzhaf *et al*., 2009 and Grimm *et al.*, 2000). Mapping urban sprawl helps to identify areas where environmental and natural resources are critically threatened and to suggest likely future directions and patterns of sprawling growth (Simmons, 2007). The physical expressions and patterns of sprawl on landscapes can be detected, mapped, and analyzed using remote sensing and geographic information system (GIS) techniques in conjunction with the secondary and ground truth data (Barnes, 2001).

Urban sprawl mapping and monitoring is one of the operational applications of satellite remote sensing data, irrespective of its spatial and spectral resolution of the satellite-borne sensors. From the earliest (Landsat-MSS-1973) 70m resolution data, with comparatively coarse resolution TM 30m to the present high spatial resolution data (IRS-P6 MSS) 5.8m, have been proved efficient and more accurate in detecting the changes in land cover and urban sprawl (Alabi and Ufuah, 2007), (Martinuzzi *et al*., 2007) and (Zhang *et al*., 2006). GeoEye-1, Ikonos and QuickBird are equipped with the most sophisticated technology ever used in a commercial satellite system. They operate in multi spectral bands and offer unprecedented spatial resolution by simultaneously acquiring panchromatic and multi-spectral imagery. Geographic Information System (GIS) together with remotely sensed data and the calculation of Shannon's Entropy values have commonly been used to measure and monitor the degree of urban sprawl.

Various studies have been done for quantifying the urban sprawl in developed countries and in developing countries. However, all these studies have come up with different methodologies in quantifying sprawl. But the common approach is to consider the behavior of built-up areas and population density over the spatial and temporal changes taking place. Typically, conditions in environmental systems with gross measures of urbanization are correlated such as population density with built-up areas (Berry, 1990). The relation of population growth and urban sprawl is that the population growth is a key driver of urban sprawl. Modeling of the sprawl can be done using both spatial and statistical parameters, i.e., land use, built-up areas, and population (Sudhira, 2003). In this study an integrated approach of GIS, Remote Sensing and Shannon's entropy has been applied to identify and analyze the patterns of urban sprawl and provide quantitative and spatial information on developments of urban areas of the town of Shashamanne.

1.2 Statement of the Problem

Various methods exist for tracking urban sprawl such as recording the location and number of building permits or simple visual assessments. However, these data are often difficult to incorporate for instance, compiling paper building permits into useful statistics, are frequently subjective and may not accurately capture temporal patterns of urban growth and change in peri-urban rural environment. The use of remotely sensed data to analyze urban sprawl and rural hinterlands distribution allows land use planners to perform large-scale temporal analyzes with minimal investment of time and money. Additionally, remotely sensed data are easily incorporated into Geographic Information system (GIS) along with other data such as zoning regions, topographic, hydrographic, geologic and political boundaries, allowing for urban managers to consider the effect of these factors may have on observed growth patterns. This ancillary information is invaluable in determining the intrinsic suitability of regions (McHarg, 1969) and aids in the development of holistic land use/urban planning.

On a local basis, the expansion of the town of Shashamanne to its rural outskirts, overtaking the wide, highly productive agricultural areas mostly used for cereal crops production, has drawn attention to consider the town being used as a case study of how remotely sensed data can be used to analyze urban sprawl and its implication on the peri-urban land's resources. It has to be noted that the process of urbanization in the town vicinity is continuing to encroach on the fertile areas of the region. Therefore, consideration and careful assessment are required for monitoring and planning land management, urban development and decision making. Although specific growth patterns of the town are important to planners, in this paper it has been sought to address the potential of remotely sensed data and application of GIS and remote sensing techniques in urban sprawl susceptibility and its influence on peri-urban environment analyses.

1.3 Justification

Urban sprawl creates inefficient use of land resources and large-scale encroachment on agricultural land. To this end, Sudhira *et al*. (2004) state that understanding the patterns of urban sprawl can help with natural resource planning, natural resource utilization, and the provision of infrastructure facilities. The most pressing problem of sprawl is the substantial loss of fertile agricultural land around many towns because of urban developments. Ewing (1997) argues that suburbanization as we know it is not the issue, but rather the wasteful form of development known as sprawl with which many towns have a problem. Nechyba *et al.* (2004) lists a surplus of ills related to sprawl: the loss of open space, urban decay, unsightly strip mall developments, the loss of a sense of community, patchwork housing developments in the midst of agricultural land, increasing reliance on the automobile, the separation of residential and work locations, and the spreading of urbanized developments across the landscape. "Sprawl has become the metaphor of choice for the shortcomings of the suburbs and the frustrations of central cities (Galster *et al*., 2001)."

1.4 Objectives of the Study

1.4.1 General Objective

The principal objective of this study was to apply remotely sensed data using GIS and Remote Sensing tools to detect, quantify, analyze and map urban sprawl susceptibility and its implication on peri-urban rural environment in the town of Shashamanne.

1.4.2 Specific Objectives

The following are some of the specific objectives of the paper:

- To investigate and quantify the urban sprawl over the study area based on the analysis of temporal images to detect the trend of land use/cover change;
- Assess pattern of the built-up areas and population density as indicators of urban sprawl thereby classifying those patterns as linear or strip along highways, expansion or cluster, and leapfrog;
- Identify and measure urban sprawl using Shannon's entropy, the renowned urban sprawl index, and map urban sprawl susceptibility by integrating parameters;
- Analyze the major impacts of urban sprawl on agricultural lands present in peri-urban areas of Shashamanne Town and predict urban future land use changes.

1.5 Research Questions

Three research questions were posed to guide this study. These questions were in turn guided by the research objectives.

1) How urban sprawl is taking place in the study area based on characteristics of new urban growth? What are the major indicators of urban sprawl?
2) What existing socio-economic and physical parameters (factors and constraints) are influencing the present and future urban sprawl in Shashamanne?
3) How the urban sprawl is affecting the peri-urban agriculture in Shashamanne and what sound solution/s will be sought?

1.6 Significance of the Study

One of the major impacts of urban sprawl is a shrinking amount of cultivated land through the development of infrastructures and various development projects. Therefore, urban land use change studies are important tools for urban or regional planners and decision makers to consider the impact of urban sprawl. The results of this study could provide information relevant to contribute in the environmental management plans and improve urban planning issues. It is also expected to:

- Provide information on the status and dynamics of the urban land use of the area and the use of remotely sensed satellite imagery for such analysis for planners.
- Assist environmentalist, regional (urban) planners, and decision makers to consider the potential of geospatial tools for monitoring and planning urban environment.
- Provide elements for long term bench-mark monitoring and observation relating to resource dynamics.
- Provide a base line for eventual research follow-up, by identifying specific and important topics that should be considered in greater detail by those interested in the area.

1.7 Limitation of the Study

It is often not uncommon for a study to have some sort of limitation/s during its course of undertaking. One limitation of my research lies in the use of Landsat imageries with course spatial resolution of 30m for urban land use/land cover classification due to expensiveness and unavailability of other imageries with the finest resolution like QuickBird which is ideal for urban features distinction. Therefore, the difficulty to discern each land use/land cover category has resulted in misclassification of one land use/land cover into another. In order to overcome this problem, field observations were repeatedly undertook to verify actual land use/land cover which in turn incurred me both time and energy expenditures.

The other major limitation is pertained to a number and types of variables aggregated to derive urban sprawl susceptibility map. Due to the complexity of urban sprawl phenomenon, more numbers of multifaceted change drivers (variables) must have been included than what have been incorporated in this study. This is because it was not possible to get data to add more equally important change drivers (e.g. lack of reliable and complete socio-economic dataset).

Therefore, the manner in which urban sprawl susceptibility is analyzed within the study area based mostly on physiographic factors leaves room for further research to consider all these limitations and incorporate other socio-economic variables like land price speculation, provision policy, developers' economic status, and ownership style and tenure system that would exhibit the proliferation of urban land development in a given area.

1.8 Organization of the Thesis

The research paper is organized into five major parts. **The first part** contains the background, purpose and significance of the study in which clear information to the readers has been provided. This part highlights the global status, prospects and problems of urban sprawl. **The second part** is devoted to different worlds' approaches, methods and mechanisms of urban sprawl studies, which have assisted the researcher to produce different arguments on the selected topic. Here the concept, both global and national trends, causes and impacts of urban sprawl have been stated in brief. The application of GIS and remote sensing techniques in urban sprawl studies is also reviewed. **The third part** starts with the description of the study area followed by the methods employed including data types and sources, software and instruments utilized to carry out the research. In this part, image classification algorithms and data analysis techniques are briefly described. **The forth part** is dedicated to the results and discussion components of the thesis. Results from the analyses of LULC change, Shannon's entropy index, demographic change and area's susceptibility to urban sprawl have been encompassed in this part. This part is concluded with the discussion, which focuses on comparison of results obtained with existing theories and practices. The conclusion and recommendations are **the fifth and the last part** of the study. These have presented conclusive remarks based on the findings and the researcher's suggestions pertaining to the mechanisms of checking urban sprawl impacts on the peri-urban green agro-rural setup of the study area.

2. LITERATURE REVIEW

2.1 Urban Sprawl Concept

Urban sprawl is often difficult to estimate because it can occur slowly over time. Wilson *et al.* (2003) argue that without a universal definition of sprawl it is extremely difficult to model. Not all urban growth is considered sprawl because what is sprawl to some may not be to others. "Creating an urban growth model instead of an urban sprawl model allows us to quantify the amount of land that has changed to urban uses, and lets the user decide what he or she considers to be urban sprawl" (Wilson *et al.*, 2003). Urban sprawl is characterized by leapfrog land use patterns, strip commercial development along highways, and very low-density single-use developments, all of which occur over a relatively short period of time (Ewing, 1997). Sprawl is urbanization that takes place in either a radial direction around a well-established city or linearly along the highways over a given period of time (Sudhira *et al*., 2004). Clearly, radial and linear are just two types of map patterns that sprawl can take. Sudhira *et al.* (2004) state that to understand the complexity of urban sprawl, land use change analyses and urban growth pattern recognition must be determined. Throughout the literature, there is ambiguity on the distinction between urban growth and urban sprawl except to suggest that urban sprawl is a type of urban growth.

Some sources have been defined in terms of associated causes: urban sprawl is generally believed to result from poorly planned, large-scale new residential, commercial and industrial developments in areas not previously used for urban purposes (Zhang, 2001). However, there is one overriding theme in the recognition of urban sprawl: a spatial-temporal signature unique to the phenomenon.

Urban sprawl can be described as low-density development occurring on the edge or outside of a municipal area that does not follow a specific growth pattern (Tallinn, 2002). As the word ’sprawl’ is a multidimensional phenomenon, it has caused much confusion. Possible mathematical regressions attempting to explain sprawl from land use perspectives such as the degree of compactness did not generate statistically significant results (Wassmer, 2005) and hence the difficulty to mathematically define the term. The Vermont Forum on Sprawl defines sprawl as: dispersed development outside of compact urban and village centers along highways and in rural countryside (web page, 2011). In her report, Revisiting Sprawl: Lessons from the Past, Burgess, (1998) defined sprawl as "...expanding physical development, at decreasing densities, in metropolitan regions, where the spatial growth exceeds population growth".

As the term is so widely used, all descriptions of sprawl leave one to search for something more definite and solid. Questions like how far should a development have to stretch, how dense or thin should it be in order to be called 'sprawl' will be left unanswered. But with an empirical definition it would be easier to conduct a discussion of the forces and factors that cause certain patterns of development and face the consequences that follow from certain urban planning forms for different population groups, such as a region's poor residents. This can make it easier to tackle problems that can arise from poor land management and therefore lead one to best and effective usage of the limited land resource.

Green space is an important feature of an urban environment that provides opportunities for outdoor recreation, wildlife habitat, groundwater recharge, pollutant filtering, urban beautification, and improved environmental health (Stephenson and Stoel, 1999). Urban sprawl leads to loss and increased fragmentation of green space areas, thereby diminishing the positive function of green space (Wang and Maskovits, 2001). Fragmentation has a particularly negative impact on wildlife in and around the urban area (Marzluff and Ewing, 2001). Determining the degree of fragmentation may prove useful to evaluation of urban green space.

2.2 Urban Sprawl Operation Using Geo-information Techniques

Urban sprawl is initially detected by gauging urban growth in many ways. Masek measures urban growth by using remote sensing and GIS to measure rates of urbanization (Masek *et al.,* 2000). Other studies have measured sprawl in terms of data layers within a GIS to detect patterns of urban sprawl (Clarke *et al.,* 1998).

Clearly, there have been many ways to measure urban dynamics indicating that there are numerous avenues to reach a similar destination. Population growth can be a driving force behind urban sprawl. To this end, Lindstrom *et al.* (2003) state that if population growth is substantial enough to produce the required consumer market, "big-box" commercial development often takes place seeking larger lots for stores, ample parking, easy access for multiple communities, and heavy commuting traffic, big-box developments locate on the outskirts rather than in the existing town commercial centers. Therefore, in order to understand urban sprawl it is important to contemplate many different urban growth dynamics including population growth, land conversion practices, and market forces.

2.2.1 The Use of GIS in Urban Sprawl Research

The complexity of urban systems makes it difficult to adequately address their changes using a model based on a single approach (Allen *et al*., 2003). Therefore, it is ideal to use a tool such as a GIS as part of the research on urban sprawl because of its capacity to handle many different types of spatial data. In South Carolina, a GIS-based integrated approach to modeling and prediction of urban growth in terms of land use change was employed to meet the challenge of studying urban sprawl (Allen *et al*., 2003). The researchers used satellite imagery incorporated into a GIS to map predictions of urban growth in the study area. The predictions were based on variables such as road density, forest, slope of the land, and population density. Each variable was entered into the system as a data layer and multiplied by a coefficient to determine how likely it was that a given parcel of land would be converted to urban land use (Allen *et al.,* 2003).

In East and West St. Paul, Winnipeg, Manitoba, Canada, most urban sprawl was occurring on prime agricultural land (Hathout, 2002). In that study, a GIS was used to predict future growth patterns and the impacts that such growth would have on agricultural land (Hathout, 2002). Hathout (2002) used the data base analysis capabilities found in a GIS to analyze aerial photographs of the study area from 1960 and 1989 to determine impacts on agricultural land. For that study, land use derived from the aerial photographs in the GIS was placed in one of three main categories: urban, agricultural, and other (Hathout, 2002).

A GIS will not only allow for powerful visualization of urban sprawl within the study area by providing maps, but it will also allow for an in depth analysis of the data by providing the capability to examine all of the data in one system, therefore facilitating the measurement of urban sprawl. A GIS is also an extremely powerful tool for creating new data from existing data and is often referred to as a decision support system (Burrough *et al.,* 1998). In China, a GIS was used as a decision support system to test different development scenarios and land consumption parameters for use by planners and local government officials (Gar-On Yeh *et al*., 1998). Using the neighborhood function in the GIS, Gar-On Yeh *et al*. (1998) were able to test development scenarios that would reduce the fragmentation of new growth, a component of urban sprawl (Gar-On Yeh *et al.*, 1998).

In another study by the same authors, it was concluded that Landsat TM images coupled with an entropy integrated GIS was successful in measuring and monitoring urban sprawl patterns when the area is large and land use changes quickly (Gar-On Yeh *et al*., 2001). Gar-On Yeh *et al*. (1998) employed a Shannon's entropy technique with the integration of remote sensing and GIS. Shannon's entropy is another landscape metric calculation technique whereby the authors measured urban sprawl patterns statistically based on the spatial variation and temporal changes of growth areas (Gar-On Yeh *et al*., 1998). A numeric value was given to the new growth areas to quantitatively describe how dense and connected growth areas were (Gar-On Yeh *et al.,* 1998).

The methods used to quantify urban sprawl throughout the literature are dependent on the intended purpose and the individual aim of each piece of research. The objective of the research conducted on the Washington-Baltimore CMSA was to relate observed changes in land cover to economic and demographic drivers of that change (Masek *et al*., 2000). They used historic and present-day satellite imagery to measure land use change, but it was unclear how the researchers were going to link those changes to economic and demographic data. The purpose of the study was to quantify and map urban growth thereby determining the geographic extent, pattern, and class of such growth over time.

2.2.2 Remote Sensing Approaches to Urban Sprawl Research

Satellite remote sensing offers a privileged gateway to the monitoring, modelling and analysis of urbanization processes, particularly in developing countries, where it makes up for the scarcity of geographic data and up to date maps (Gadal, 2003). Satellite images, which are rapidly accessible and have been available for the past thirty years or so from the Landsat satellite series and then from the Spot series4, are used to monitor at regular intervals, annually or more frequently, the dynamics of urbanization and land use transformation, particularly in countries which have very high rates of urbanization (Sudhira *et al*., 2003). Maps and geographic databases, which rapidly become obsolete, can thus be updated. Satellite images can be used to monitor the development of urbanization continuously over geographic areas of differing sizes. Spatial modeling of urbanization processes is carried out apparently by historical analysis of remote sensing, i.e. by comparison of images or spatio-maps between two or more dates (Kumar *et al*., 2008).

Integrated into a Geographic Information System, structured and associated with other geographic information such as, for example, digital terrain models showing types of relief and roads, the geographic models produced give a specialized representation of the urban development of land areas. There is a growing tendency to combine satellite remote sensing and GIS into a single system for analyzing geographic space and its dynamics although it seems difficult to find a single definition for the approach (Mesev *et al*., 2007). The use of integrated approaches combining satellite remote sensing and GIS to monitor, analyze, geographically model and spatially represent urbanization is combined with two other approaches: the integration of 3D geo-visualization and dynamic cartography/ representation, i.e. the representation of urban growth in the form of a 3D animation. Dynamic representation or cartography of geographic processes is used in physical geography to model and represent changes in relief, or a water course (Drogue, 2002 and Pilouk, 2007).

2.3 Global Trends in Urban Sprawl

As population increases, urban sprawl on a global scale is becoming more apparent than ever. Increases in population often lead to increases in development, which has a direct influence on agricultural land conversion. Masser (2000) states that urban growth is inevitable over the next two decades and that most of this growth will take place in less developed countries. In China, rapid land use change has occurred since economic reform (Gar-On Yeh *et al.,* 1998). A study done there measures urban sprawl in terms of land suitability and the favorability that land has for being converted to urban use (Gar-On Yeh *et al.*, 1998). The authors were interested in developing a model that could be used for sustainability purposes in an attempt to control urban sprawl under rapid rural urbanization (Gar-On Yeh *et al*., 1998). "This is most severe in southern China and the coastal areas where the economy is developing very rapidly and the conflict between the environment and economic development is most severe (Gar-On Yeh *et al*., 1998)." In Dongguan, a fast growing city in southern China, the conversion of agricultural land into urban land has removed the possibility for food production forever (Gar-On Yeh *et al*., 1998).

Southern China is not the only place where patterns of urban sprawl are very common due to sharp increases in population and the creation of new infrastructure. In other developing countries like India, where the population is over one billion, one-sixth of the world's population, urban sprawl is taking its toll on natural resources (Sudhira *et al*., 2004). "This indicates the alarming rate of urbanization and the extent of sprawl that could take place. In order to understand this increasing rate of urban sprawl, an attempt is made to understand the sprawl dynamics and evolve appropriate management strategies that could aid in the region's sustainable development (Sudhira *et al*., 2004)."

The approach to the Sudhira (2004) study is to use change at the landscape level within a Geographic Information System to calculate the fragmentation and patch density of new growth areas and classify those areas as sprawl. While many models seek to achieve this goal, they do not relate urban sprawl to anything more than urban growth. "The inadequacy in some of these is that the models fail to interact with the causal factors driving the sprawl such as population growth, availability of land and proximity to city centers and highways (Sudhira *et al.,* 2004)."

According to Sudhira *et al.* (2004), the use of GIS, remote sensing, and landscape metric techniques to quantify urban sprawl is ideal platform by measuring densities and spatial distributions of built-up land. Using landscape metrics that show densities of urban land and connectivity of that land, the authors are able to justifiably classify different types of urban sprawl: cluster, leapfrog, and linear (Sudhira *et al*., 2004). More dense and compact areas of built-up land are classified as cluster, while medium density areas with low connectivity areas are indicative of leapfrog patterns. The linear pattern of sprawl is classified as high and medium density built-up areas of development located along the highways (Sudhira *et al*., 2004). This technique for quantifying urban sprawl is perfectly adequate based on the assumption that it is the pattern and spatial distribution of urbanization that is the key component to urban sprawl.

2.4 National Trends in Urban Sprawl (Ethiopian Context)

Ethiopia is the third most populous country in the whole of Africa exceeded only by Nigeria and Egypt. The total number of persons enumerated in the third Population and Housing Census -- aggregating the May and November, 2007 data sets -- was 73,918,505. Of these, 37,296,657 (50.5%) were males and 36,621,848 (49.5%) were females. The population of the country in the previous censuses of 1984 and 1994 were 39,868,572 and 53,477,265, respectively (CSA, 2008). The distribution of the total population varies by place of residence. About 84 percent of the total population in the country was found in rural areas, while the remaining 16 percent lived in urban areas. Urban population growth in Ethiopia is estimated at 6%, a much higher figure compared to other African countries. Serious social problems still prevail in large cities. The country is one of the least urbanized areas in the Third World. Its economy almost entirely depends on agriculture, although production and food provision is low due to bad weather conditions and lack of effective technology. Poverty prevents the country from using high tech and non-seasonal means of production. In addition, almost 80 percent of the populations practice only agriculture and animal rearing as a means to sustain them.

Another aspect of urbanization in Ethiopia is the wide range of regional differentials or polarization in the level of urbanization. Like most developing countries, serious rural to urban migration is a common phenomenon. Tribal wars and conflicts are common phenomena driving people from their villages. Slums are emerging in different parts of cities, especially the capital, and are the only choices for the majority of the city dwellers that are poor. Additional population increase in bigger cities is accommodated by crowding of existing houses. Rather than new construction developments, existing houses are often extended or divided illegally so that they can be rented for migrants. The need for housing is not integrated with the need to prevent horizontal expansion and hence saving land.

Formal and informal settlements are stretching out horizontally from the central cities in all directions. Land is ineffectively used; new developments are planned on virgin land usually leapfrogging from cores. Generally, as pointed by (Haregewoin, 2005), sprawl and misuse of land in Ethiopia is the result of population pressure (both from natural births and migration), poor land policies, lease system and planning and regional imbalance. Action is therefore needed to provide for immediate needs of the population while trying for solutions to overcome mismanagement of land and further horizontal expansion with minimum financial expenditure (Haregewoin, 2005).

2.5 Causes of Urban Sprawl

Generally, population growth, rise in household income, subsidization of infrastructure investments like roads, ineffective land-use, excessive growth, social problems in central cities and poor land policies are taken to be the main causes of sprawl. One of the main factors that help in explaining the increasing sub-urbanization of population in rich countries is the demand for larger suburban lots. With rise in household incomes, people who move into the suburbs are motivated to a significant degree by the desire for more living space. Between 1950 and 1980, one-half of the increased sub-urbanization in America can be explained by people getting richer (Glaeser and Kahn, 2003). Compared to people who live in cities suburbanites live in larger houses on larger lots and use automobiles more often. Developed countries like the USA also invest substantial amounts of money on road and transport infrastructures encouraging the use of private cars. The high correlation between using automobiles and living in low-density edge cities may not prove that cars caused sprawl but is an indication that the two strongly complement each other. Both rising incomes and automobile ownership were therefore necessary conditions. Most people do not want to live in the cities - they choose to move out. Thus, sprawl in developed countries is usually a matter of preference. In the developed world, the movement of people from rural area of the country to more heavily populated cities and towns has been reversed.

In contrast, for developing countries sprawl is largely a result of necessity- people move to the city in search of better employment and opportunities (Menon, 2001). They could be driven out of their farmlands for different reasons such as bad weather conditions, poor harvest or simply because they do not have the means of income. Increased urban population leads to an increase in size well beyond the limits of the city. When the cities are not expanding, the people are forced to live in informal settlements with increased congestion and density (higher number of people per household and no basic services).

2.5.1 Population

Often, one comes across population growth as the main cause of urban problems and urban sprawl. The global population has doubled over the past 40 years with remarkable shifts in geographical distribution (State of World Population, 1999). Africa has grown the fastest. Asia, by far the most populous region, has more than doubled in size (to over 3.6 billion), as has Latin America and the Caribbean. In contrast, the population of Northern America has grown by only 50 percent, and Europe's has increased by only 20 percent and is now roughly stable. An increase in a country's urban population can be due to three causes: the natural growth rate of the urban population, the re-classification of rural settlements as they grow and reach a certain number that makes them cities and towns, and rural-urban migration. Although data was unavailable to distinguish among the three, a 1979 study showed that in 29 developing countries, between 1960 and 1970, about 61 percent of urban growth resulted from natural growth-the excess of births over deaths. Of greatest interest especially in more recent years, however, is rural-urban migration, as this is what is most commonly thought of as 'urbanization' and accounts for 40 percent of urban population increase (web page, 2012).

Change in land-use can produce a change in quality of life for those living within the landscape. This alters the attractiveness of living in the countryside compared to urban life and, therefore, affects the net migration between urban and rural locations. For many years though, rural-urban migration was viewed favorably in the economic development literature, migration was thought to be a natural process in which surplus labor was gradually withdrawn from the rural sector to provide much needed manpower for urban industrial growth process. But it has greatly exceeded rates of job creation and service provision, and has become the cause of many cities' political and social problems. Population mobility in the 20th century is constrained by availability of jobs and supply rate of housing. Countries are directing policies at reducing and through time stopping the flow of people.

Even though all the evidence points at population pressure as the key factor for change in land use and hence urban sprawl, cities with no population growth were also observed to sprawl (Blankenship, 2001). Therefore, the acre of land that is sprawled is not proportional to population growth in most cases. Nevertheless, the only way to stop urban crowding and to solve most of the urban problems of both the developed and developing countries, lies in reducing the overall rate of population growth.

2.5.2 Land-use and Land Consumption

There is a major controversy whether land-use and consumption decisions are the primary engines of urban sprawl or whether it is continuing population boom that provides most of the expansion. Some argue that sprawl is first and foremost a land-use phenomenon, since even an area of static population can experience sprawl as its built environment is modified in a sparse, low-density, auto-friendly way pushing city limits further and further out. A careful analysis of U.S. Census Bureau data found that these two sprawl factors share equally the blame for some, if not all, of the sprawl in some regions of the country.

Therefore, questions like "Is population growth or land-use change worse for sprawl?" can only be answered after a deeper observation of the situation, causes and effects within the area in question. Cities grow, with or without planning, and develop landscape characteristics that persist through time determining how they will function. Fulfilling the resource requirements of a growing population ultimately requires some form of land-use change in order to provide for food, living space, recreation, infrastructure development and service provision.

Historical constraints on city size limitation were cost of transport to export goods/ import agricultural products, the degree of economy of scale relative to market demand and the cost of carrying on day-to-day activities within the city itself (commuting to work, delivery of water, disposal of waste and sewage). These were all relaxed with time. Some possible forces driving land-use and land-cover changes are population, technology (mainly automobile), political economy and political structure. Land consumption - the amount of land used per person-is the inverse of population density, the higher the population the lower the amount of land used per person. The other alternative reasoning as to why growth of the suburbs has come about is because people have fled the social problems of the inner city. In addition, population pressure in city centers enhances the competition for employment, production and sales and hence some planning policies favor decentralization, and locate firms and residences in the urban fringes creating edge cities (web page, 2012). Urban land use generally expands at the expense of agriculture as demand for housing grows. This brings about differences between land consumption in the centre and fringe of the urbanized area and creates changes in land consumption rates through time.

2.6 Impacts of Urban Sprawl

Environmental impacts of urban sprawl as pointed out by (Knight *et al.,* 1995, and Auld, 2001) comprise: Loss of arable land to development, decreased aesthetic value of the town due to unauthorized developments and elevated air and noise pollution. Urban sprawl also can have substantial economic impact on communities through increased cost of services such as emergency response, infrastructure, or public works and utilities (Chen, 2000; Speir and Stephenson, 2002).

'Sprawl' in simple terms is just spreading out of a city and its suburbs over more and more rural land at the periphery of an urban area, while in reality it is a complex phenomenon that means different things in different areas and conditions. Early uses of the term suggest that it consumes excessive space in an uncontrolled, disorderly manner leading to poor distribution and loss of open spaces, high demand for transportation, and social segregation.

There is a division between the place of sprawl (origin) and the location of its impact (destination). When sprawl takes place at the periphery of a certain locality it could have its direct or indirect impact on other parts of the same locality within its border, or on a neighboring community. Generally, there are two conflicting ideas about the consequences or effects of sprawl. While some argue that it is harmful and stress measures that should be taken to combat it, others support and even encourage it.

2.7 Land use/land cover change as an assessment of urban sprawl

Change detection is the process used in remote sensing to determine changes in the land cover properties between different time periods. It is also viewed as the process for monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution in the area of interest (Tardie and Congalton, 2004). Change detection has been applied in different application areas, ranging from monitoring general land cover change using multi-temporal imageries to anomaly detection on hazardous waste sites (Jensen *et al.*, 2005). One of the most common applications of change detection is determining urban land use change and assessing urban sprawl. This would assist urban planners and decision makers to implement sound solutions for environmental management in general and urban environs in particular.

3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location

Shashamanne, the capital town of West Arsi Zone, is located 250km south of Addis Ababa, the capital city of Ethiopia, with a surface area of 12,868 ha. The town is located between 7°8′50″N to 7°18′17″N latitude and 38°32′43″E to 38°40′58″E longitude (Figure 3.1). As to the recent organizational division, Shashamanne is divided into eight sub-cities, namely: Awasho, Abosto, Dida-Boke, Bulchana, Burqa-Gudina, Arada, Alelu and Kuyera.

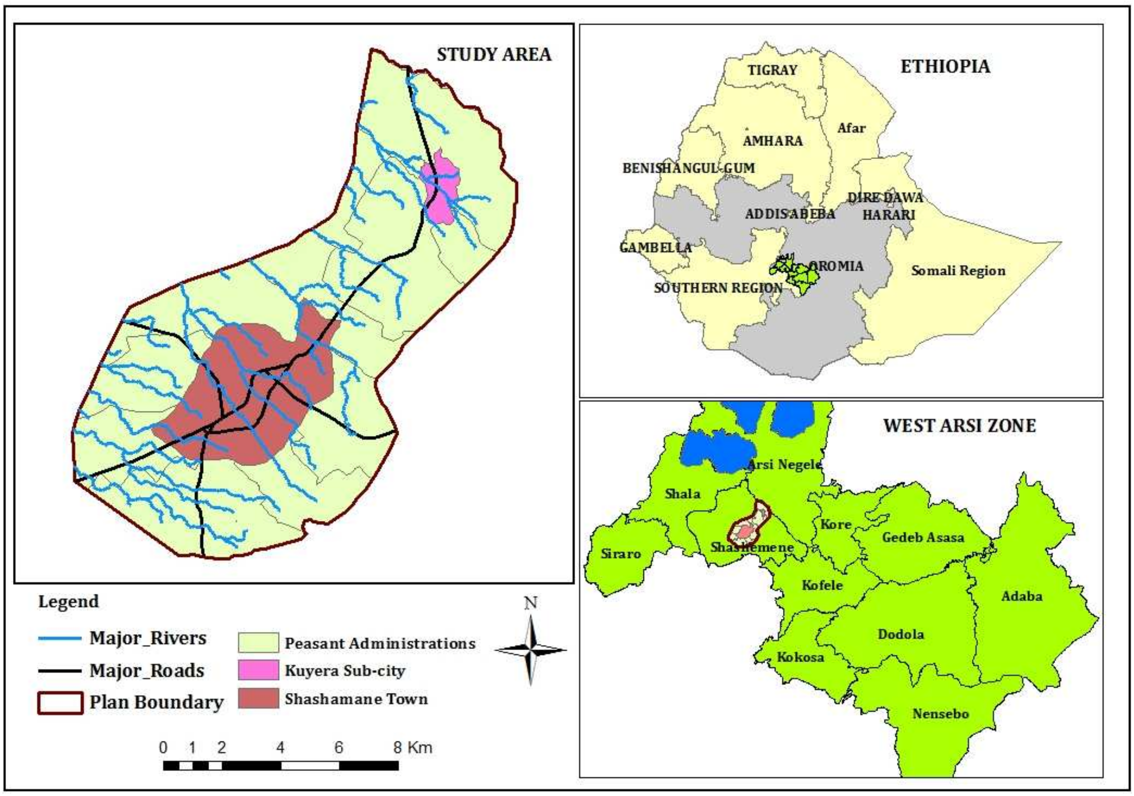

Figure 3.1. Location map of the Study Area.

3.1.2 Physiographic Setting of the Study Area

Shashamanne extends to the south-eastern escarpment of the Rift Valley. The town is located on a plateau with an elevation ranging from 1,826 to 2,107 meters above mean sea level (figure 3.2). The mountain ridge in the south-east of the town is called Abaro ridge. The urbanized area of the town is slightly dissected by numerous valleys formed by the four major river systems crossing the city from south-east to north-west.

The catchment areas of the rivers crossing Shashamanne are, on the one-hand characterized by the large urban area of the town and on the other-hand, cultivated area, woodland and grassland are found at the banks of the rivers. The southern part (Essa and Gogeti river basins) is mostly covered with grassland. The northern part (Malka-oda and Dhadhaba sub-watersheds) is more or less covered with woodland, but a certain part is intensively cultivated land and the urbanization is closed to the basin boundary and expands further (plate 1).

Plate 1. Partial view of Essa River catchment areas, and anthropogenic activities.
Photo by author (23-01-2012)

Thematic maps in figure 3.2 reveal some of the general physical characteristics of the study area. As it is evident from the maps, the slope of the area ranges from 0 (flat) to 20 (steep) degrees. The drainage pattern is dendritic with flow direction from south-east to north-west along elevation orientation. The micro watersheds delineate the catchment areas of the major rivers, which drain into Lake Shala Basin, located 50 km away in the north-west part of the town. Evidence from (OUPI, 2010) show that the drainage pattern of the river is the result of the geological events of the tertiary period of Cenozoic era.

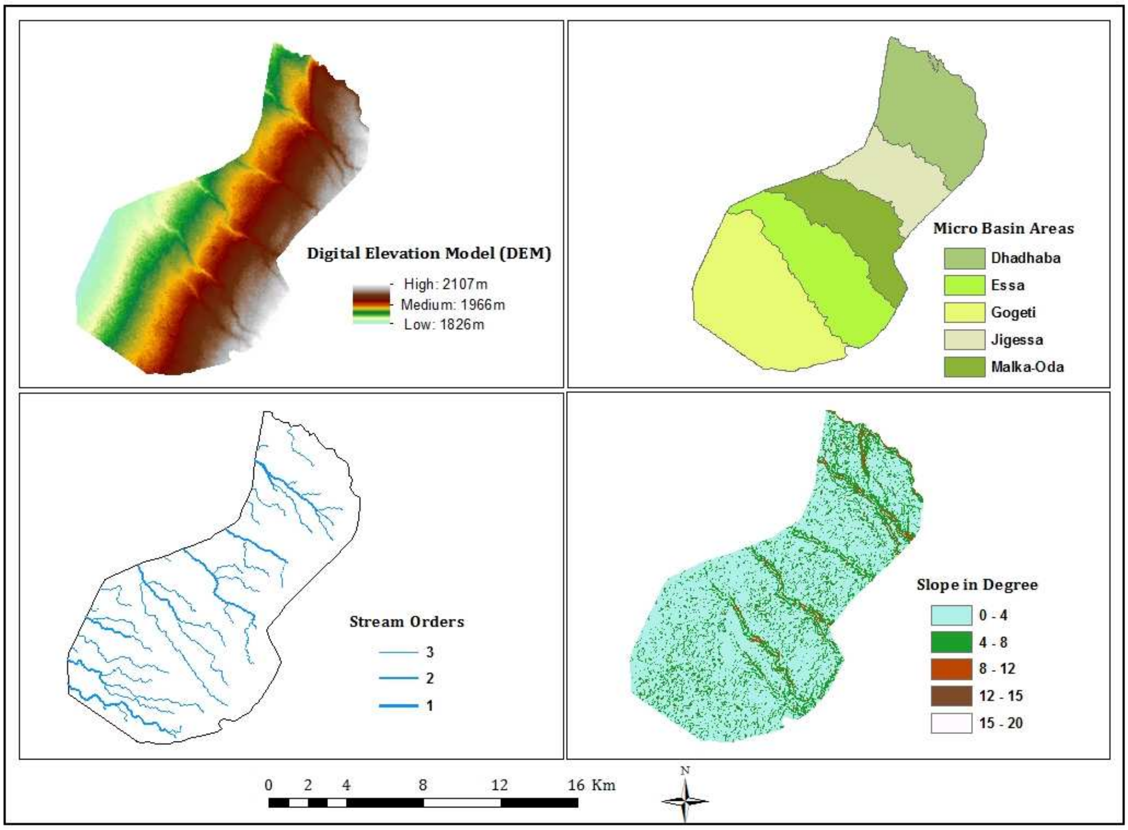

Figure 3.2 Map showing major physiographies of Shashamanne Town.

The **climate** in Shashamanne is characterized by the average maximum and minimum temperature of 24.3°C in May and 7.5°C in December, respectively. The average annual rainfall in Shashamanne amounts to 1200mm. The main wet season takes place from June to September, causing about 70% of annual rainfall with the highest peak in August. Another small peak of rainfall is observed in April (OUPI, 2010).

According to OUPI, 2010, **geologically**, the largest part of Shashamanne Town is covered with volcanic material. The hill chain (Abaro) in the south-eastern part of the town is composed of basalts, and it is covered with volcanic topsoil materials of about one to two meters thick.

3.1.3 Demographic Description

Evidences from the available literature show that the fast growth of Shashamanne's population has been observed since the 1990s, with an annual growth rate of 6%. This can partly be attributed to population growth due to higher migration from rural areas to the town rather than the natural increase of (2.9%), and the population in the town was 102,062 (51,477 male and 50,585 female) (CSA, 2007). Because of demographic uncertainties, such as high net migration, and natural population increment, currently, the exact number of inhabitants is not really known. However, when projected using 6% annual growth rate, the town's total population in the structure plan were 240,540 inhabitants in 2011. This figure encompasses 13,946 residents from the former Kuyera Town, the current sub-city of Shashamanne, and 85,693 occupants from peasant administrations (PA) adjacent to the urban periphery that were incorporated into the town vicinity during planning. According to the projection by OUPI, Shashamanne is expected to host 295,898 inhabitants by 2020 (OUPI, 2010). Table 3.1 presents population of the town by administrative divisions for the years 2007 and 2011.

The rapid growth of population of the city has put great pressure on the demand for urban spaces. In response to this demand, efforts are being made by the town administrative to incorporate the peripheral areas of the town, which is resulting in hastening the sprawl of the built-up area of the vicinity. Being one of the major centers of conurbation in the southern Oromia, and a hub for commercial activities, the town has significant economic importance. The majority of the land use pattern consists of built-up areas (residential, industrial, commercial, institutional, recreation area, road, infrastructure, and utilities) and non-built (agriculture, forest, bare land, and water bodies).

Table3.1. Population of Shashamanne by administrative divisions.

Shashamanne's Population by Sub-city								
Sub-city	Population 2007 (CSA, 2007)				Population 2011 (projected)			
	No of HH	Total	Male	Fem.	No of HH	Total	Male	Fem.
Awasho	2582	12,907	6,557	6,350	3,722	18,615	9,456	9,159
Abosto	3016	15,079	7,619	7,460	3,943	19,716	9,956	9,760
Dida-Boke	2738	13,691	6,932	6,759	3,904	19,518	9,875	9,642
Bulchana	3079	15,396	7,557	7,839	4,314	21,571	10,591	10,980
Burka-Gudina	3235	16,177	8,194	7,983	4,476	22,382	11,347	11,035
Arada	2732	13,661	6,921	6,740	3,510	17,550	8,898	8,651
Alelu	3030	15,151	7,697	7,454	4,310	21,550	10,948	10,602
Kuyara	2118	10,586	5,414	5,172	2,789	13,946	71,26	6,820
Total	22530	112,648	56,891	55,757	30,969	154,847	78,198	76,649
Shashamanne's Population by PAs embedded in Structure Plan in 2010								
PA Name	Population 2007 (CSA, 2007)				Population 2011 (projected)			
	No of HH	Total	Male	Fem.	No of HH	Total	Male	Fem.
Maja- Dama	737	5,149	2,549	2,600	914	6,385	3,161	3,224
Bulchana-Danaba	866	5,327	2,478	2,849	1,074	6,605	3,073	3,533
Alelu-Ilu	1,004	4,745	2,381	2,364	1,245	5,884	2,952	2,931
Awasho-Dhanku	890	4,450	2,218	2,232	1,104	5,518	2,750	2,768
Idola-Burka	362	2,075	1,067	1,008	449	2,573	1,323	1,250
Alache-Harabate	807	7,263	3,284	3,979	1,001	9,006	4,072	4,934
Bute-Filicha	1,040	7,558	3,826	3,732	1,290	9,372	4,744	4,628
Karara-Filicha	1,114	10,300	4,990	5,310	1,381	12,772	6,188	6,584
Ilala-Qorke	1,103	7,723	3,822	3,901	1,368	9,577	4,739	4,837
Hagugata-kuni	629	4,404	2,200	2,204	780	5,461	2,728	2,733
Turufe-W/Elemoo	1,445	10,113	4,999	5,114	1,792	12,540	6,199	6,341
Total	9,997	69,107	33,814	3,5293	12,396	85,693	41,929	43,763

Source: Adopted from CSA, 2007 and projection by author, 2012.

These data were mainly used to describe, compare and analyze the pattern of urban sprawl using the population density layer (figure 3.3) with other parameters. This was because demographic characteristics of an area could affect the rate of urban sprawl.

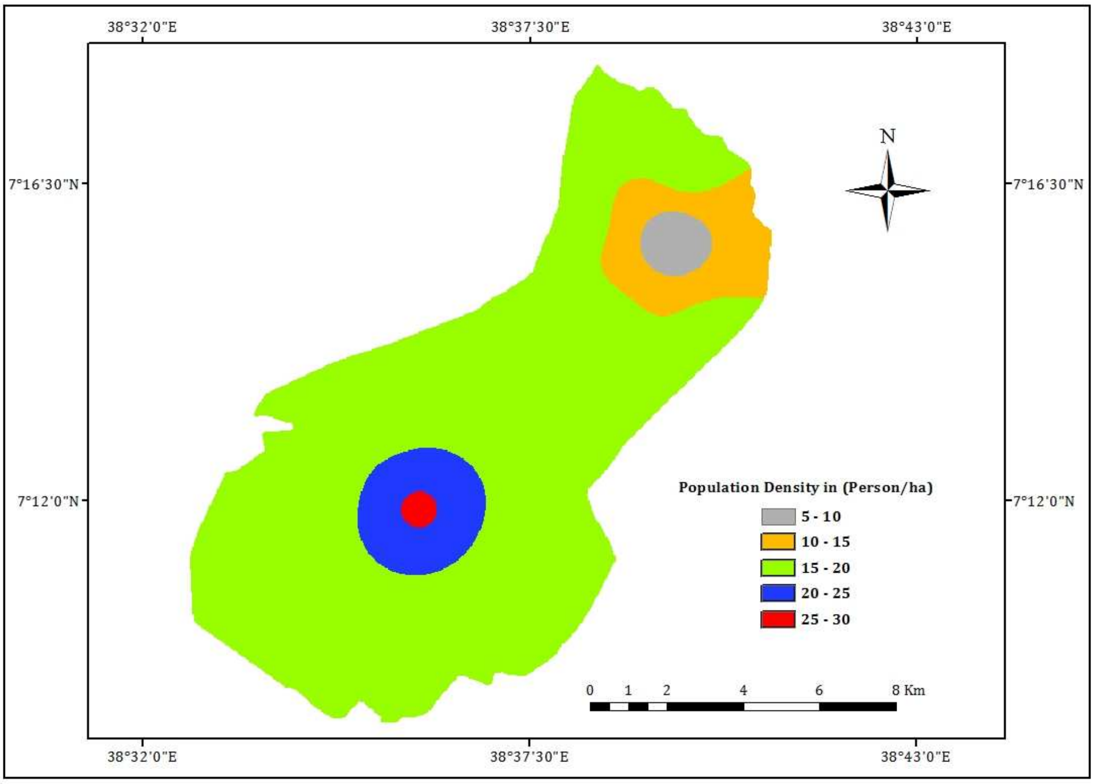

Figure 3.3. Population density map.

Source: *Interpolation from CSA, 2007 population data*

As far as the establishment history of the town is concerned, Shashamanne was formally founded as an urban settlement in 1915 (Ababu, 1997 and Benti, 1988). The town, which began with small trade during this period, gradually developed into a big commercial center as communication and transport net-works expanded. According to a document from the municipality, the town of Shashamanne first attained the municipal function in 1943, which was followed by the first developmental plan introduced in 1950/1. The second master-plan for the town was carried out in 1961/62. However, both the former and the latter plans were not implemented due respectively to the unavailability at the town level, and incompleteness of the plan itself. Therefore, as to OUPI, (2010) the complete master-plan for the town only began to be implemented in 1967. According to structure-plan employed by OUPI in 2009/10, the current boundary of Shashamanne includes many parts of the surrounding peasant administrations (PA) and Kuyera town, which became a sub-city of Shashamanne in 2009.

3.2 Data Sources and Methods

3.2.1 Data Sets and Sources

Landsat TM and ETM+ satellite data during 1986, 2000 and 2011 and DEM 30m were mainly utilized in this study. Landsat imageries were downloaded from the GLCF web site. The resolution of the images is 30 meters. Therefore, they are conducive for comparison of changes and patterns, which have occurred in the time under discussion, due to their constant spatial and spectral resolutions. These remotely sensed images were used and processed for identifying urban land use/land cover change as an indicator of sprawl patterns of the study area. In order to minimize seasonal vegetation differences and the effects of varying sun positions, the images that were acquired within the same approximate yearly time frame January and February (dry season in Ethiopia), were selected.

In addition, the ancillary data including the QuickBird, population data and structure plan supplied by the Oromia Urban Planning Institute were utilized. The characteristics of the satellite and other ancillary data, software and instruments used in this study are summarized in the table 3.2.

Table3.2. Characteristics of satellite data, Software and Instruments.

Sensor	WRS: P/R	Spatial Resolution	Acquisition date	Sources
Landsat4/5 TM	2:168/055	30m	1986 /01/21	GLCF;ESDI
Landsat7 ETM+	2:168/055	30m, pan15m	2000/02/05	GLCF;ESDI
Landsat7 ETM+	2:168/055	30m	2011/01/10	USGS data portal
QuickBird	-	2.5m, pan 61cm	2005	OUPI
Population	-	-	2007	CSA, 2008 report
Software	ArcGIS 10, ERDAS IMAGINE 9.2, IDRISI Andes and Global Mapper 12			AAU; GIS Lab and Open Sources
Instruments	GPS (GARMIN) and Digital Camera			Lend

The availability of multi-temporal data to produce land use/land cover changes is useful because it solves the problems associated with single dated land cover information. It also provides diverse changes which have occurred on the surface on different land use classes. Therefore, it is preferable to use multiple dated data type to detect the dynamism of urban features. However, it is not easy to have multi-date data of the same time of the year, particularly, in tropical regions where cloud cover is common (Mas, 1999).

3.2.2 The Research Methods

There are a number of different kinds of methods, strategies and techniques to process input data so as to generate the required research output in an efficient and sufficient way with desired quality. In fact, the choices of general methodology and specific technical arrangements are largely guided by the availability of the desired input data, the quality of available information, the strength of logistic support including the software employed, the researcher's experience and skill to manipulate the data, as well as the necessary funds allocated for the task. In order to understand the dynamic phenomenon of urban sprawl, the basic requirement is the availability of information on land use/land cover change, urban sprawl pattern identification and demographic features (Cihlar and Jensen, 2003).

Data analysis for this study was started by geo-referencing the coordinate system for each GIS data layer thereby ensuring spatial consistency with demarked structure plan of the town of Shashamanne. Geo-referencing entailed making sure that all spatial data layers used the same coordinates of the map projection. Therefore, all the data sets were projected to WGS 1984 UTM Zone 37N to avoid image distortion and have the same geographic coordinate system. The spatial extent covering the entire Shashamanne Town was then extracted from the images using spatial analyst tool in ArcGIS. All GIS shapefiles were clipped in ArcMap using the 2010 Structure Plan boundary to ensure that all files covered the same area.

ERDAS IMAGINE 9.2, ArcGIS10 and IDRISI Andes were the principal Digital Image Processing software used in this study, to classify and reclassify the satellite images, produce various thematic layers, standardize sprawling variables and finally, generate the urban sprawl susceptibility map. Apart from these, slope and stream were generated from DEM 30m resolution in ArcGIS environments using spatial analyst tools: surface and hydrology, respectively. Major roads features were digitized in the QuickBird image. Distances from road networks and water bodies were then calculated in the ArcMap spatial analyst tool.

In this study, the post-classification comparison approach was employed for the detection of land use/land cover changes, by comparing independently produced classified land use/land cover maps. The main advantage of this method is its capability to provide descriptive information on the nature of changes that occur.

Finally, Weighted Overlay Analysis in ArcGIS to integrate data sets to map urban sprawl susceptibility was employed in this study. It was also important to know the characteristic features of each band of the landsat image. In this study various bands were composed to visualize the color scene of the features on the image (figure 3.4). True Color Composite images were created by combining the TM spectral bands that most closely resemble the true color of the features. A true color composite uses the visible red (band 3), visible green (band 2), and visible blue (band 1) channels to create an image that is very close to what a person would expect to see in a photograph of the same scene. Another band composition employed for this study was False Color Composite (4, 3, 2), which eliminates the visible blue band and uses a Near Infrared (NIR) (band 4) to produce the image. The resulting composite does not resemble what the "True Color" looks like. Thus, the study comprised band 1, 2, 3, and 4 to detect land use changes of the study area for the years 1986, 2000 and 2011.

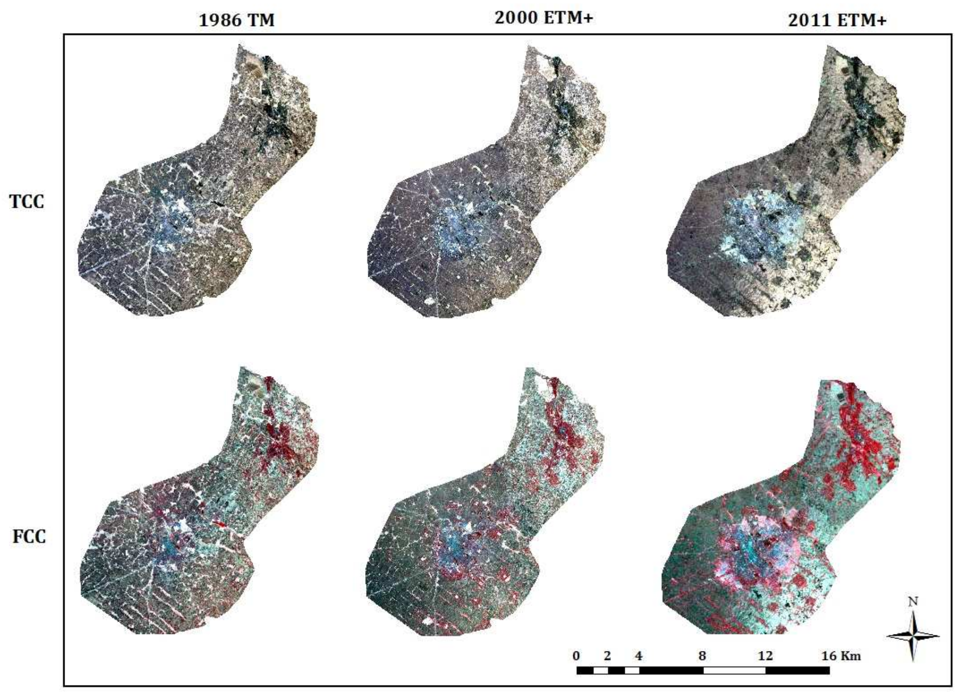

Figure 3.4. True color and false color composites of Landsat Imageries.

The flow diagram (figure 3.5) summarizes the overall methods, techniques and approaches used to carry out this study, so as to figure out the land use/land cover changes and predict the urban sprawl susceptibility areas and its implication on the peri-urban non-built up areas.

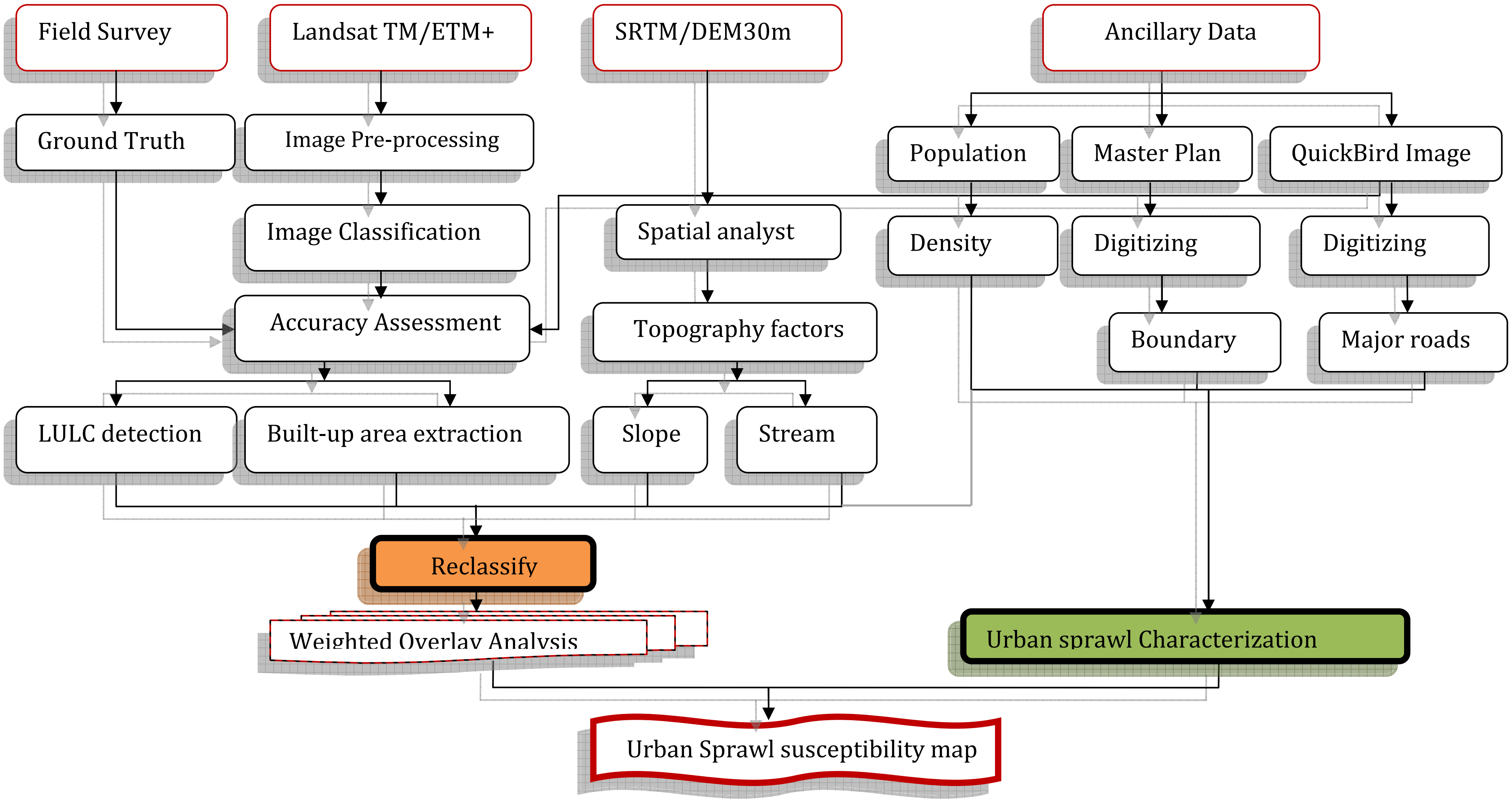

Figure 3.5. Methodology flowchart.

3.2.3 Characterization of Urban Sprawl

Urban sprawl has a variety of different patterns like fragmentation, leapfrogging, and discontinuous development, for instance. For urban sprawl, a clear and unique distinction requires justified rules in weighing up several components and indicators. In order to scientifically measure the extent of urban sprawl, many scholars and research institutions presented their "Sprawl index" (Jiang Fang *et al.*, 2007).

In this study, indicators adopted for urban sprawl (figure 3.6) were largely reflecting spatial features such as density of built-up area, land use/land cover change; reflecting the scale of growth such as the area or share of urban growth, reflecting growth speed such as temporal change, correlation between urban growth and population, and reflecting landscape configuration such as slope, streams and roads networks.

Considering the built-up area as a potential and fairly accurate parameter of urban sprawl, the built-up area was taken as an important indicator of measuring urban sprawl (Sudhira, *et al.*, 2004). The result of research by Fina and Siedento (2008) indicated three different types of indicators that can be used to measure urban sprawl, including density, pattern and surface indicators which cover the different dimensions of sprawl corresponding with environmental, social and economic impacts of urban land use change.

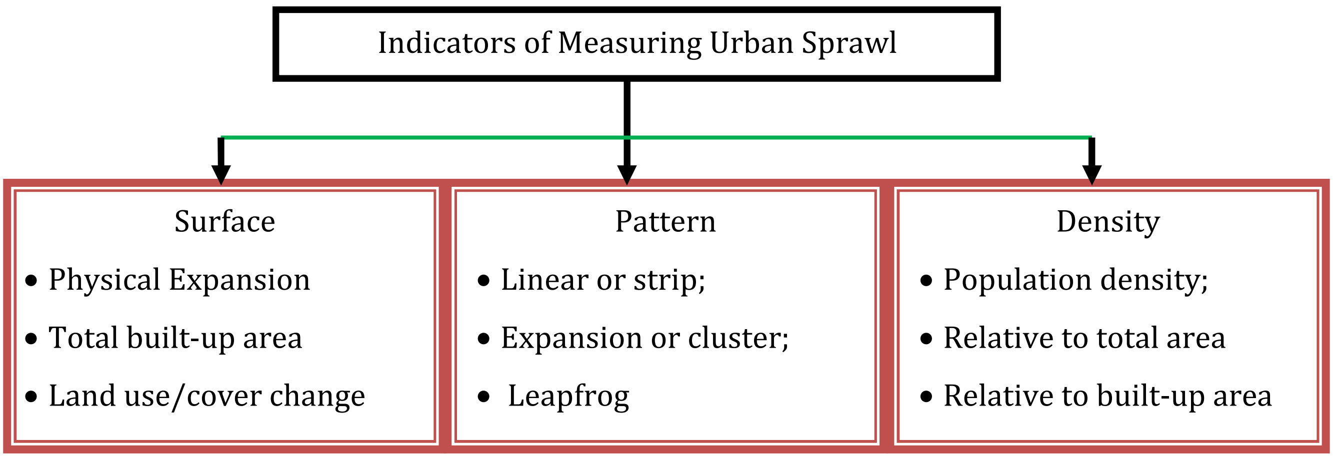

Figure 3.6. Parameters of urban sprawl characterization.

3.2.4 Land Use/Land Cover Description

In order to make sample collection and classification easy, land use/land cover nomenclatures are required to create and define the possible land use/land cover classes first. Although the focus of the paper was on built-up areas, the land use/land cover map of the study areas were first generated using land use/land cover classes presented in table 3.3.

The land use/land cover classes applied in this paper are adopted from AFRICOVER land use/land cover classification scheme which is widely applied in East African Countries (AFRICOVER, 2002). For the sake of simplicity, the researcher modified the descriptions of some of the land use/land cover classes considering the land use/land cover diversity of the study area. Therefore, four major land use/land cover nomenclatures: urban areas, agricultural lands, vegetated areas and bare fields were used to produce the final land use/land cover map of the study area.

Table 3.3. Land use/land cover classes and description.

No.	**Land use/land cover**	**Descriptions based on the AFRICOVER land cover classes**
1	Urban/Built-up Areas	Continuous and discontinuous urban fabric, Residential, industrial and commercial units, road and railway networks and other associated lands.
2	Agricultural Lands	Irrigated and rain fed arable lands, crop land with permanent crops, farming and fallow fields
3	Vegetated Areas	Natural and manmade forests, natural grasslands, woodland shrubs, sparsely planted trees.
4	Bare Fields/others	All vacant spaces, sands, rocky areas

Because of the major objective of this study, these nomenclatures were further merged and regrouped as built-up and non built-up classes (Table 3.4). This helped the analyst to discuss and analyze the extent and pattern of urban sprawl. This helped to categorize the heterogeneous nature of different classes under certain major categories. However, it was not an easy task to distinguish similar spectral values of the features in urban centers; it was an unavoidable factor which could distort the accuracy of classification.

Table 3.4. Regrouped land use/land cover classes and description.

No	Classes	Classes Description
1	Built-up Areas	Comprises commercial, residential, road and impervious features, Continuous and discontinuous urban fabric, Bus stations, road networks and other associated lands, construction sites,
2	Non-Built-up Areas	Irrigated and rain fed arable lands, crop land with permanent crops, farming and fallow fields, Natural and manmade forests, natural grasslands, woodland shrubs, sparsely planted trees, sands and rocks. Sport and Leisure facilities are also categorized under this class

3.2.5 Training Site Selection for Image Classification

Supervised classification was used, in this study, to cluster pixels in data sets into classes corresponding to user defined training classes. This classification type requires selecting training areas for use as the basis for classification. Of the most common supervised classification techniques, maximum Likelihood Classifier (MLC) for parametric rule was applied. Having prior acquaintance with the study area, in the present study, GARMIN GPS provided from West Arsi Zone Agriculture Office was used to collect representative points of various land cover classes during the field visit. Apart from identifying land use/land cover classes, these points were used to validate similar spectral response confusions created by different spatial features, like for example, the tree canopy and settlement roofing materials.

3.3 Data Analysis

3.3.1 Images Classification Paradigm for Image Analysis

Remote Sensing research focusing on image classification has attracted the attention of many researchers (Lu and Weng, 2007) and a number of studies have been conducted using different classification algorithms. It should be noted that valuable surface information extraction and analysis is also well performed using image classification. Image classification is the process of assigning pixels of continuous raster image to predefined land cover classes. It is a complex and time consuming process, and the result of classification is likely to be affected by various factors (e.g. nature of input images, classification methods, algorithm, etc). In order to improve the classification accuracy, therefore, selection of appropriate classification method is required. This would also enable analyst to detect changes successfully. In various empirical studies, different classification methods are discussed and figure 3.7 summarizes the different types of classification techniques using different criteria for categorization. Two classification paradigms: pixel and object-based as well as advanced classification approaches are discussed below in brief.

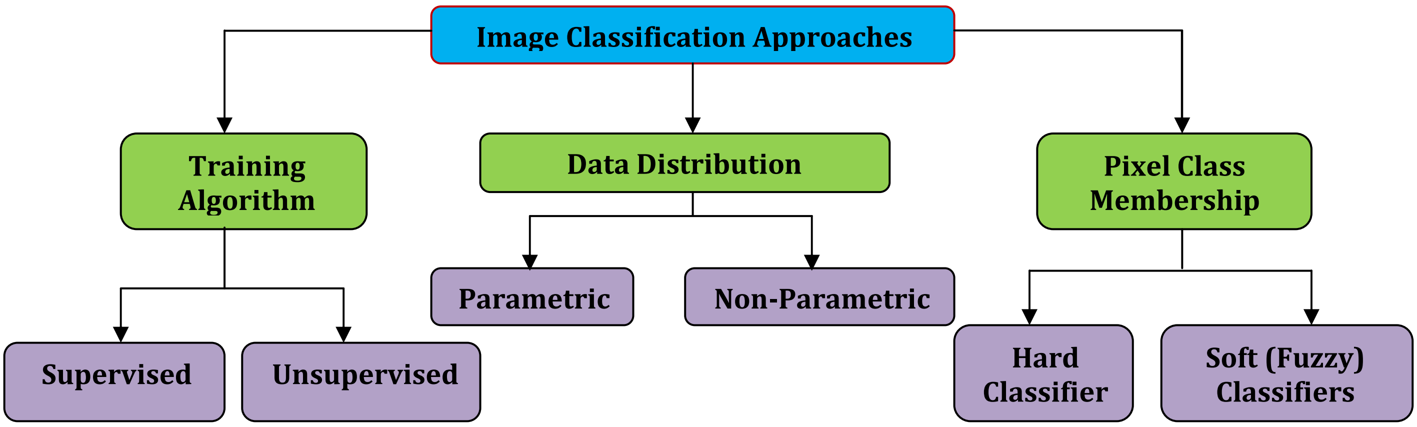

Figure 3.7. Image Classification Methods.

3.3.1.1 Pixel-based Paradigm

In this method, each pixel is classified based on the spatial arrangement of edge features in its local neighborhood (Im *et al.,* 2008). Image classification at pixel level could be supervised or unsupervised; parametric and hard classifiers. In a supervised classification method (e.g. maximum likelihood), the analyst is responsible for training the algorithm.

Input from the analyst is very limited in an unsupervised method i.e. specifying the number of clusters and labeling the classes. The statistical properties of training datasets from ground reference data are typically used to estimate the probability density functions of the classes (Santos *et al.*, 2006). Each unknown pixel is then assigned to the class with the highest probability at the pixel location. However, a pixel-based method is associated with the mixed-pixel problem and it might not clearly show the required classes of interest, although they are the most commonly used technique. Hence, detecting changes using this approach may not be effective.

3.3.1.2 Object-based Paradigm

The advent of object-oriented approaches provides a tool for mapping detailed land uses (Mori *et al.*, 2004). This approach considers groups of pixels and the geometric properties of image objects. It segments the images into homogenous regions based on neighboring pixels' spectral and spatial properties. It is based on a supervised maximum likelihood classification. Thus, an object-oriented method has been applied in this project to avoid the mixed pixel problems. The overall procedure is described below.

3.3.1.3 Advanced classification approaches

Recently, various advanced image classification approaches have been widely used (Lu and Weng, 2007). These include artificial neural networks, fuzzy-set theory decision tree classifier, etc. The pixel-based approach is referred to as a "hard" classification approach and each pixel is forced to show membership only to a single class. The "soft" classification approach is thus developed as an alternative because of its ability to deal with mixed pixels. The soft classification method provides more information and produces potentially a more accurate result (Jensen *et al.,* 2005).

3.3.2 Image classification and validation techniques used

Analysis of the literature reviewed and the analyst's personal experiences revealed that pixel-based classification produces inconsistent "salt and pepper" output. This is true not only with coarse resolution images but also with fine resolution images (e.g. QuickBird). Recent studies indicate that an alternative object-oriented approach produces better and more effective results than the pixel-based does. This is because the world is not pixelated rather it is arranged in objects. The object-oriented processing technique segments the images into homogenous regions based on the neighboring pixels' spectral and spatial properties. Image analysis techniques that consider both the measured reflectance values and neighborhood relations (object-oriented analysis) are available in ERDAS and GIS software packages. Such object-based schemes are essential for urban growth studies (Moeller *et al.,* 2004).

In this study, the ERDAS IMAGINE 9.2 software was used to classify the Landsat images. It has the capabilities to collect training samples and classify. It also supports different methods to train the algorithm and build up resource, and knowledge-based image classification. ArcMap was used to perform mapping operations and sprawl susceptibility analysis. The object-oriented classification method for change detection holds much promise (Civco *et al.*, 2002). Moreover, object-based analysis offers great potential and opportunities for identifying and characterizing LULC change processes.

Land use classification requires a classification scheme and algorithms. As mentioned above, the AFRICOVER land use/land cover classification scheme was applied to define the land use/land cover classes of the study area. In order to facilitate the task of mapping relatively homogeneous areas over different time periods to enable spatio-temporal analysis, geospatial tools are very essential. The presence of multi-temporal satellite data also provided an opportunity to generate land use/land cover maps of the areas to observe the changes in urban characteristics. Figure 3.8 was derived using an object-oriented image analysis technique to detect, quantify and map the urban sprawl of the study area.

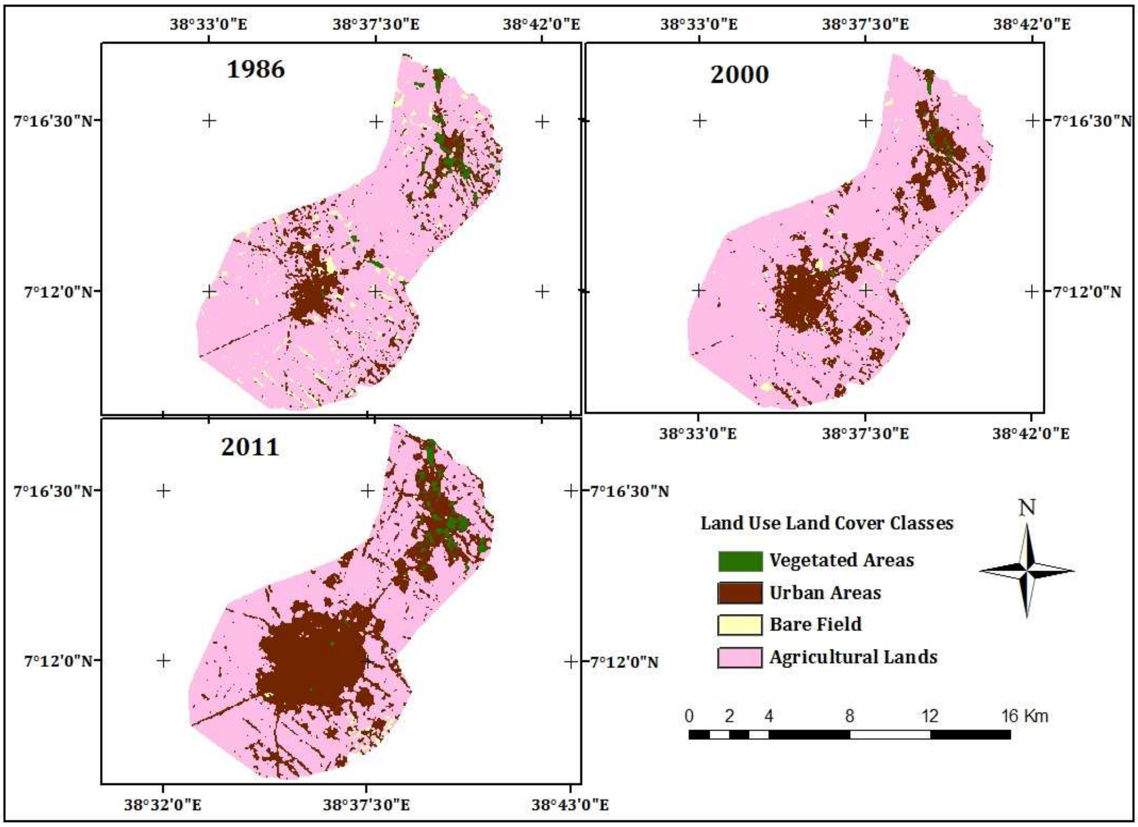

Figure 3.8. Land use/land cover map of the years 1986, 2000 and 2011.

Table3.5. Areas of land use/land cover for the years 1986, 2000 and 2011.

Land Cover	1986 (Area ha)	2000 (Area ha)	2011 (Area ha)
Vegetated Areas	462	162	416
Urban Areas	1977	2677	4329
Bare Field	728	261	176
Agricultural Lands	9701	9768	7947
Total	**12868**	**12868**	**12868**

Furthermore, in order to examine the nature and spatial extent of built-up areas, the LULC maps were also simplified into two broad classes (figure 3.9). This simplified graphic presentation enables direct visual comparisons of urban land use/built up area (alternatively used) change with respect to non-built up areas in the periods under discussion.

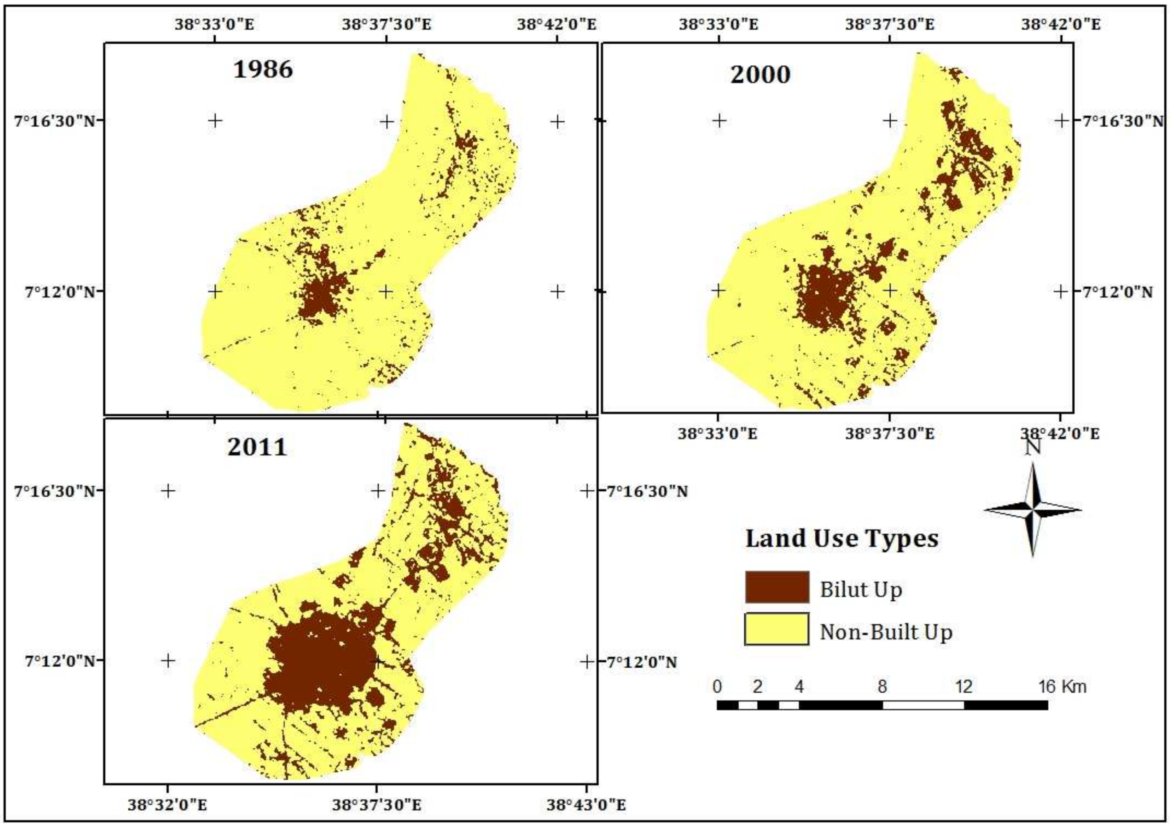

Figure 3.9. Built up and non-built up areas during 1986, 2000 and 2011.

3.3.3 Image classification validation

Accuracy assessment is a process used to validate the accuracy of image classification by comparing the classified map with a reference data (Caetano *et al.,* 2005). It is critical for a map generated from any remote sensing data. Although accuracy assessment is important for traditional photographic remote sensing techniques, with the advent of more advanced digital satellite remote sensing the necessity and possibility of performing advanced accuracy assessment have received new interest (Congalton, 1991). Currently, accuracy assessment is considered as an integral part of any image classification. This is because image classification using different classification algorithms may classify pixels or group of pixels to the wrong classes. The most obvious types of error that occurs in image classifications are errors of omission or commission. In order to use the derived land use/land cover maps for further change analysis, the errors need to be quantified and evaluated in terms of classification accuracy. The technique provides some statistical and analytical approaches to examine the accuracy of the classification. Kappa's Coefficient, which is one of the most popular measures in addressing the difference between the actual agreement and change agreement, was also calculated from the error matrix. The reference data used for accuracy assessment are usually obtained from aerial photographs, high resolution images (e.g. Ikonos and QuickBird), and field observations.

In this study, the assessment was carried out using QuickBird image and ground truth points from field observations as the major sources of reference data. A set of reference points has to be generated to assess accuracy and stratified random points were generated for each derived maps. These points were verified and labeled against reference data i.e. ground truth and QuickBird image (figure 3.10).

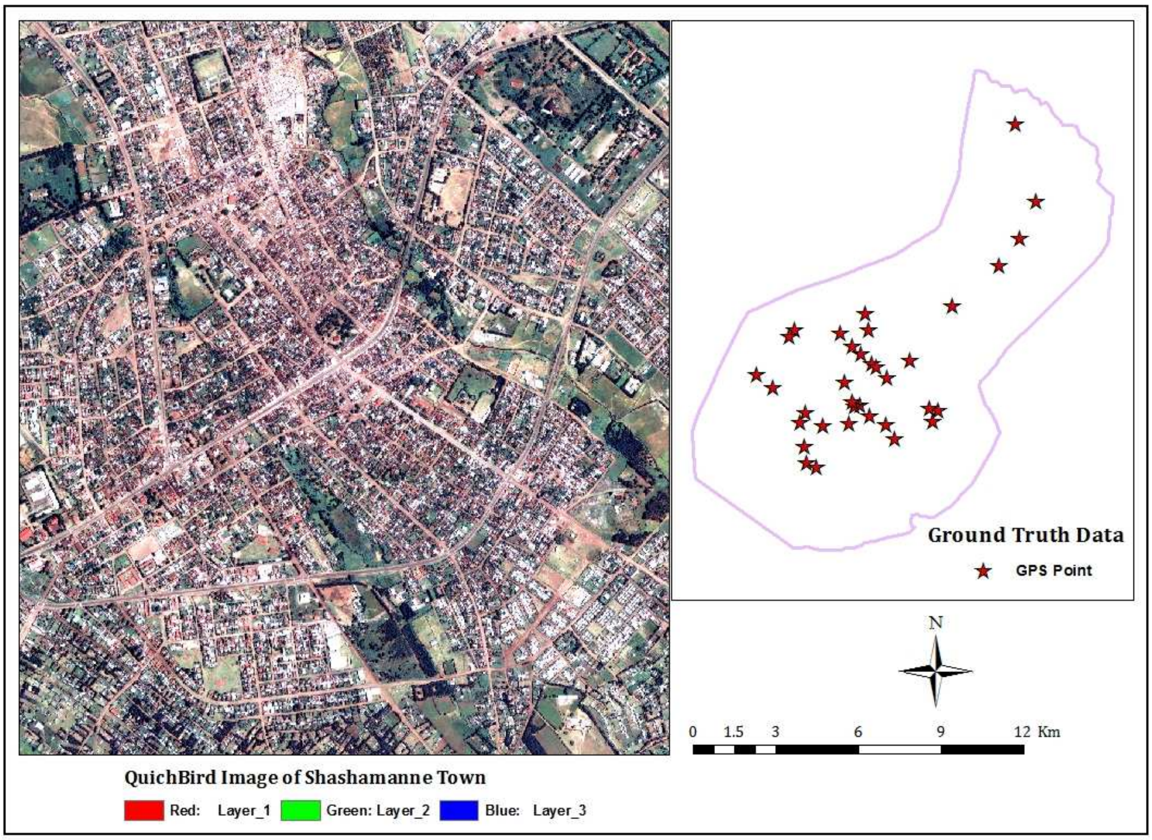

Figure 3.10. QuickBird image and GPS points.

The overall, user's and producer's accuracies, and the Kappa statistic were then calculated from the error matrices (table 3.6) and followed by a brief explanation of each type of accuracies and Kappa statistic.

Table3.6. Error matrices of land use/land cover maps derived from Landsat data.

	Reference Data							
	(a) 1986 (TM)						Producer's Accuracy %	User's accuracy %
	Data	1	2	3	4	Total		
Classified Map	1	94	5	2	0	101	83	93
	2	6	113	4	0	123	93	92
	3	10	4	80	2	96	88	83
	4	3	0	5	53	61	96	87
	Total	113	122	91	55	381		
	Overall Accuracy 89 %, Kappa Statistic 0.85							
	(b) 2000 (ETM+)							
	1	100	3	2	7	112	81	89
	2	6	91	7	3	107	93	85
	3	10	4	97	2	113	84	86
	4	7	0	9	103	119	90	87
	Total	123	98	115	115	451		
	Overall Accuracy 87%, Kappa Statistic 0.82							
	(c) 2011 (TM)							
	1	94	3	2	7	106	80	89
	2	6	100	7	3	116	93	86
	3	10	4	91	2	107	83	85
	4	7	0	9	77	93	87	83
	Total	117	107	109	89	422		
	Overall Accuracy 86%, Kappa Statistic 0.81							

1, Urban/built-up areas; 2, Agricultural lands; 3, Vegetated areas; 4, Bare fields

3.3.3.1 Overall Accuracy

This is computed by dividing the total correct number of pixels (i.e. summation of the diagonal) to the total number of pixels in the matrix (grand total). It can be expressed by $\mathbf{X_{ii}}$ and $\mathbf{N}$ as:

$$\textbf{Overall Accuracy} = \Sigma X_{ii} / \mathbb{N}$$

Where, X_{ii} = Number of correctly classified pixels, or the diagonal value and

N= entire number of pixels in the matrix.

Various standard threshold levels were applied to the lower and higher tail of each distribution, in order to find the threshold value that produced the highest change classification accuracy (Mas, 1999). In some empirical studies (Anderson *et al.,* 1976), it is noted that a minimum accuracy value of 85% is required for effective and reliable land cover change analysis and modeling. However, another author (Bedru, 2006) pointed out that the expected accuracy threshold is usually determined by the users themselves depending on the type of application the map product will be used for later. Depending upon the purpose of the land cover map, different people use different accuracy levels. The present study's confusion matrix of all the derived land use/land cover maps has revealed the overall accuracy levels of more than the minimum accuracy threshold defined by Anderson.

3.3.3.2 Producer's Accuracy

This refers to the probability of a reference pixel being classified correctly. It is also known as omission error because it only gives the proportion of the correctly classified pixels. It is obtained by dividing the number of correctly classified pixels in the category by the total number of pixels of the category in the reference data. The result of this work revealed that the lower producer's accuracies exist in the land use classes "urban areas" and "vegetated lands". This is probably attributed to the similar spectral properties of some of the features in these land use/land cover classes with others (e.g. bare land with urban areas, urban areas with vegetated lands and agriculture during the dry season with bare land).

3.3.3.3 User's Accuracy

This presents the probability that the pixels in the classified map or image represent that class on the ground (Congalton, 1991). It is obtained by dividing the total number of correctly classified pixels in the category by the total number of pixels on the classified data. In the present study, from the user's accuracy point of view, vegetated areas and bare fields presented low accuracy in the study years on average. This implies that "vegetated areas" and "bare fields" were, to some extent, misclassified as "urban areas" and "agricultural land", respectively. This is probably caused by the spectral signature of the features, particularly the nature of tree canopies in the study area.

3.3.3.4 Kappa Coefficient

The Kappa coefficient, which is a measure of agreement, can also be used to assess the classification accuracy. It expresses the proportionate reduction in error generated by a classification process compared with the error of a completely random classification (Congalton, 1991). The Kappa statistic incorporates the off-diagonal elements of the error matrices (i.e., classification errors) and represents agreement obtained after removing the proportion of agreement that could be expected to occur by chance. The Kappa coefficient (K) is calculated using the information in tables 3.6 and the following formula given by Congalton, 1991.

$$K = \frac{N\sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r}(X_{i+} \times X_{i+1})}{N^2 - \sum_{i=1}^{r}(X_{i+} \times X_{i+1})}$$

(Adopted from Congalton, 1991)

Where: r = is the number of rows in the matrix; X_{ii} = is the number of observations in rows i and column i (along the major diagonal); X_{i+} = the marginal total of row i (right of the matrix); X_{i+1} are the marginal totals of column i (bottom of the matrix); N is the total number of observations.

It was calculated to be 0.85, 0.82 and 0.81 for the land use/land cover maps of 1986, 2000 and 2011, respectively. It is not uncommon that the Kappa coefficient appears to be low, giving the impression that the classification of remote sensing performed better than chance only by K point of proportion (Muzein, 2006). However, the results obtained from classification and the validation statistics for this study were higher than the minimum validation threshold defined. Therefore, it was reasonable to employ the derived maps for further change analysis and sprawl quantifying studies.

Even though satisfactory results were obtained from classification of Landsat images, there was a challenge of misclassification of one land use/land cover into another due to poor spatial resolution of the images and similar spectral response of different features (e.g. agricultural lands with bare field and corrugated roofs with tree canopies). To minimized this challenge I executed field observation and ground truth data collection for sample sites to arrive at the reasonable validation statistics. The ground truth points collected during field observation for selected sample sites are presented in the table 3.7 and a few sites were also plated as follows.

Table3.7. GPS Points.

No	Northing	Easting	LULC		Northing	Easting	LULC
1	798041.92	453437.45	Agriculture	17	796931.09	457619.20	Bare Field
2	794743.56	458447.77	Agriculture	18	795312.27	455804.60	Built Up
3	794091.63	457074.55	Agriculture	19	794947.71	456154.74	USH10
4	797804.94	453255.46	Agriculture	20	796841.16	456238.45	Vegetation
5	796437.92	452081.94	Agriculture	21	797170.43	455854.69	Vegetation
6	795952.02	452656.68	Agriculture	22	797441.60	455560.18	Bare Field
7	793233.55	453883.35	Agriculture	23	798036.51	456136.41	Vegetation
8	793088.39	454237.67	Agriculture	24	796719.14	456426.34	Vegetation
9	797927.81	455093.31	Agriculture	25	796314.83	456800.09	Built Up
10	798632.77	456011.35	Agriculture	26	795209.61	458352.56	Built Up
11	795119.54	458673.04	Agriculture	27	794619.91	456773.37	Built Up
12	805510.88	461445.67	Agriculture	28	795292.64	455620.26	Built Up
13	802696.92	462185.80	Built Up	29	795449.63	455538.78	Built Up
14	801366.01	461614.96	Built Up	30	796143.92	455248.22	Built Up
15	800383.20	460848.44	Built Up	31	795061.60	453861.80	Built Up
16	798908.39	459176.33	Built Up	32	794692.63	453653.60	Built Up

Sample Sites Profiles

The sample sites were mostly residential with a few industrial developments and community features that have been encroaching on peri-urban arable lands. Each of these developments has had somewhat different characteristics as far as sprawl patterns and community features are concerned. In central Shashamanne, the headquarter office of West Arsi Zone is a sampled as a community feature (plate 2). The other samples that were considered to represent examples of urban sprawl pattern as expansion, linear, leapfrog and cluster in various sites of the study area are respectively shown in plates 3, 4, 5 and 6. Plate 7 shows an example of urban sprawl encroachment on fertile agricultural land in Alelu-Ilu peasant administration.

Plate 2. West Arsi Zone Headquarter Office.

Photo by author: 07-04-2012

Plate 3. Industrial Zone expansion in Alelu Sub-city.

Photo by author: 07-04-2012

Plate 4. Linear urban sprawl pattern in Awasho Sub-city.

Photo by author: 07-04-2012

Plate 5. Leapfrog urban sprawl pattern in Awasho-Dhanku PA

Photo by author: 07-04-2012

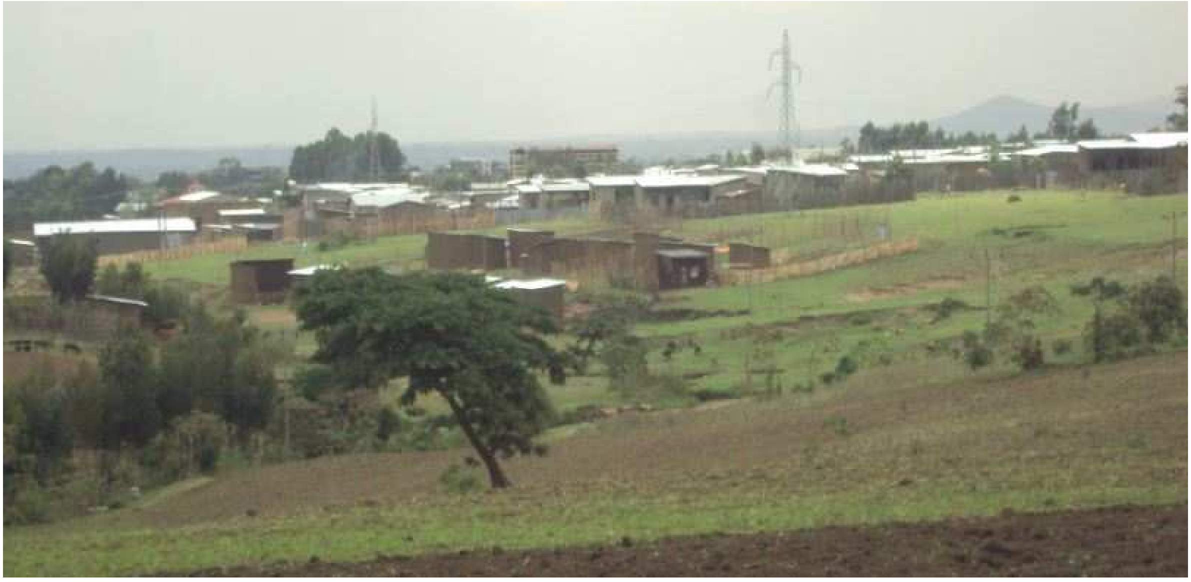

Plate 6. Cluster pattern of urban sprawl.

Photo by author: 08-04-2012

Plate 7. Urban encroachment on fertile agricultural land.

Photo by author: 08-04-2012

3.3.4 Urban Sprawl Measurement Using Shannon's Entropy

Many attempts have been made to measure sprawl (Leta *et al.*, 2001; Yeh and Li 2001; Sun *et al.*, 2007). One of the most commonly used approaches, in most urban sprawl studies, is to integrate Shannon's Entropy with GIS tools. This is relatively straight forward and efficient approach to analyze urban sprawl. Shannon's entropy is used to measure the degree of spatial concentration and dispersion of urban sprawl, defined by geographical variables (Leta *et al.*, 2001; Yeh and Li 2001; Sudhira *et al.*, 2004). The entropy value varies from 0 to 1. A minimum value of 0 is obtained if the distribution is maximally concentrated in one region while an evenly dispersed distribution across space gives a maximum value of 1.

The dispersion of built-up areas from a city centre or road network leads to an increase in the entropy value. This gives a clear idea to recognize whether land development is more dispersed or compact. The Shannon's entropy (En) is given by;

$$En = \sum_{i}^{n} P_i log(1/P_i)/log\ (n) \quad \text{.. (4.1)}$$

Where;

$Pi = Xi/\sum_{i}^{n} Xi$ and Xi is the density of land development, which equals the amount of built-up land divided by the total amount of land in the i^{th} zone in the total zone of n zones.

The number of zones means the number of buffer zones around the city center or around selected roads. Since entropy can be used to measure the distribution of a geographical phenomenon, the difference in entropy between two different periods of time can also be used to indicate the change in the degree of dispersal of land development or urban sprawl (Yeh and Li, 2001).

$$\Delta En = En(t+1) - En(t) \quad \text{.. (4.2)}$$

Where ΔEn is the difference of the entropy values between two time periods; En (t+1) is the entropy value at time period (t+1); En (t) is the relative entropy value at time period t.

In this study an attempt was made to measure urban sprawl during 1986, 2000 and 2011years using Shannon's entropy by considering two scenarios to calculate the entropy.

Scenario 1: 5 and 7 (figure 3.11) concentric buffer rings around two centers Kuyera and Shashamanne each having ½km were needed to cover all parts the sub-city and town respectively. This scenario treated the centers of Kuyera and Shashamanne separately.

Scenario 2: The 12 number of "peasant" administrative divisions in the study area were treated as a buffer zone between the two centers (figure 3.12).

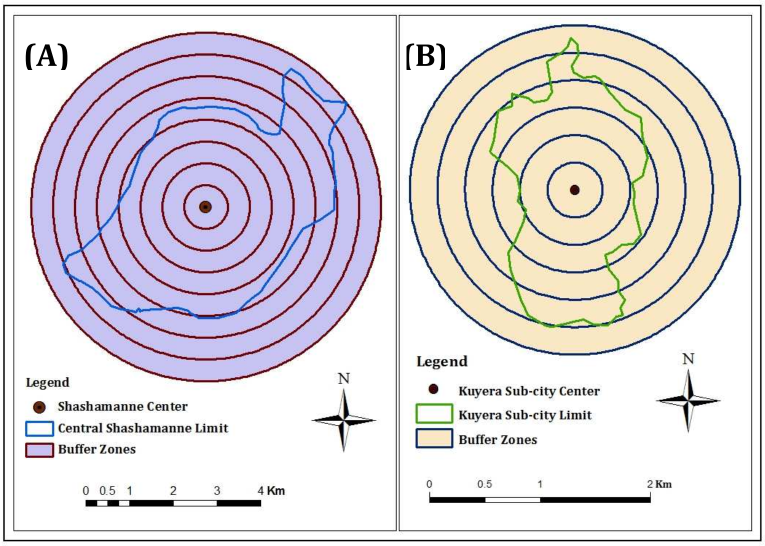

Figure 3.11 Buffer zones around Shashamanne (A) and Kuyera Sub-city (B) centers.

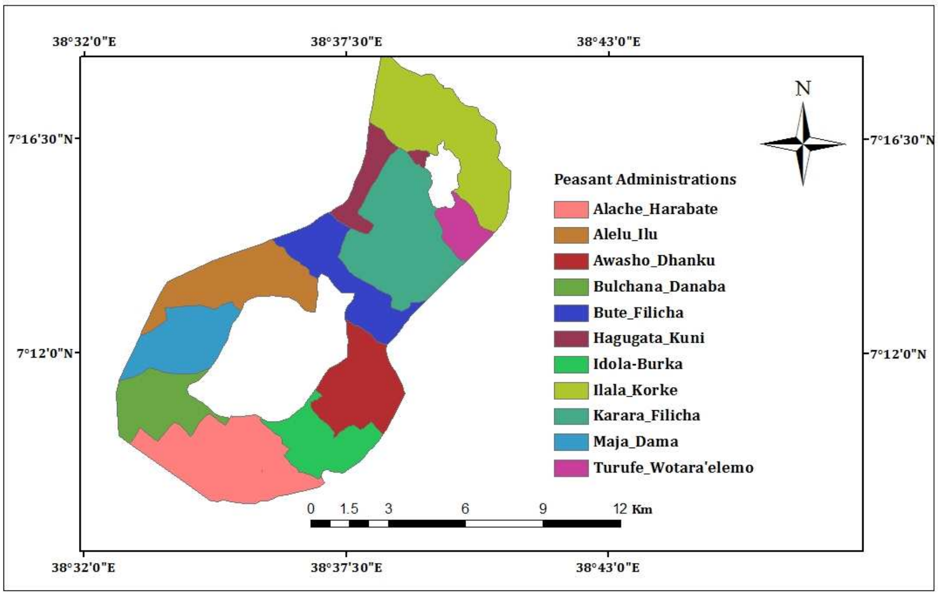

Figure 3.12. Peasant Administration divisions in Shashamanne Town's Structure Plan.

However, both scenarios have their own limitations; the buffer ring, for example, includes areas outside the study limit, though it is a good approach for measuring urban sprawl. The second scenario is likely to be affected by the size of the PAs.

Nonetheless, both scenarios were attempted to measure urban sprawl. Table 3.8 presents entropy values of the administrative divisions in the periods under discussion.

Table 3.8. Shannon's Entropy values during 1986, 2000 and 2011.

Administrative division	1986	2000	2011
Kuyera Sub City	0.73	0.83	0.88
Central Shashamanne	0.73	0.80	0.89
Surrounding PAs	0.88	0.91	0.94

Source: *computed using equation 4.1, concentric buffer zones and 12 "PAs".*

4. RESULTS AND DISCUSSION

4.1 Results

4.1.1 Land use/land cover changes as an indicator of Urban Sprawl

The results from satellite imagery analysis (table 4.1) indicated that 17% of the vegetated lands and 26% of barren land has been transformed into built up and agriculture land per annum during the period between 1986 and 2000. A drastic transformation per annum has been observed in the next eleven years between 2000 and 2011 when 129% of agricultural land and 6% of barren land has been converted into urban/built up area and this is evident from 117% rose per annum by the built up area during the same period of time. During this period, vegetation area has been raised by 18% due to two reasons: 1) the informal plantation of exotic trees (e.g. eucalyptus tree) around built up area and 2) the delusive spectral response of other spatial features with vegetation (e.g. roofing materials of settlement).

Table 4.1. Area and percentage rate of LULC change during 1986, 2000 and 2011.

Land use/land cover class	Area in ha & percentage during						Percentage rate of change per annum		
							1986 – 2000	**2000 – 2011**	**1986-2011**
	1986		**2000**		**2011**		**%**	**%**	**%**
Vegetated Areas	462 ha	4%	162ha	1%	416ha	3%	-17	+18	-1
Urban Areas	1977 ha	15%	2677ha	21%	4329ha	34%	+39	+117	+73
Bare Field	728 ha	6%	261ha	2%	176ha	1%	-26	-6	-17
Agricultural Lands	9701 ha	75%	9768ha	76%	7947ha	62%	+4	-129	-55
Total	12868 ha	100%	12868ha	100%	12868ha	100%	0	0	0

***Source**: Analysis of satellite imageries*

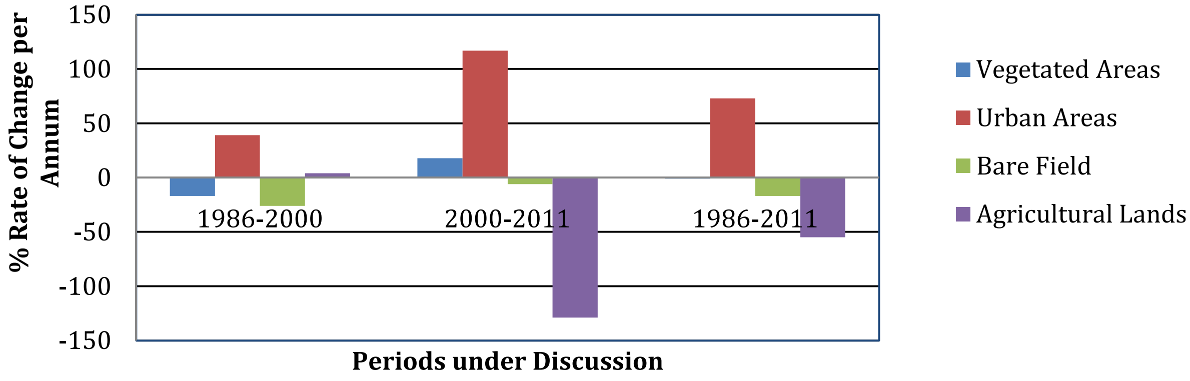

Figure 4. 1. Trends of LULC change in percent per annum between 1986 and 2011.

The summary of changes in trends of LULC for Shashamanne Town in (figure 4.1) and the visual comparison of built up and non-built up areas depicted in (figure 3.9 on page 39) have indicated the rate of encroachment of built up areas on other land uses has been rapid, with discontinuous patches of urban development characterizing urban sprawl. Viewed as a time series, the rates of land use/land cover changes have substantially been varied over the study period. Urban land/built up areas in Shashamanne Municipality has almost doubled during the period between 2000 and 2011. This can possibly be attributed to rapid socio-economic changes.

The periodic built up areas change maps in figure 4.2.was generate by overlaying the corresponding simplified LULC maps for clear observation of urban sprawl phenomena in the study area. These maps provide the reader with vivid impression of urban sprawl occurrence and gradual changes from non-built up to built up areas.

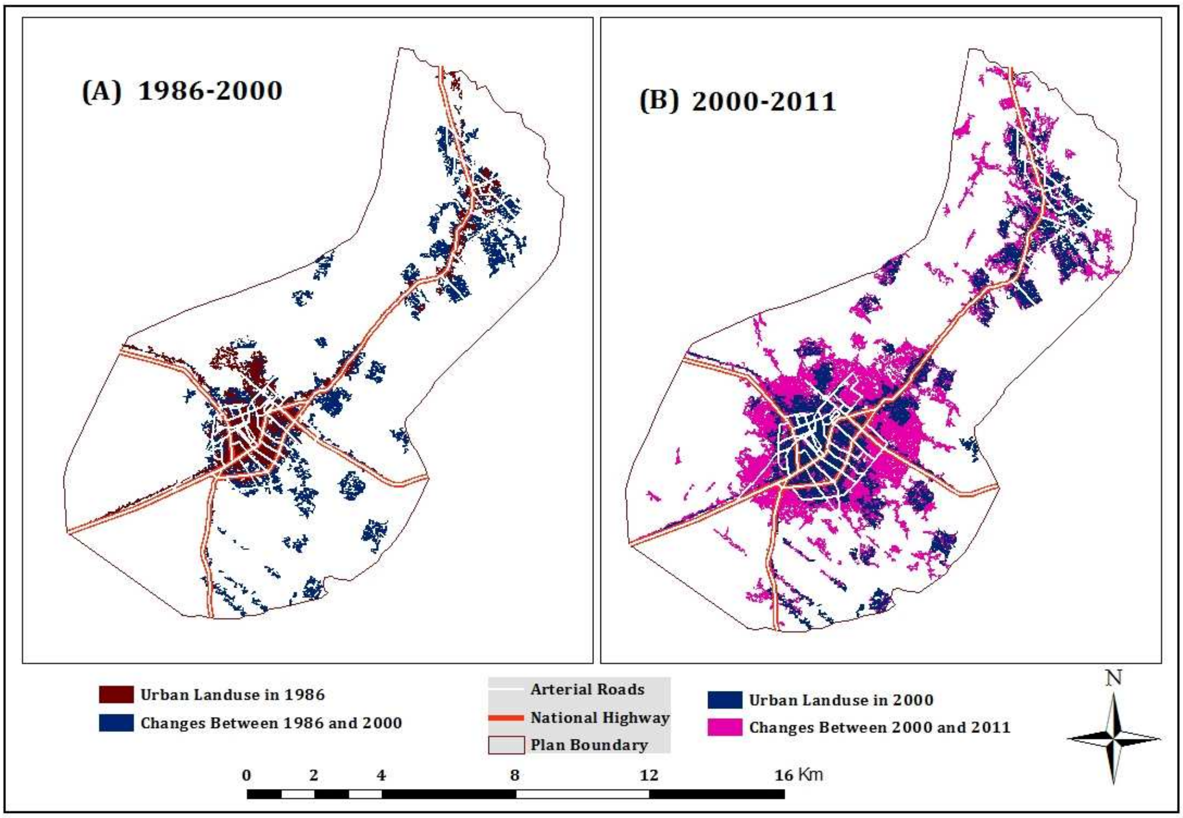

Figure 4.2. Built up area change map during 1986-2000 and 2000-2011 periods.

It has been noted that the expansion of the built-up area is predominantly at the expense of peri-urban agricultural lands, vegetated and barren areas. Preliminary results from the multi-date visual change detection indicate that urban land use has changed significantly over the period from 1986 to 2000 (figure 4.2, A) and the trend continued in the period from 2000 to 2011(figure 4.2, B). Notably, most of the changes occurred in the peripheries of the existing built up areas. Some of the observed types of change revealed by the study were urban expansion and densification.

The researcher's prior knowledge and current field observation coupled with the multi-temporal land use/land cover maps revealed that the town of Shashamanne has been expanding in almost all directions having unprecedented pattern of urban sprawl. Unlike the renowned urban sprawl patterns: linear or strip along highways, expansion or cluster, and leapfrog (Sudhira *et al.,* 2004), the sprawl pattern of Shashamanne Town has been observed so haphazardly irregular that I have termed it amoeboid. However, a major and significant scale of the town expansion direction is shown along the outlets to the Addis Ababa, Robe (Bale), Wondo, Hawassa and Arbaminch major roads (figure 4.3). Therefore, it is possible to conclude that the result from the image classification has indicated not only built up area tenancy change but also provided an estimate of the extent, pattern and direction of urban sprawl changes in the study site.

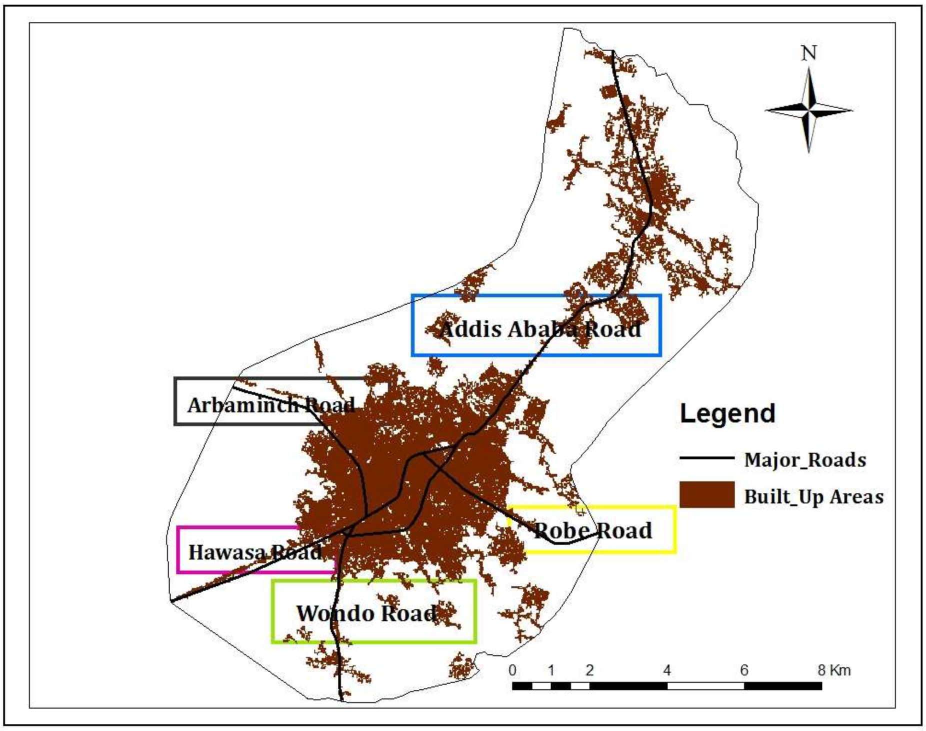

Figure 4.3. Urban sprawl expansion direction map of 2011.

As it is true for most urban centers in developing countries, the pattern of urban sprawl in this town has been characterized by horizontal expansion following the developments of roads, highways and other services' sites. Therefore, the sprawl pattern of Shashamanne has largely been influenced by the main roads development which are radiating to various provinces and zones of the country. Driven also by other factors like population growth and suitable topography, Shashamanne has been extending to all directions even though the overwhelming tendency has mainly been observed along roads (highways) connecting the town with the local towns and the capital city of the country.

4.1.2 Urban Sprawl Measurement Using Shannon's Entropy

The result obtained from entropy evaluation for the study area has indicated that all sites have undergone significant dispersed land development or urban sprawl during the considered periods. As it is evident from table 4.2, the entropy values during 1986, 2000 and 2011 for Kuyera, Central Shashamanne and "surrounding PAs" are above 0.50, indicating a high rate of the urban sprawl in the study area, in general. The entropy value for the year 2011, however, shows a highly dispersed development in both scenarios compared to the entropy values in 1986 and 2000.

A marginal increase in the level of sprawl (figure 4.4) also indicates the study site was continuing to sprawl between 1986 and 2011. Therefore, an increase in the entropy value in the vicinity of Shashamanne Town has clearly indicated an increase in urban sprawl and more dispersed development at the expense of peri-urban agricultural and other land uses.

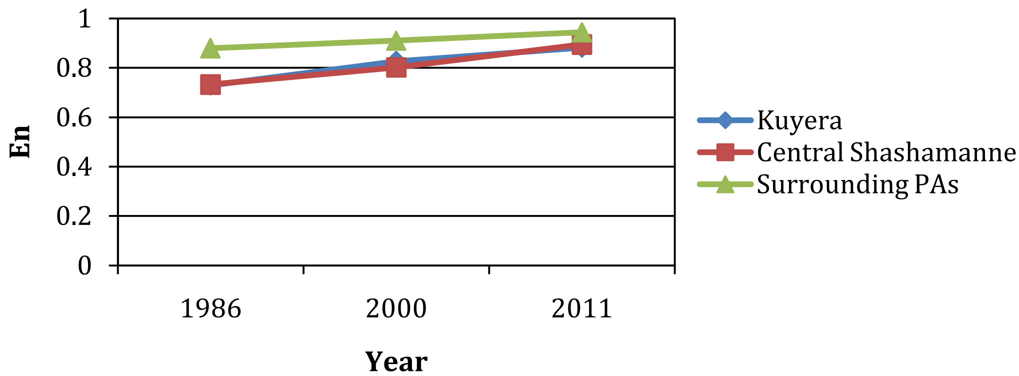

Figure 4.4. Entropy values of Shashamanne Town during 1986, 2000 and 2011.

Furthermore, the measurement of the difference in entropy between two time periods: (t) and t+1 was also obtained using Equation 4.2 to indicate the temporal change in the degree of dispersal of land development or urban sprawl. The change in the entropy values is given in table 4.3 and graphically represented in figure 4.5.

Table 4.2. Change in Entropy values between the pair of periods.

Administrative Divisions	ΔEn		
	Periods		
	1986-2000	2000-2011	1986-2011
Kuyera	0.097	0.069	0.153
Central Shashamanne	0.056	0.093	0.162
Surrounding PAs	0.031	0.033	0.064

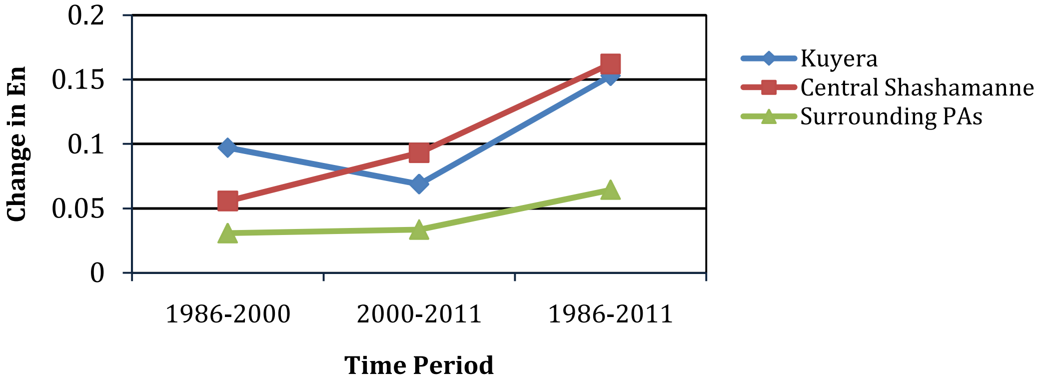

Figure 4.5. Change in entropy values in different pair of years.

It is evident from both table 4.2 and figure 4.5 that there is a significant entropy change in the last 25 years indicating the marginal increase of urban sprawl between 1986 and 2011. The increase of entropy values further indicates the dynamics of urban sprawl with spatio-temporal changes. It has also been noted that the rate of dispersion of urban sprawl in Kuyera sub-city is more extensive between 2000 and 2011 than it was between 1986 and 2000. The entropy difference in the "surrounding PAs" has shown a gradual increase implying urban sprawl or land development was unevenly distributed in the study area's outskirts. Therefore, the study proves that entropy is a good indicator for identifying the spatial dispersion or concentration of land development or urban sprawl.

4.1.3 Demography and Urban Sprawl of Shashamanne

Demographic change can affect social, economic, environmental and other factors in either negative or positive ways. More specifically, land is a base for all developments. Therefore, change in population growth accelerates the demand for land and the dynamics in land use/land cover change. In this study, the researcher was curious about the relationship between population growth and urban sprawl mainly focusing on average annual growth rate. Data presented in table 4.3 were compiled from statistical and census reports of CSA in various years (e.g. first count for the towns in 1967, the national population sample survey in 1970, and the national population and housing censuses of 1984, 1994 and 2007).

Table 4.3. Shashamanne's total population between the years 1967 to 2007.

Year	Total Population	Average Annual Growth Rate (%)
1967	16,410	Base year
1970	20,609	8.53
1972	21,293	1.66
1984	31,884	4.14
1987	36,067	4.37
1994	52,080	6.34
2007	102,062	7.38

Source: Compiled from CSA Statistical Reports and Censuses of various years.

Population size in the study area steadily rose up from 1967 to 2007(figure 4.6) with a variable growth rate per annum and the highest annual growth rate (8.53%) was registered between 1967 and 1970. This factor triggers the ever-growing demand for urban services: demand of land for residence, economic and industrial activities and other public services.

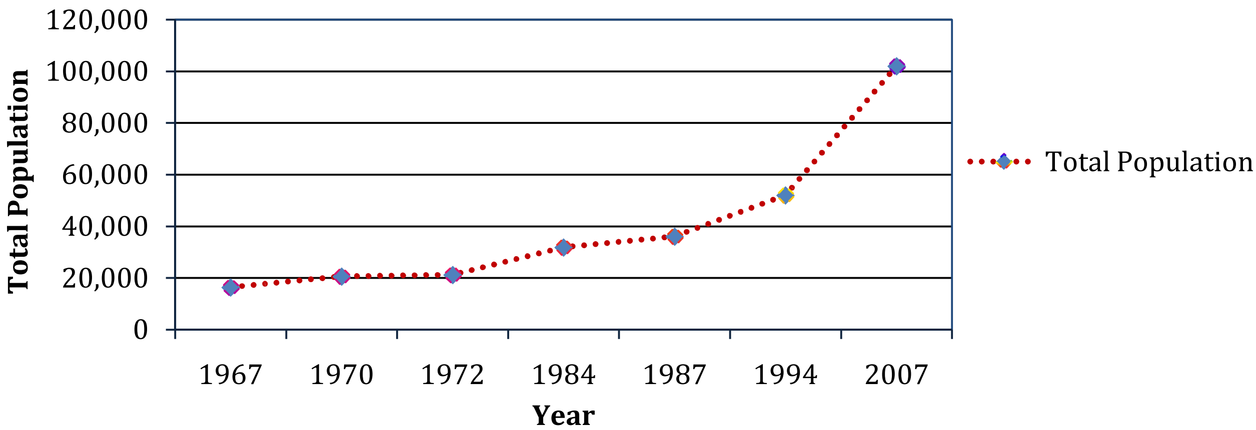

Figure 4.6. Population size of Shashamanne over 40 years.

In order to better understand the situation, the population density per administrative divisions in the study area was calculated considering two aspects: population density A and population density B. The population density A (table 4.4) is the population of the town region divided by the total area of the region and the population density B was calculated by dividing the population of the town areas to the built-up area of the major administrative division. This shows how much pressure has been given to the available land.

Table 4.4. Population size and built-up areas by administrative divisions.

	Administrative Division	Total area in ha	Area ha (built areas)	Pop. projected 2011	% of built-up area	Pop. Den. A (Pop./total area)	Pop. Den. B (Pop./built areas)
1	Kuyera	2,471	597	12,164	24	5	20
2	C/Shashamanne	4,957	3,943	130,094	80	26	33
3	Surrounding PAs	5,440	2,423	91,415	45	17	38
Total		12,868	6,963	233,673	54	18	34

Source: analysis of image (2011) and Population size projected from CSA, 2007 by the author

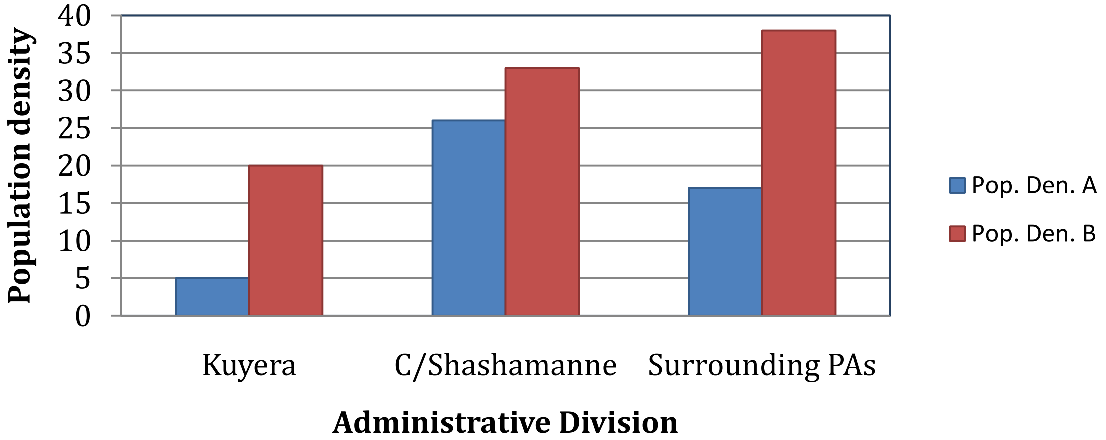

Figure 4.7. Density of population with respect to total and built-up areas.

The chart in figure 4.7 has illustrated that in all administrative sites the density of population with respect to built-up area (Pop.Den.B) has exceeded the crude density, i.e. the ratio of total population to the total area (Pop.Den.A). This implies that there is high pressure upon the existing built-up areas. In response to overcrowding, people's demand for further built-up areas becomes high, which has intensified urban sprawl in the study area. More importantly, the comparative analysis of both urban and population growth rate revealed that the percentage change in built-up (73%) was found to be very much higher than the percentage change in population growth (9.14%) during the discussion period characterizing typical urban sprawl feature.

4.1.4 Urban Sprawl Susceptibility of Shashamanne Town

4.1.4.1 Criteria Setting for Urban Sprawl Susceptibility Mapping

The relations of urban sprawl with the physico-social factors that determine its occurrence were used as criteria, which imply the governing factors of likely occurrence of sprawl episode, to select most susceptible zones in the study area. The factors such as existing built-up areas, distance from major road axis, slope gradient, population density and distance from water bodies and their property and implication to urban sprawl susceptibility (table 4.5) were considered in the analysis.

In order to determine lands susceptible to urban sprawl development, a set of criteria has to be determined and two types of criteria: constraints and factors have been used. All the criteria are expressed as raster images.

A) Constraints

There are many factors responsible for urban sprawl and urban land use change such as urbanization, population growth, industrialization and land allocation policy, to mention some. In spite of this, there are some constraints for the urban development. The most obvious constraints are topography, water bodies and existing urban/built up areas. Local administrators may also pose protection of urban development towards water bodies and preserved green areas (e.g. urban parks). However, in this case, two major constraints: water bodies and existing built-up areas were considered.

B) Factors

Unlike the constraints, factors define some degree of susceptibility. These criteria do not absolutely constrain development, but enhance or detract from the relative susceptibility of an area for urban development (Eastman, 2001). The criteria are often obtained from urban planners, administrators, environmentalist or legislation.

4.1.4.2 Ranking classes of factors

i. Land use factor: The present condition of land use/land cover influences the susceptibility of the study area to urban sprawl. This shows the spatial extent of land available for development of urban form. Therefore, high ranks are given to agricultural, vegetated and barren lands whereas the existing built up areas are assigned the least rank.

ii. Distance from road networks: the major road axis obtained from the QuickBird image by digitization was used and its effects are determined by the distance function. The influence of the road network is measured in terms of accessibility, and areas close to road access have greater probability to be changed into built up areas. This is because development closer to road reduces development costs.

iii. Slope: Slope of an area plays a major role in urban sprawl susceptibility. Slope steepness/gradient is important because it influences land development for urban form. Most often, urban development takes place in relatively flat areas rather than hilly ones. The study area is situated in a topographically low plain so the difference in elevation is minimal as the slope is very low. In order not to highly tradeoff the other factors, the weight given to the slope factor is low.

iv. Distance from water bodies: The proximity to water source has negative impact on development of built up area due to likely flooding and cost of construction. There is a distance limit set by urban planners from water body within which urban development is prohibited. This reveals that the more the parcels are close to the water bodies, the less is the susceptibility to change into urban use. Therefore, a low rank is give to proximity to rivers and the relatively high ranking with increasing distances away from water bodies.

v. Population density: Population as a major segment of urban sprawl force is indicative of the built up area expansion condition of urban form. The areas where the number of persons per unit area is higher are less prone to urban sprawl. In the area where the density is less there is more likely of occurrence of sprawl phenomenon. High ranks are given to low population density area and vice versa. Table 4.5 shows the factor maps, relative susceptibility and assigned ranks from 1 to 5 showing increasing urban sprawl susceptibility.

Table 4.5. Derived criteria maps and ranking for sprawl susceptibility analysis.

Factor	Rank	Relative susceptibility	Factor	Rank	Relative susceptibility
1.Distance from River			**4.Distance from roads**		
<50m	1	Restricted	<50m	5	Highly susceptible
>50m	5	Highly susceptible	50-500m	4	Moderately susceptible
2.LULC			500-1500m	3	Marginally susceptible
Agriculture	5	Highly susceptible	>1500m	2	Currently not susceptible
Vegetated	4	Moderately susceptible	**5. Slope**		
Built up	1	Restricted	0 –3	5	Highly susceptible
Bare field/others	3	Marginally susceptible	3 -7	4	Moderately susceptible
3.Population density			7 – 11	4	Moderately susceptible
5-15	5	Highly susceptible	11- 15	3	Marginally susceptible
15-25	4	Moderately susceptible	>15	2	Currently not susceptible
25-35	3	Marginally susceptible			
> 35	2	Currently not susceptible			

4.1.4.3 Standardization of factors

The selection of the parameters for standardization is subjective and depends on the analyst's knowledge and experience (Eastman, 2001). Table 4.6 describes the functions used for standardizing the variables.

Table 4.6. Standardization of variables.

Layer	Description
Land use/land cover factor	Based on the trend of land use change between 1986 and 2011, and visual interpretation of the changes; agricultural land, vegetated area and barren lands are considered as the possible land use types available for sprawl development while existing urban area is treated as completely not susceptible but as distance from built-up areas increases, its susceptibility decreases.
Distance from the major road factor	Areas within 500m from major road networks are considered susceptible while areas beyond 500m are less susceptible. It is stated that areas within 50m are the most susceptible.
Distance from water bodies factor	A protection buffer of 50m from the major rivers was created and areas within 50m of the water bodies are considered not susceptible while areas beyond 50 are susceptible and susceptibility increases with distance.
Slope factor	Areas that have low slopes (less than 15%) are highly susceptible for sprawl development while areas greater than 15% are less susceptible. Beyond 15%, susceptibility begins level off.
Population density factor	Areas that have low density (sparsely developed) are susceptible to sprawl phenomena whereas areas with high density (concentrated) are less susceptible.

A group of maps in the figure 4.10 shows the corresponding original and reclassified thematic layers derived after standardization of the criteria in a scale from 1 (the least susceptible) to 5 (the most susceptible).

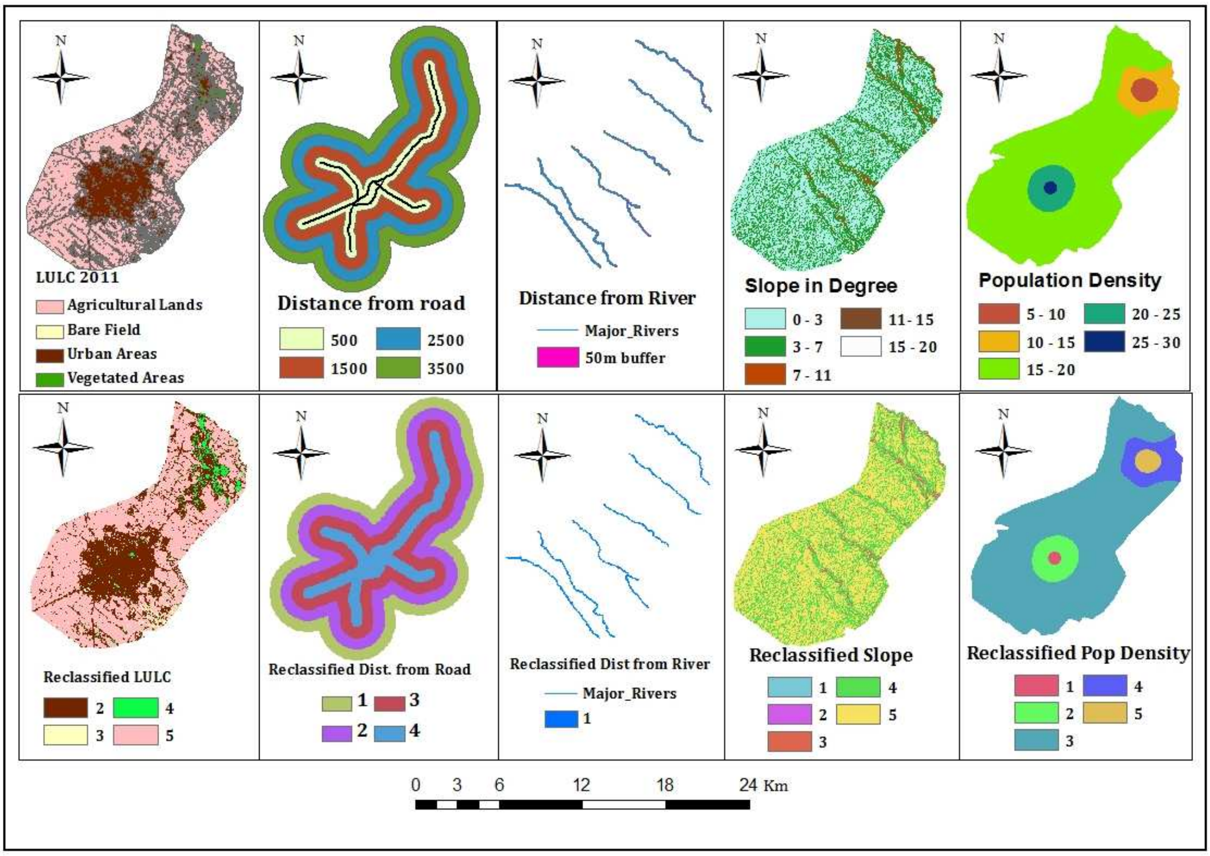

Figure 4.8. Original and reclassified thematic maps.

4.1.4.4 Weighting factors

The next step was to establish a set of weights for each of the factors studied, and the analyst has to fill out the pairwise comparison matrix using the WEIGHT-AHP module in Idrisi. The pairwise comparison was developed by (Saaty, 1977) in the context of a decision making process known as the Analytical Hierarchy Process (AHP). This module uses a pair-by-pair technique to compare the relative importance of one factor (e.g. road) against another factor (e.g. slope). The rating ranges from “extremely less important” (1/9) to “extremely more important” (9). The rating is subjective and entirely depends on the analyst. The analyst compares every pair and assigns the rating into the matrix as shown in table 4.7.

Table 4.7. Pair-wise comparison of the factor layers.

Layers	Land use/ cover	Roads Axis	Rivers	Slope	Pop. Density
Land use/ cover	1				
Roads Axis	1	1			
Rivers	1/3	1/3	1		
Slope	1/3	1/5	1	1	
Pop. Density	1	1/3	3	5	1

Once the pair-wise comparison was filled, a consistency ratio (CR) was calculated to identify inconsistencies and develop the best fit weights in the complete pair-wise comparison matrix. As noted by (Saaty, 1977), CR is the procedure by which an index of consistency can be produced. It also indicates the probability that the matrix ratings were generated randomly and shows possible inconsistencies in the matrix. It is argued that, a consistency ratio greater than 0.1 should be re-evaluated. In this case, the CR was calculated to be 0.04 indicating that it is reasonable to accept the matrix ratings generated randomly. The eigenvectors of weights derived from the pair-wise comparison matrix and assigned to variables triggering the sprawl susceptibility are summarized in table 4.8.

Table 4.8. Principal Eigenvector of the pair-wise comparison matrix.

Factor	**Weight**
Land use/land cover	0.2512
Distance from Road axis	0.3663
Distance from Rivers	0.0837
Slope	0.0684
Population Density	0.2305
Total	1.0001

Consistency ratio (CR) is 0.04

Factors derived have different degree of influence on urban sprawl susceptibility evaluation. As it is evident from table 4.9, the weight assigned to the variables reveals the relative importance of each parameter in exposing an area to sprawl phenomena. In this study, the highest weight was given to distance from roads axis (36.60%) followed by land use/land cover (25.10%), population density (23.00%), distance from rivers (8.37%) and slope (6.84%) in the descending order of their importance. These imply that the higher the weight in percentage of a factor, the more influence it has in urban sprawl susceptibility analysis.

4.1.4.5 Weighted Overlay Analysis for Urban sprawl susceptibility

Once the criteria maps and weights have been developed and established, respectively, a decision rules of MCE module was use. There are three common decision rules in MCE such as Boolean overlay, Weighted linear overlay and Ordered averaging, as pointed by (Jiang and Eastman, 2000; Malczewski, 2000; Malczewski, 2003). In this case, the weighted linear combination (WLC) was applied to aggregate the standardized layers. With a WLC, each standardized factor image is multiplied by its weight, and then the results are summed up. This can be expressed by using the equation (**4.3**) to derive the intended map i.e. urban sprawl susceptibility map for the town of Shashamanne, in the present study.

$$\mathbf{S} = \sum_{i=1}^{n} \mathbf{W}\boldsymbol{i} * \mathbf{F}\boldsymbol{i} \quad \ldots\ldots \quad (4.3)$$

Where; **S** is Susceptibility index (score); $\mathbf{W_i}$ is weight of i^{th} factor;

$\mathbf{F_i}$ is rank /rating of i^{th} factor and **n** is a number of factors.

(LULC) $\times$ **0.2512** + (Distance from Road axis) $\times$ **0.3663** + (Distance from River) $\times$ **0.0837** + (Slope) $\times$ **0.0684** + (Population Density) $\times$ **0.2305** = **Urban Sprawl Susceptibility Map.**

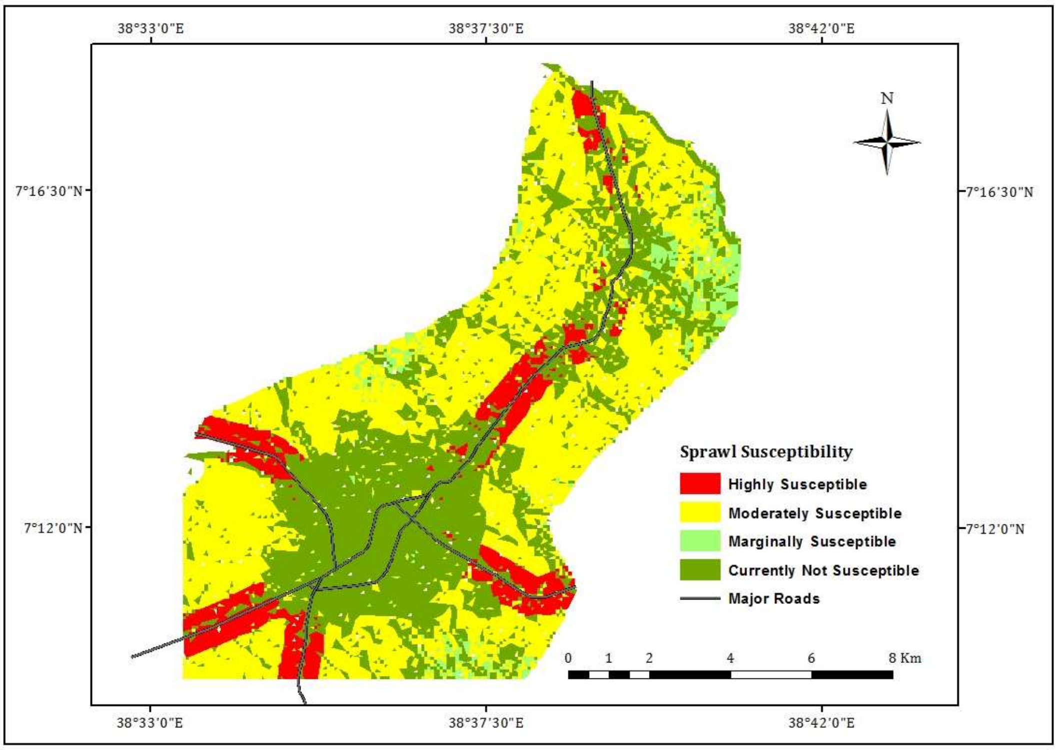

Figure 4.9. Urban sprawl susceptibility map.

The urban sprawl susceptibility map in figure 4.9 and computational results in table 4.9 depicts that the majority of existing built up areas (4310 ha) is currently not susceptible, while the other parts of the study area reveals that: 394 ha (3%) is marginally susceptible, 5279 ha (41%) is moderately susceptible and 1023 ha (8%) is highly susceptible to urban sprawl. Hence, from these figures it is possible to conclude that about 52% of the total area is prone to urban sprawl with slightly different levels of susceptibility. The remaining 48% is currently not susceptible because it has either already sprawled or inaccessible due to physical factors, predominantly topography.

Table 4.9. Urban sprawl susceptibility.

Susceptibility class	Area (ha)	Area (%)
Highly Susceptible	1023	8
Moderately Susceptible	5270	41
Marginally Susceptible	394	3
Currently not Susceptible	4310	33
No data	1971	15
Study Area	12868	100

Source*: computed from urban sprawl susceptibility map (figure 4.11)*

The results also reveal that areas dominated by agricultural lands and nearby the road axis with a moderate slope gradient are identified as highly susceptible to urban sprawling.

Therefore, it is worth mentioning to infer that, regardless of other factors that might have had an impact on sprawl development, the current trend of land use/land cover dynamics and relatively high susceptibility of the areas to urban sprawl, the study site will continue sprawling and the livability of peri-urban fertile agricultural lands will remain under question in the next few years.

4.2 Discussion

The rapid population growth of the world has resulted in uncontrolled haphazard growth in the fringes of urban areas without the knowledge and consent of both concerned cities' and bordering rural administrative bodies. Ethiopia being the third most populous countries in Africa has been a victim of this phenomenon, notably, the horizontal expansion of urban areas often encroaching on arable lands on the outskirts. Apart from ecological influences, the urban sprawl episode has further been creating amorphous suburbs obstructing an authorized growth of the cities themselves. The study area, Shashamanne Town, is no exception in this regard. Therefore, such illegitimate land development needs an effort like this research to address the problem before it threatens the livelihood of the inhabitants in the hinterlands. The fact that the study area has so far been rarely studied for the same purpose makes this study significant and timely effort to highlight the dynamism sprawl and predict proneness of the area to urban sprawl.

It is found to be important to gauge urban sprawl and its impact on peri-urban ecology and seek sound solution to minimize the stress or even avoid it. Urban sprawl is initially detected by gauging urban growth in many ways. The study done by Masek has well thought-out urban growth/sprawl by using remote sensing and GIS to measure rates of urbanization (Masek *et al*., 2000). Other studies have measured sprawl in terms of data layers within a GIS to detect patterns of urban sprawl (Clarke *et al*., 1998). Clearly, there are many ways to measure urban dynamics indicating that there are numerous avenues to reach a similar destination. Population growth can be a driving force behind urban sprawl. Urban sprawl is difficult to measure because it is difficult to define. Further, definitions and ideas about urban sprawl proliferate and are largely shaped by contributions of many different disciplines and their ideas about urbanization. A starting point for much of the research on urban sprawl is measurement and understanding of urban growth processes. Specifically, much of the quantitative research on urban sprawl begins with measurements of urban growth over a given time period to mean the spetio-temporal changes detection.

The spetio-temporal changes detection approach has also been followed in the present research to quantify urban sprawl. Results from the land use/land cover maps derived in the years 1986, 2000 and 2011 has revealed that the study area has undergone tremendous change in a twenty five year period. During this time period, the built up areas increased from 1977 ha (15%) in 1986 to 4329 ha (34%) in 2011 indicating an average annual growth rate of 73% whereas the non-built up ones, in total, were decreased from 10891 ha (85%) to 8539 ha (66%) of which the dominant part is fertile agricultural lands. On top of this, the result of image analysis has further shown that the study area has experienced a unique pattern of urban sprawl, for which I have given a term amoeboid to mean the most uniquely irregular shape.

The urban form of an area is also measured to examine a change in shape, size, and configuration of the built-up environment (Gar-OnYeh et al., 2001). With this intention, an attempt was made in the present study to measure the extent to which the study area has undergone urban sprawl using Shannon's entropy, which measures the degree of spatial concentration or dispersion of a geographic variable, coupled with a GIS and remote sensing technology to calculate sprawl. To this end, two scenarios were considered: 1) the concentric buffer zones around Kuyera sub-city and Shashamanne town centers and 2) the surrounding 12 peasant administrations in the Structure Plan of the town as per the OUPI, 2010. With these baselines, the key component of the entropy value calculation is the density of land development, which equals the amount of built-up land divided by the total amount of land in a given zone in the total number of zones.

The result of the present scenarios has revealed that the sprawl is normally uneven with the highest value being in the surrounding PAs of the town with its high entropy value of 0.94. The entropy values in peri-urban areas are much higher than in the urban core, indicating rapid urbanization process in the fringe areas of the town. With the development of urban utility and service facilities around the city centers, urban sprawl is likely to mainly impact on natural resources, i.e., agricultural land, water bodies, forest and fringe ecology. Hence, the wisdom lies in how effectively the urban growth is planned and governed without hampering the natural resources and disturbing the green agro-rural setup.

In order to gauge urban sprawl susceptibility the factors like distance from road axis, LULC, population density, distance from river and slope were considered with different degrees of their importance and the highest was given to road axis while slope was given the least. The result has revealed that 52% of the study area is susceptible to urban sprawl. It has also been noted that the less densely populated agricultural areas closer to the major road networks with moderate slope gradient are highly susceptible. The only currently not susceptible area is predominantly the existing already sprawled built up areas and the inaccessible remnant sites along river banks.

To sum up, urban sprawl is occurring around the world. In recent years, the negative social and environmental effects of urban sprawl have been realized by more and more researchers and city planners. Smart Growth is a policy oriented strategy for fighting sprawl (Freilich, 1999) and is primarily based on the implementation of higher residential densities (Danielson *et al.*, 1999). This approach to combating urban sprawl now has a strong advocacy presence on the Internet (www.smartgrowth.org/). Faced with ongoing urban sprawl and strong population growth, the Town of Shashamanne needs to consider smart growth policies to encourage the efficient and effective use of newly developed land or the re-use of established land.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study has been carried out to investigate the extent of urban sprawl in totality and predict the likely level of area's susceptibility to sprawl and its impacts on peri-urban green agro-rural environment in Shashamanne Town. The research has been conducted and aimed at the use of remote sensing and GIS techniques to analyze the urban sprawl and detect changes of urban land use/land cover based on multi-temporal satellite data. Landsat imageries during 1986, 200 and 2011 were utilized to track urban sprawl in the study area via analysis of LULC changes during these periods. As a principal measurement of urban sprawl Shannon's entropy was used to gauge spatial dispersion or concentration of sprawling development in the study area. The factors considered for the evaluation of sprawl susceptibility are distance from the major roads axis, LULC of 2011, population density, distance from rivers and slope in the descending order of their degree of influence. Results have revealed that in the study area, the largest LULC is occupied by agriculture, which covers 75% of entire area in 1986 and 62% in 2011. Its conversion to urban area is the main factor for its decline in 2011. The urban/built up areas, vegetated and barren lands possess 15%, 4% and 6% of entire study area in 1986 and 34%, 3% and 1% in 2011 respectively. Even though many changes have observed among the LULCs in the year between 1986 and 2011, the highest rate of changes are seen in agricultural lands which is decreased by 55% in every year and urban areas which is increased by 73% per annum. Beside vegetated and barren lands are also decreased in size by 1% and 17% respectively in 2011 when compared with 1986. The increase of urban/built up use is mainly at the expense of other land uses and this is attributed to population growth in the last 25 years. Being the entropy values in peri-urban areas are much higher than in the urban core, has indicated uneven sprawl and rapid urbanization process in the fringe areas of the town. As per the result of urban sprawl susceptibility analysis, 52% of entire study area is susceptible to urban sprawl while the remaining 48% is currently not. Agricultural lands nearby major road axis with moderate slope are targets of sprawl. Finally, GIS and remote sensing tools are proved powerful to analyze urban sprawl more effectively and sufficiently.

5.2 Recommendations

The thesis addressed the potential of remote sensing and GIS tools for scrutinizing urban sprawl and its impacts on peri-urban productive agricultural lands. It pointed out that the current trend of urban land use and on-going urban sprawl will have remarkable impacts on the surrounding land resources. It also contributes to improve our understanding of the dynamics of urban land use and urban sprawl in the town of Shashamanne. The study may assist environmentalist and planners to consider the impacts of haphazard urban development by identifying the current trend of urban land use and predict sprawling potentiality.

Urban land use change and sprawl are some of the major environmental concerns currently seen in the world and their social and environmental impact is becoming evident. In order to minimize the impacts of urban growth, a policy oriented urban development strategy "Smart growth" suggested by the (EPA, 2000) is also my considered recommendation for the town of Shashamanne. The strategy advocates the implementation of higher residential densities. Smart growth is a development strategy that serves the economy, community and the environment (EPA, 2001). Considering the on-going urban land use changes and sprawl in the study site, it is important to consider smart growth for the efficient and effective use of newly developed land (e.g. vertical development or expansion of areas to preserve natural environments). For effective urban developments, Environmental Impact Assessment (EIA) and public participation in decision making are also recommended. These are essential to assess the likely impacts of urban development on the surrounding ecosystems. Finally, urban growth and urbanization should involve different governmental and non-government agencies. Therefore, institutional collaboration among those various ministerial offices at different administrative hierarchies is required for sustainable development and environmental management.

The sprawl susceptibility map was derived with a limited number of change drivers (thematic layers) and most of them were generated from physiographic maps. This is because the analyst was not able to get data to add more equally important change drivers (e.g. lack of reliable and complete socio-economic dataset). Hence, future work will consider all these limitations and incorporate socio-economic variables like land price speculation, provision policy, per capita income of developers, and ownership style and tenure system, as well as the demography of the area like population growth rate due to biotic and abiotic factors.

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Declaration of Originality

This is to avow that the work is entirely my own and it was carried out under the supervision of Dr. Yirgalem Mahiteme, Department of Geography and Environmental studies and Dr. K.V. Suryabhagavan, Department of Earth Sciences, Addis Ababa University in the year 2012 as a part of fulfillment for an MSc program in Geo-information Science. It is also my strong conviction that the work is not of any other person, unless dully acknowledged (including citation of published and unpublished sources) and it has not previously been submitted in any form to Addis Ababa University or to any other institution for assessment or any other purpose.

Genemo Berisa

Signed ___________________________________

Date: 30th May 2012

Addis Ababa, Ethiopia

Certificate

This is to certify that the thesis entitled "Remote Sensing and GIS Based Urban Sprawl Susceptibility Analysis: the case of Shashamanne Town" is bona fide by Genemo Berisa under our guidance and supervision. This is the actual work done by the candidate for the partial fulfillment of the award of the Degree of MSc in Geo-information science from Addis Ababa University in 2012.

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