ADDIS ABABA UNIVERSITY

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DEPARTMENT OF EARTH SCIENCE

GIS AND REMOTE SENSING

URBANIZATION, URBAN SPRAWL PATTERN RECOGNITION AND MODELING OF AWASA ASHASHEMENE

(MSc. THESIS)

A thesis submitted to school of graduate studies
Addis Ababa University
As partial fulfillment of the requirement for the degree of
Masters of Science in GIS and remote sensing

Amaha G/Medhin

July, 2007

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Abstract

Rapid urban development and increasing landuse changes due to increasing population and economic growth is being witnessed of in Ethiopia and other developing countries. The measurement and monitoring of these land use changes are crucial to understand land use cover dynamics over different spatial and temporal time scales for effective land management. Urban sprawl may be defined as the scattering of new development on isolated tracts, separated from other areas by vacant land (Ottensmann, 1977). Geographic Information System and Remote Sensing data were used to analyze the pattern of urbanization. This was done using temporal satellite image of the study area in year 1986 and 1999 and demographic details from central statistics agency of FDRE. This enabled in quantifying the increase in the built-up area for nearly 14 years. The built up also helps to identify the Shannon¡fls entropy, which is a measure of concentration of dispersion. With intent of identifying the causal factors, this could be modeled and projected for the future decades. This study is aimed at helping scientists, policy makers, engineers, urban planners and ultimately the common man to visualize how towns and cities grow over a period of time based on investigations in the regions around the highway and cities.

CHAPTER 1

1. Introduction

1-1. Background

Ethiopia was under-urbanized, even by African standards. In the late 1980s, only about 11 percent of the population lived in urban areas of at least 2,000 residents. There were hundreds of communities with 2,000 to 5,000 people, but these were primarily extensions of rural villages without urban or administrative functions. Thus, the level of urbanization would be even lower if one used strict urban structural criteria. Ethiopia's relative lack of urbanization is the result of the country's history of agricultural self-sufficiency, which has reinforced rural peasant life. The slow pace of urban development continued until the 1935 Italian invasion. Urban growth was fairly rapid during and after the Italian occupation of 1936-41. Urbanization accelerated during the 1960s, when the average annual growth rate was about 6.3 percent. Urban growth was especially evident in the northern half of Ethiopia, where most of the major towns are located.

The period 1967-75 saw rapid growth of relatively new urban centers. The population of six towns-Akaki, Arba Minch, Awasa, Bahir Dar, Jijiga, and Shashemene-more than tripled, and that of eight others more than doubled. Awasa, Metu, and Goba were newly designated capitals of administrative regions and important agricultural centers (CSA).

With increased population growth and migration to urban areas， urban growth is becoming unplanned and reaching uncontrolled level. More and more cities and towns are blooming with a change in land use along the highways and in the immediate vicinity of a city. This disperse development outside the compact urban and village centers along highways and in rural countryside is defined as sprawl. (Theobald 2001).Sprawl is considered to be an unplanned growth of urban centers along the peripheries of the cities, along highways, along the roads connecting the cities, etc. Due to lack of prior planning these outgrowths are devoid of basic amenities like water, electricity, sanitation, etc.

Some of the causes of sprawl include population growth, economy, patterns of infrastructure, initiatives like the construction of roads，industries and etc.

The direct implication of such urban sprawl is the change in land use and land cover of the region. The impacts of sprawl generally refer to loss of agriculture land, open space and ecological sensitive habitats.

The multidisciplinary range of the subject invokes the interest from ecologists, to urban planners and civil engineers, to sociologists, to administrators and policy makers, and finally the common man.

1-2 Mapping Urban Sprawl

Mapping urban sprawl provides a "picture" of where this type of growth is occurring, and helps to identify the social，environmental and natural resources threatened by such sprawls, and suggests the likely future directions and patterns of sprawling growth. Analysing the sprawl over a period of time will help in understanding the nature and growth of this phenomenon. Ultimately the power to manage a sprawl resides with local municipal governments that vary considerably in terms of will and ability to address sprawl issues.

1-3 Impacts of Sprawl

Impacts of sprawl can be categorized as

a) Social consequence
b) Environmental resource consequence and
c) Impact on natural resources

1-3-1 Social impact

Sprawl has increased the affordability of housing in both suburbs and cities, but this has a negative effect in that it will drive up the housing prices. Nevertheless sprawl imposes economic, emotional, aesthetic, and physical impact in communities living in metropolitan areas.

Economic impact include higher tax, higher costs of providing infrastructure increased basic community costs like transportation cost, adverse fiscal impacts on local government, ill health from air pollution generated by traffic, and reduce worker productivity.

Emotional impacts include loss of community spirit and values, loss of a sense of place as a result of overcrowding.

Aesthetic impact includes less leisure time and more ugly and monotonous sub urban landscapes.

Physical impacts include overcrowded schools, increased traffic congestions, workers commute longer times from their residence to the central city and more aggressive driving patterns

1-3-2. Impact of sprawl on environmental resource

Sprawl has a considerable impact on ecosystems and other environmental resources, which provide societal and environmental benefits simply by existing and functioning. These essential biological and physical systems include wetlands that provide flood control and wastewater renovation; atmosphere, forests, and grasslands that provide climate regulation; biodiversity factors that contribute to healthy, well-functioning ecosystems; and goods such as solar energy, wind energy, aesthetics, clean air, clean water, and potential resources.

The environmental impact of sprawl spans local, regional, and global geographical scales. For example, the cumulative effect on energy consumption and air pollution of individual urban and suburban community commuting back and forth to work are considerable and global in significance. The carbon dioxide in vehicular emissions is a major greenhouse gas that has been linked to global warming. Traffic-generated air pollution threatens human health, agricultural production, and ecological systems. This is illustrated by ground -level ozone, a major air pollutant linked to the patterns and volumes of traffic stimulated by sprawl development. Ozone impairs respiratory functions in healthy individuals and aggravates the ill health of those suffering from heart and respiratory diseases. Other health problems arising from ozone exposure include chest pains, nausea, and throat irritation. Ozone also damages plant growth, interferes with the physiological operations of plants, and is responsible for an annual loss of million in reduced crop production. In addition to poor air quality, other environmental impacts of sprawl include poor water quality stemming from urban non-point sources of pollution; destabilization of stream channels and flooding due to storm water runoff from developed areas; alterations of micro-climates and local climates, including the urban heat island effect and increases in extreme summer heat hazard; loss and fragmentation of wildlife habitats; degradation of landscape aesthetics; and noise and light pollution (Barkley et.al.2005).

Another significant threat to environmental resources is the greatest threat to wildlife in the United States because of loss of habitat (Vaux 1982). Urbanization alters landscapes and fragments prior patterns of land use and land cover, dramatically reducing the amount of habitat and the size of remaining patches of habitat. Land development increases the distances between remaining fragments of habitat, making interactions between isolated populations of plants and animals difficult and hazardous. Sprawl not only consumes wildlife habitats, but also degrades adjacent habitats with light and noise pollution emanating from developed areas (Barkley et.al.2005).

Other effects of sprawl include, it impairs the quality of both ground and surface waters, poorly performing septic systems pose a significant environmental threat. Residents who are dependent on nearby or on-site wells for their water supply may find that groundwater contamination by failing septic systems threatens their health and welfare. In addition, influent from polluted groundwater sources and storm-water runoff originating from impervious surfaces degrades aquatic, estuarine, and near-shore marine ecosystems.

1-3-3 Impact on natural resources

Natural resources are the building blocks of economic systems, without which economies would cease to function. Natural resources are extracted from the environment and transformed into finished goods or used for power. Agricultural lands, timber, and water are renewable resources in that they respond to human manipulation, and, with careful management, their use can be extended almost indefinitely. Minerals such as fossil fuels and metallic ores are nonrenewable, for they are consumed in the production of goods, and humans cannot induce their accumulation.

Sprawl threatens farming directly with heavy traffic and congested roads, damage to crops from air pollution, fragmentation of farms, increase of weeds, higher taxes, high land prices, and declines in farm service infrastructure (Hess; 2001). Farmers often find themselves legally and socially harassed by urban and exurban communities who object to farm odors and noises, dust, movement of equipment, and long farm operating hours. Sprawl is amplifying the conflict in values and landuse between farm and more recent non-farm residents. Moreover, urbanization is radically transforming rural landscapes, shifting the economic base away from agriculture toward other uses, and changing the aesthetic characters of these landscapes.

Forest resources have made significant contributions to the economic development and industrial growth a country. However, the future of timber harvesting operations in many areas is now uncertain. In some cases, harvesting of timber is prevented or severely curtailed in order to preserve habitat needed for endangered and threatened species, or to support economically important, non extractive uses of forests, such as recreation. In other cases, harvesting of timber is threatened by sprawl. Timberlands close to metropolitan areas must increasingly compete economically with residential land use as commuters choose to live farther away from metropolitan areas. In fact, with expanding residential land use, forests become more valuable for development than for timber production. For example, in a non-metropolitan area of New York State, most of the land converted to urban use was formerly forest (LaGro and DeGloria 1992). Vaux (1982) observes that value conflicts over the use and management of forestlands intensify as urban uses consume more and more open spaces and more urbanites and suburbanites turn to remaining forests for recreation. The economic value of forestlands for any use, such as timber production, recreational, or residential, has risen dramatically over the past several decades. The proximity to urban development and higher population densities lead to a decline in timber harvest. In some areas, the decline in harvests, in part, is attributable to increased restrictions placed upon the timber industry, such as harvesting permits, buffer zones, and restrictive forestry practices

Summary of sprawl¡¯s impacts upon social, environmental and natural resources

As residential, commercial and industrial uses consume more and more land, conflicts over the use and management of remaining agricultural and resource lands will intensify. Such conflicts are not limited to urbanizing political jurisdictions, but extend at various spatial scales to public and private lands beyond built-up areas. As agricultural land, wetlands, forests, and streams are lost or degraded due to land development within metropolitan areas and beyond, what remains becomes more and more ¡°valuable¡± to those with interests in the lands. This includes farmers concerned about the lack of land to rent or to purchase at affordable prices in order to expand operations or to continue in farming; wildlife and rural preservation advocates acting to halt or reverse the continued loss of valuable habitats and rural landscapes; and land developers, timber and mining advocates, and those in the construction industry, who hold that their livelihoods are threatened by land-use restrictions and the ¡°locking up¡± of lands suitable fo development. The question that begs an answer is: Should remaining landscapes be valued and managed solely for the environmental services they provide in place or for the natural resources that can be extracted, or can an acceptable compromise over their management be reached? Concern over sprawl highlights the differences between these two broad classes of resources and the conflicts over their uses.

Sprawl has a positive impact on a community in such a way that it increases the affordability of house even though this also has a negative impact on the community in a way it increases the price of house. Highway expansion encourage businesses and industries to locate themselves in suburban locations that not provide good access to the highways but also imposes lower costs to their operations.

1-4. Spatial forms of sprawl

There are three basic spatial forms of sprawl, low-density sprawl, ribbon sprawl and leapfrog development sprawl (Harvey and Clark 1971). They are shown in table 1 and graphically presented in figure 1.

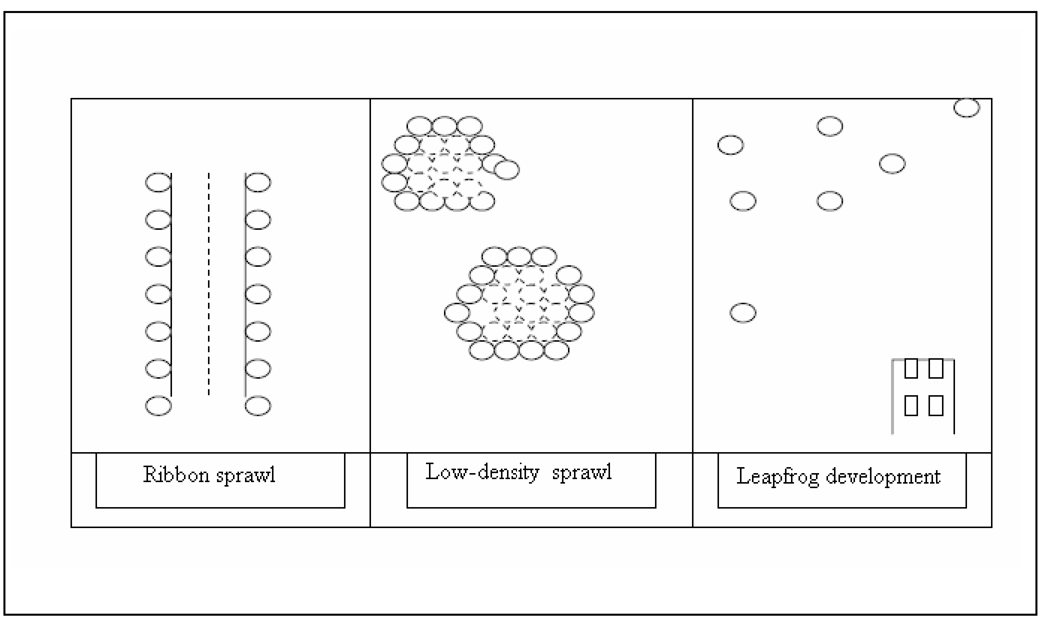

Fig 1 Types of urban sprawl growth

No	Form of sprawl	
1	Low-density sprawl (radial pattern growth)	Low-density sprawl is the consumptive use of land for urban purposes along the margins of existing metropolitan areas. This type of sprawl is supported by piecemeal extension of basic urban infrastructures such as water, sewer, power, and roads
2	Ribbon sprawl (linear pattern growth)	Ribbon sprawl is development that follows major transportation corridors outward from urban cores. Land adjacent to corridors is developed, but those without direct access remain in rural uses/cover. Over time these nearby ¡°raw–lands ma be converted to urban uses as land values increase and infrastructure is extended perpendicularly from the major roads and lines
3	Leapfrog development (dispersed pattern growth)	Leapfrog development is a discontinuous pattern of urbanization, with patches of developed lands that are widely separated from each other and from the boundaries, albeit blurred in cases, of recognized urbanized areas. This form of development is the most costly with respect to providing urban services such as water and sewerage

Table 1 spatial forms of sprawl

1-5. Objective of the study

The objective of this study is

- Identify the patterns of urban sprawl spatially and temporally;
- Analyse the urban sprawl pattern through remote sensing and geographic information system techniques;
- Analyse causal factors of urban sprawl, and
- Model urban sprawl.

CHAPTER 2

2. Literature review

Urban sprawl is often difficult to gauge because it can occur slowly over time. George (2001) argues 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" (George, 2001).

A confusing aspect of sprawl is the lack of agreement over its definition (Johnson 2001).Johnson (2001) presents several alternative definitions for consideration, concluding that there is no common consensus. Because sprawl is demonized by some and discounted by others, how sprawl is defined depends on the perspective of who presents the definition.

Sprawl must be considered in a space-time context as not simply the increase of urban lands in a given area, but the rate of increase relative to population growth. ¡°At a metropolitan scale, Sprawl may be aid to occur when the rate at which land is converted to non-agricultural or non-natural uses exceeds the rate of population growth¡±

Urban sprawl is also referred as irresponsible, and often poorly planned development that destroys green space, increases traffic, contributes to air pollution, leads to congestion with crowding and does not contribute significantly to revenue, a major concern. Increasingly, the impact of population growth on urban sprawl has become a topic of discussion and debate. Typically conditions in environmental systems with gross measures of urbanisation are correlated such as population density with built-up area (George, 2001). The relation of population growth and urban sprawl is that the population growth is a key driver of urban sprawl. The population growth variable was responsible for about 31 percent of the growth in land area leading to suburban sprawl over the course of the 1980s in 282 metropolitan areas of United States of America. The population increased from 95 million to 140 million (47 percent) while urbanised land increased from 25,000 square miles to 51,000 square miles (107 percent) among 213 urbanised areas in USA between 1960 and 1990 (George, 2001). This implied that density per square mile decreased by 28%.

Regardless of how it is defined and evaluated, sprawl is a response to often bewildering sets of economic, social, political, and physical forces (McCauley and Goetz, 2004). These forces include municipal fragmentation, the patterns of infrastructure investments, subsidization of infrastructure, and “white flight” fro cities.

Urban sprawl is characterized by leapfrog landuse patterns, strip commercial development along highways, and very low-density single-use developments, all of which occur over a relatively short period of time (Barkley, 2005). It has also 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. Over the past 50 years the process of urbanization, suburbanization, counter-urbanization, and re-urbanization, has allowed for urban expansion into rural areas taking the form of low-density development, predominantly single family residential subdivisions and strip commercial development (Lee et al 1998).

"The result of this development process is commonly called 'urban sprawl.' In this form, urbanization spreads outward in a haphazard pattern, consuming more land than is necessary and creating excessive public costs for community facilities and services (Lee et al., 1998).

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 difference between urban growth and urban sprawl except to suggest that urban sprawl is a type of urban growth.

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. Urban sprawl creates inefficient use of land, land resources, and large-scale encroachment on agricultural land (Gar-On Yeh et al 2001).

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). Wilson et al. (2003) not only measure change of an individual pixel, but also changes within a framework of a neighborhood of pixels. This technique is known as neighborhood statistics and is extremely useful in visualizing densities of new growth areas.

In modeling the complex nature of urbanization, it is often necessary to apply more than one technique to understand how to measure an increase in urban growth or urban sprawl. In South Carolina, Allen et al (2003) used an integrated approach to model urban sprawl in which aspects of three different techniques were employed to model urbanization. The first enlisted a logistic regression model to predict urban transition probabilities. Next, a relative probability model was used to test different growth scenarios. Later, they organized focus groups to help set growth scenarios.

Much of the quantitative research on urban sprawl begins with measurements of urban growth over a given time period. Gar-OnYeh et al. (2001) measure the urban form of an area to examine a change in shape, size, and configuration of the built-up environment. They use 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. This type of research keys in on aspects of sprawl such as density, connectivity, and location of new urbanization.

While quantification of urban growth often involves a direct measurement of new built-up or urban land, it is also important to include qualitative information. A study done in the Chicago metropolitan region by Zhang (2001) found that social-economic factors were most important in attracting residents to a new development, potentially leading to urban sprawl. The discernment of qualitative data does not come from any single computer program because of the complexities of urbanization.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.

The built-up is generally considered as the parameter of quantifying urban sprawl (Torrens and Alberti, 2000; Barnes et al., 2001; Epstein et al., 2002). It is quantified by considering the impervious or the built-up as the key feature of sprawl, which is delineated using toposheets or through the data acquired remotely. Yeh and Li (2001) use Shannon's entropy, which reflects the concentration of dispersion of spatial variable in a specified area, to measure and differentiate types of sprawl. This measure is based on the notion that landscape entropy, or disorganisation, increases with sprawl. The urban land uses are viewed as interrupting and fragmenting previously homogenous rural landscapes, thereby increasing landscape disorganisation. Lata et al. (2001) employed a similar approach of characterising urban sprawl for Hyderabad City, India, in terms of Shannon's entropy. In an attempt to map the sprawling trends and changes in the urban core Jothimani (1997) used Landsat-MSS and IRS LISS-II data through visual interpretation techniques for analysis and identified the trends of emergence of sprawl along transportation network for Surat and Ahmedabad cities.

A study done by Sprawl City, a non-profit organization that researches urbanization issues shows that there is a correlation between the amount of population growth and the consumption of land in what the United States Bureau of the Census calls urbanized areas (Sprawl City, 2005). Urbanized areas are comprised of the contiguous developed land of the central city and its suburbs (Sprawl City, 2005). 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

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, 1). Therefore, it is ideal to use a tool such as a GIS as part of 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 (Barkley, 2005). In that study, a GIS was used to predict future growth patterns and the impacts that such growth would have agricultural land (Barkley, 2005). Barkley (2005) 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 (Barkley, 2005).

A study conducted on the Washington-Baltimore CMSA used a cellular automata model combined with historical maps in a GIS to determine where future development may occur (Clarke et al 1998). The cellular automata model assumes an action within a given space, viewed in this case through a GIS grid, a set of initial conditions, and a set of behavior rules (Clarke et al 1998). GIS grid data layers were incorporated into IDRISI, GIS software, and iterations were performed to show different growth scenarios given different behavior rules (Clarke et al 1998). The same study was also able to use the GIS to produce maps of different growth scenarios, which allowed visualization of the results. 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 (Zhang 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¡fls entropy technique with the integration of remote sensing and GIS Shannon¡fls 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 impacts of urban patterns on ecosystem dynamics should focus on how patterns of urban development alter ecological conditions (e.g. species composition) through physical changes (e.g. patch structure) on an urban to rural gradient. The use of gradient analysis for studying urban-to-rural gradient of land-use intensity to explain the continuum of forest change from city centre to non-urban areas might help to explore ecosystem effects of different urban configurations, but current applications do not differentiate among alternative urban patterns (Alberti et al., 1999). Most studies of the impacts of urbanisation do not differentiate among various urban patterns. Planners need this ecological knowledge, so that their decisions can minimise impacts of inevitable urban growth. Decisions by urban dwellers, businesses, developers, and governments all influence patterns. Spatial pattern is one (of very few) such environmental variable, which can be controlled to some extent by landuse planning. Design strategies for reducing urban ecological impacts will remain poorly understood and ineffectual if spatial pattern issues are not addressed in ecological studies of urban areas.

In urban growth modeling studies, the spatial phenomenon is simulated geometrically using techniques of cellular automata (CA). The CA technique is used extensively in the urban growth models (Clarke, et al., 1971) and in urban simulation (Torrens and Sullivan, 2001; Barkley, 2005). The inadequacy in some of these is that the models fail to interact with the causal factors driving the sprawl such as the population growth, availability of land and proximity to city centres and highway. Cheng and Masser (2003) report the spatial logistic regression technique used for analysing the urban growth pattern and subsequently model the same for a city in China. Their study also includes extensive exploratory data analyses considering the causal factors. The inadequacies in these were to accurately pinpoint spatially where the sprawl would occur. This problem could be effectively addressed when neural network is applied to the remote sensing data especially for classification and thematic representation (Madhavi, et.al, 2001). The neural spatial interaction models would relieve the model user of the need to specify exactly a model that includes all necessary terms to model the true spatial interaction function (Madhavi, et.al, 2001).

CHAPTER 3

3. Study area and methodology

3-1.General

Ever Since Awasa is designated as the capital city Sidamo and now of Southern Nations, Nationalities and Peoples' Region (SNNPR) of Ethiopia and the city is comparatively the closest to Addis Ababa, the capital city of Ethiopia. The city is also at a convenient location on the Addis Ababa-Nairobi highway there has been a rise of population due to rural to urban migration to the city from neighboring Woredas and zones.

With the construction of the highway from Addis Ababa to Awasa in the mid nineties has made the city feel very near to the capital city of Ethiopia. And the Awasa Lake surrounding the city in the western side has given the city beautiful scenery.

Shashemene is a town in central Ethiopia. It is located in the Misraq Shewa Zone of the Oromia Region.Shashemene is known for its Rastafarian movement. In 1963 Emperor Haile Selassie I donated 500 hectares of land to allow Rastafari movement settlers from Jamaica and other parts of the Caribbean to return to their ancestral homeland in Africa.

3-2. Location

This study is carried out in the region located within the coordinates of latitudes 7º14′12″ N and 7º00′30″ and longitudes 38º25′50″ and 38º39′26″ E surrounding the national highway between Awasa and Shashemene. The two cities are apart from each other by 32Km.The total study area is 158.59 km^2 (Figure 2)

Both of the cities lie in the Great Rift Valley. Shashemene and Awasa are located 241and 272km from Addis Ababa, capital city of Ethiopia.

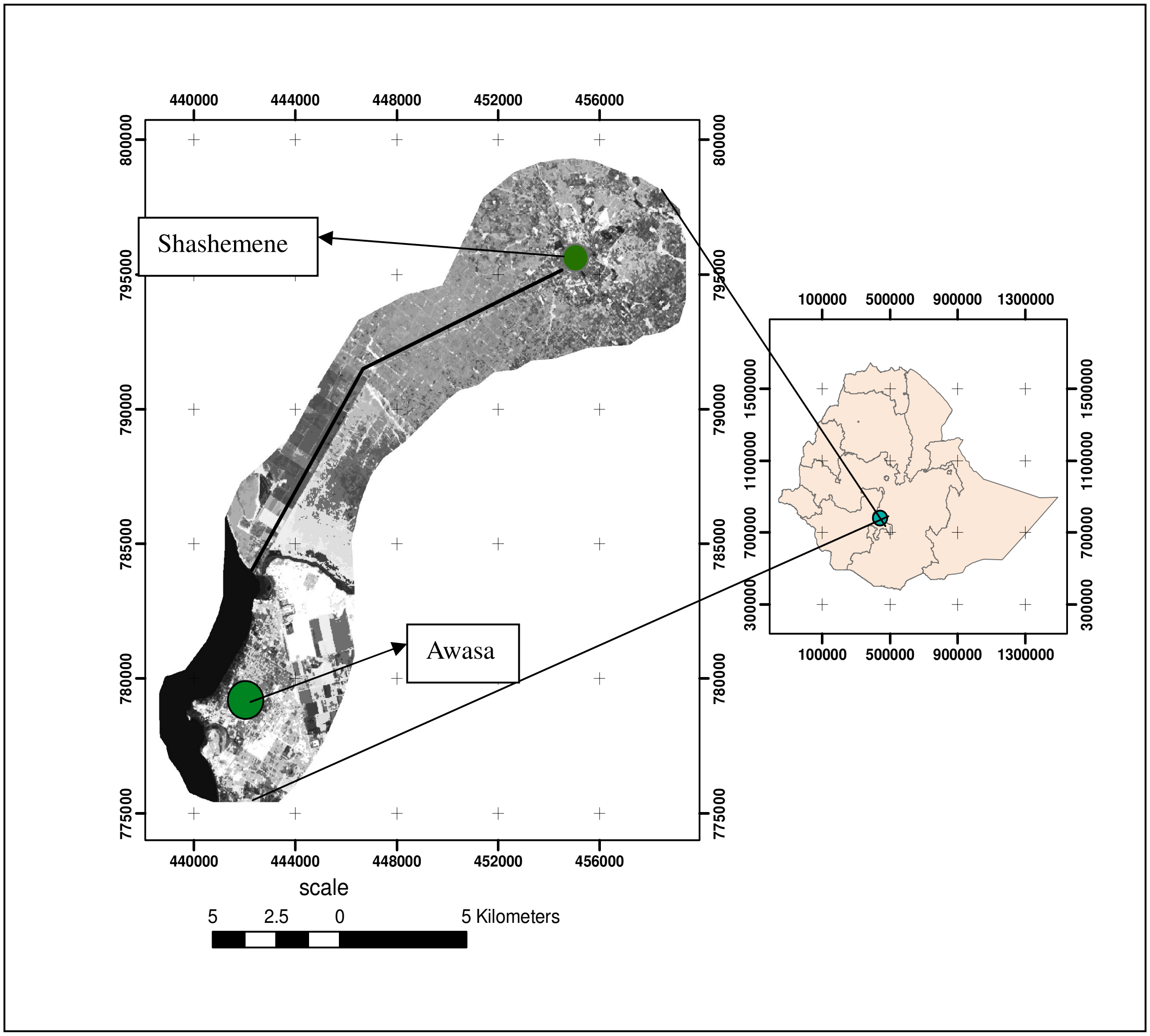

Fig 2 Location map of study area

3-3. Climate and agriculture

The annual precipitation of the area 1040mm and the mean annual temperature ranges from 12.3oC to 31.2oC. (National meteorological agency FDRE)

Cereals dominantly maize and pulses (peas and beans) are the dominant crop types produced in the area。

3.4. Material and data collection

The data collection was carried out in two phases: primary and secondary data collections. The nature of these data and their sources are shown in table 2

Type	Data/material	Source
Primary data	Toposheets number 0638B1 (Wajigra), 0638A2 (Leku), 0738C4 (Awasa) 0738D3(Shashemene)	Ethiopian mapping agency Scale 1:50000
	Landsat Satellite image dated January 21,1986 and landsat satellite image December 9 1999	Special resolution of 28.5
Secondary data	Demographic data from primary census abstracts for 1987 and 1999	Central statistics agency of FDRE

Table 2 material and data collection

3.5. Methodology

The growth of urban sprawl over 15 years was determined by computing the classified built-up area of landsat satellite image of year 1986 and comparing it with the area obtained from the classified satellite imagery for the built-up area of satellite image of year 1999.

The dynamic phenomenon of urban sprawl could be understood with the analyses of land use changes, sprawl pattern and computation of sprawl indicator index. For this purpose the highway passing between the two cities was digitised separately and a buffer region was created. This buffer region is created to demarcate the study region around the road.

The Landsat satellite images and the topographic sheet of the area were Geo-referenced and Image processing was applied. Geo-referencing was done using cubic convolution resampling technique. From the topographic sheet highway between the two cities was digitized and a buffer region was created. And for Shashemene city taking a central point and creating a 3Km buffer region to demarcate the study boundary for the city.

The Landsat satellite images of both year 1986 and 1999 has seven layers. False color composite of both temporal images was generated by linear stretching each image and with this composite unsupervised classification for both images is generated for each imagery.

After collecting control points and checking it with the ground truth and the topographic map supervised classification was done using maximum likelihood classifier into four broader groups. These are built-up, vegetation, open land and water bodies.

Then the study area is quantified by calculating the built up area and using Shannon¡fls ertr op.

The methodology is summarized in flow chart in figure 3

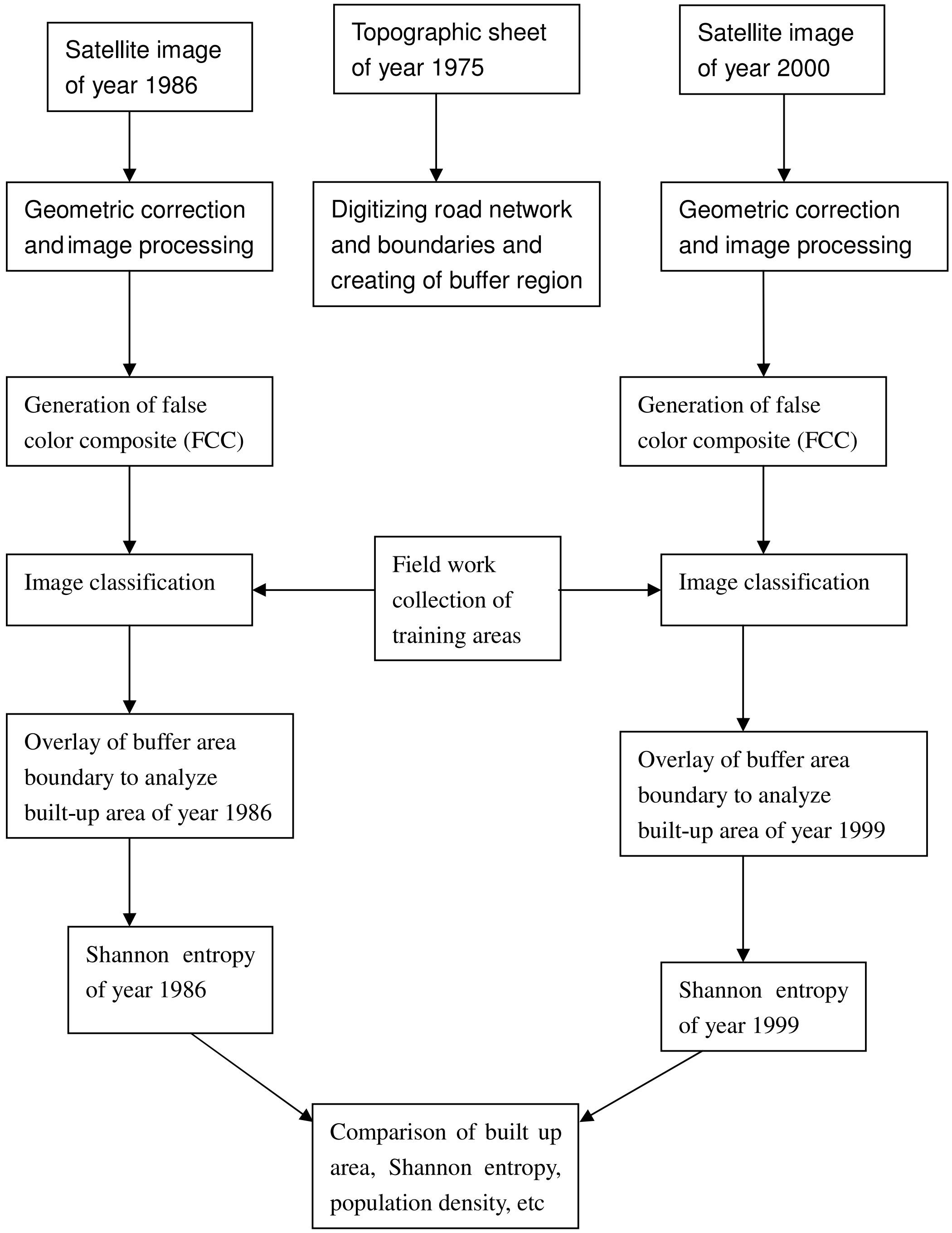

Fig 3 Methodology of the study represented by flow chart

CHAPTER 4

4. Data analysis

Image processing techniques were applied to the 1986 landsat satellite imagery of the study area. The true color composite blue, green and red (band 3, band 2 and band 1) of the study area is shown in the figure 4.

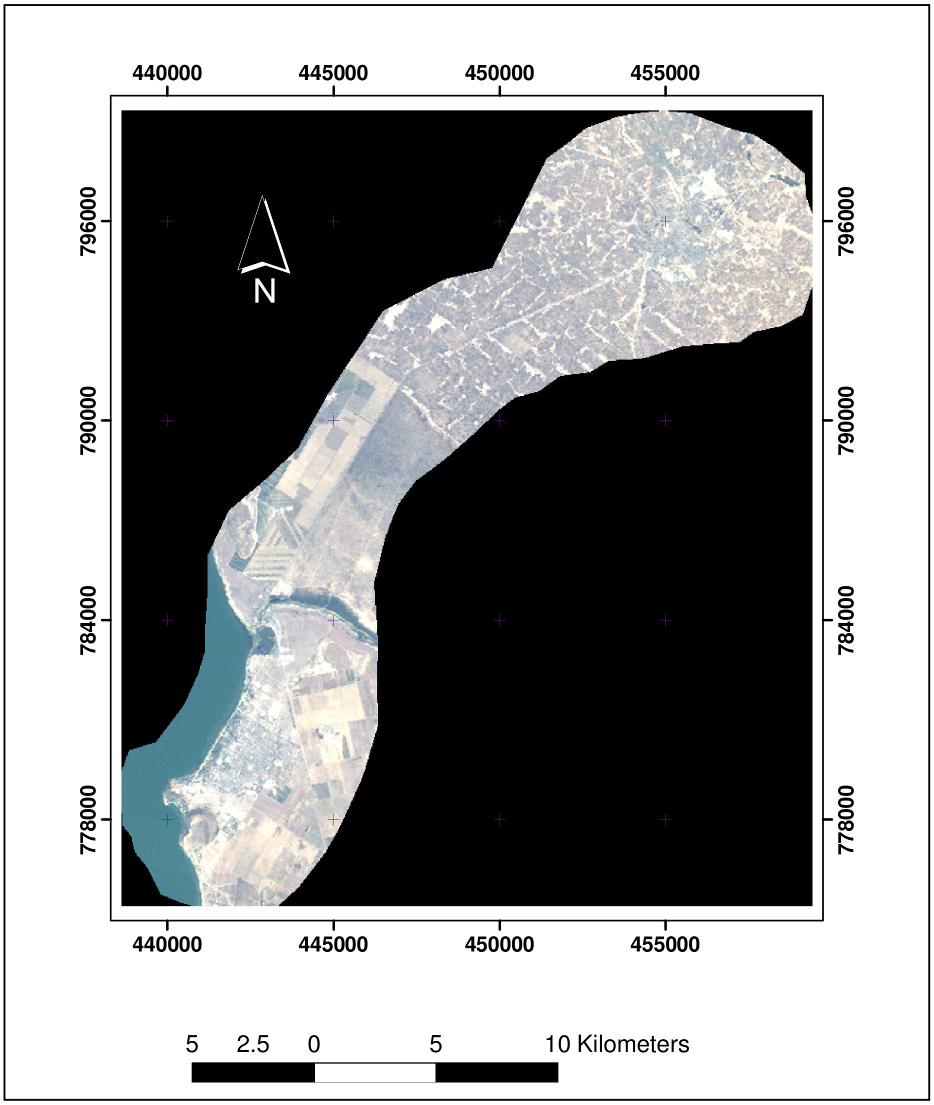

Fig 4 True color composite of study area in 1986

False color composite of the landsat satellite image is generated by linearly stretching each band. Other image enhancements have resulted in no significant change of features identification as probably due to clear sky condition in the area during accusation of the images. The false color composite of this imagery is generated using band combination band 7, band 4 and band 1 as shown in figure 5.And the histograms of the original (unstretched) image and the linearly stretched images of each band are shown below.

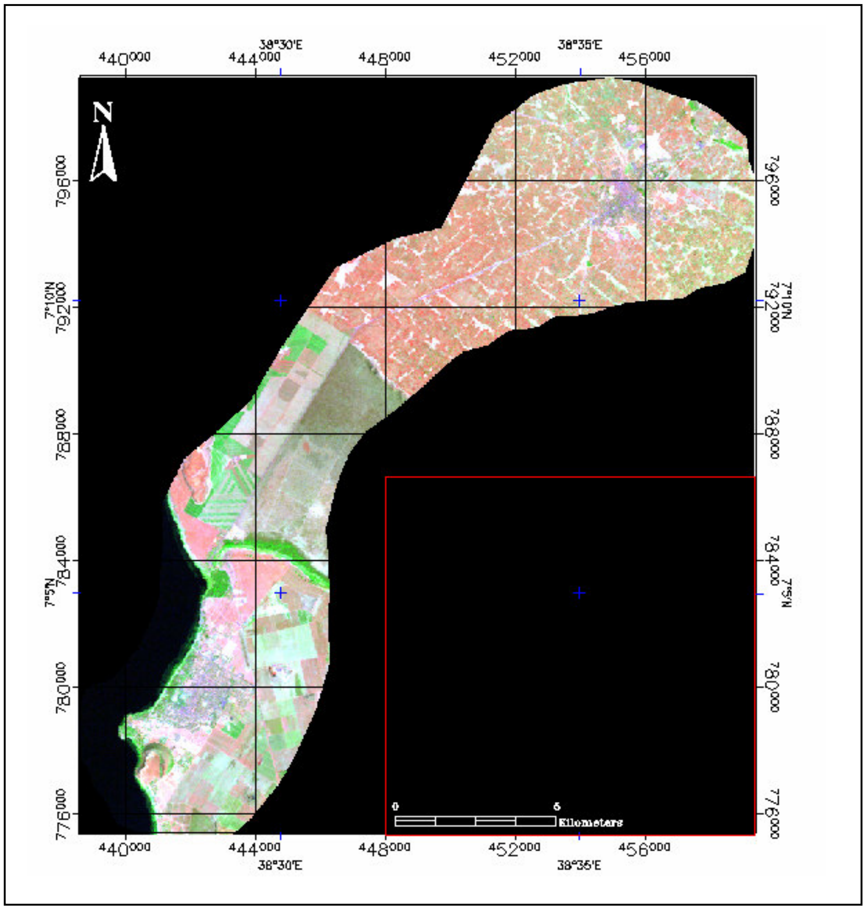

Fig 5 False color composite (FCC) imagery of study area in year 1986

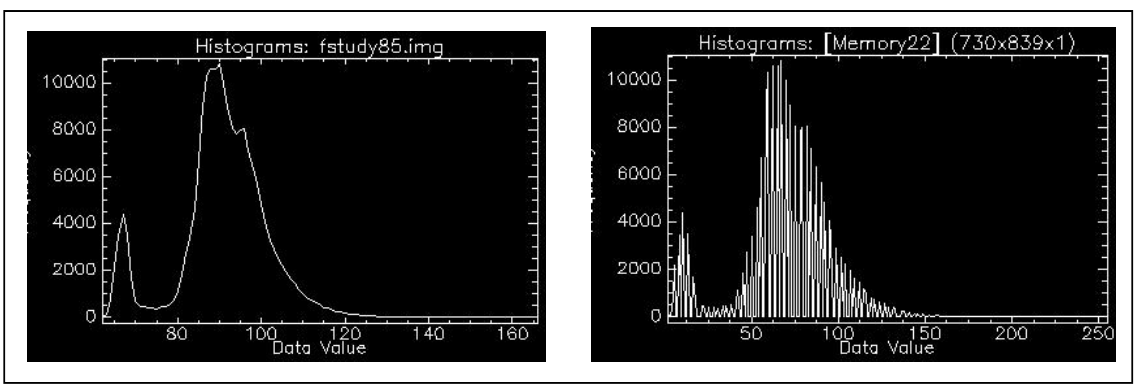

Fig 6 Histogram of band 1 image original (left) and linearly stretched image (right)

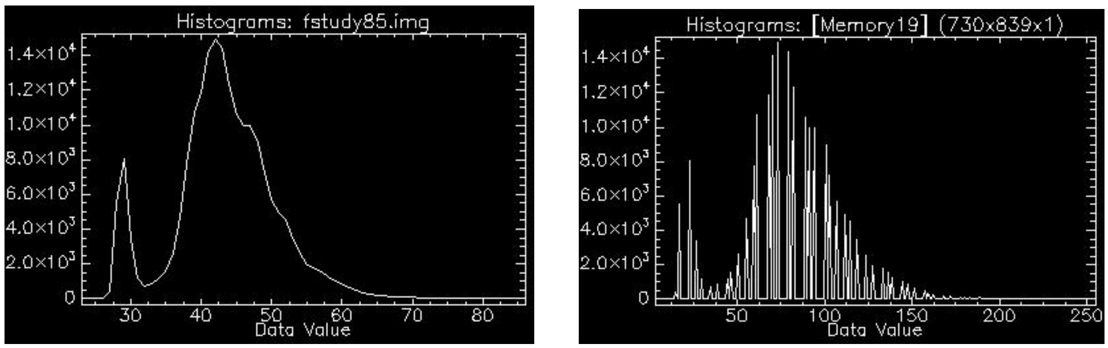

Fig 7 Histogram of band 2 image original (left) and linearly stretched image (right)

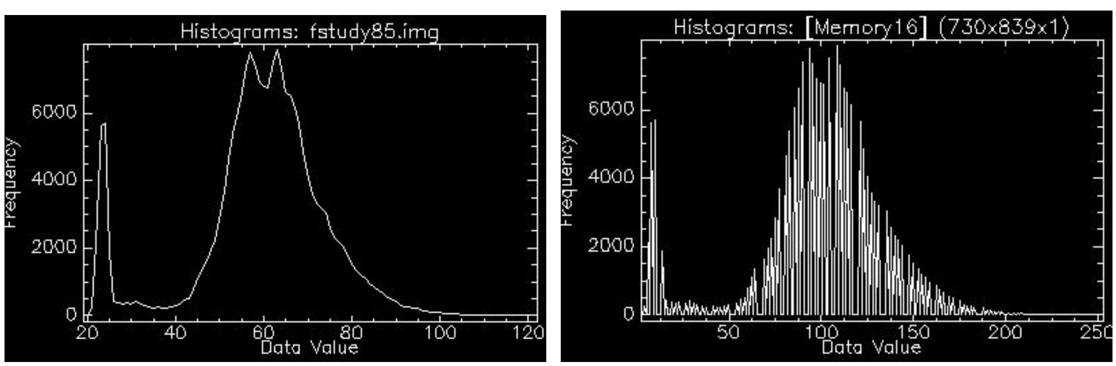

Fig 8 Histogram of band 3 image original (left) and linearly stretched image (right)

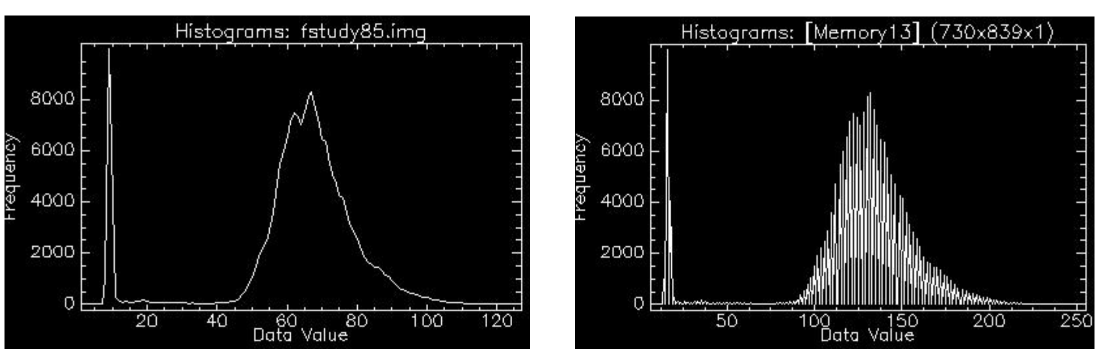

Fig 9 Histogram of band 4 image original (left) and linearly stretched image (right)

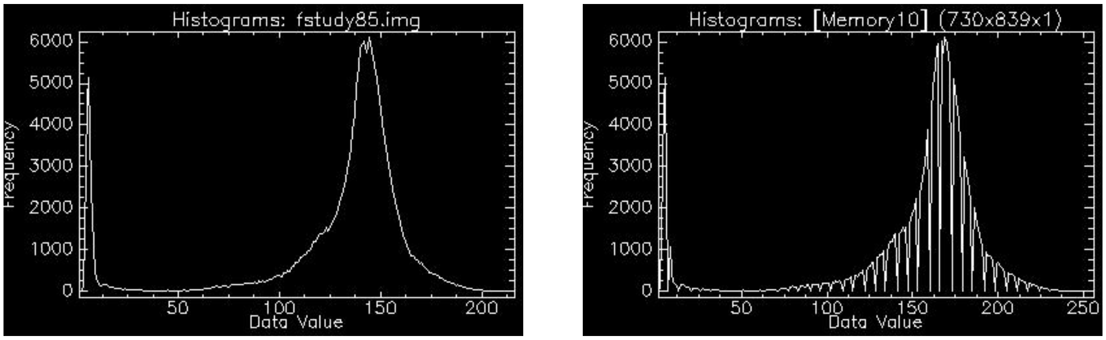

Fig 10 Histogram of band 5 image original (left) and linearly stretched image (right)

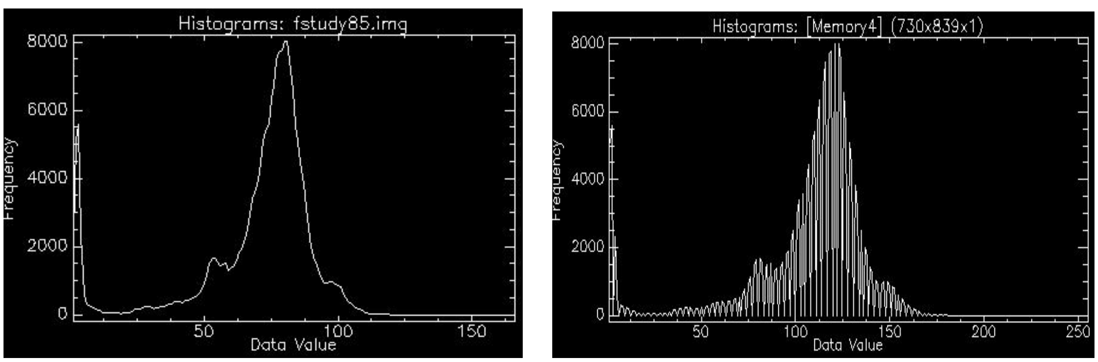

Fig 11 Histogram of band 7 image original (left) and linearly stretched image (right)

Using the false color composite unsupervised classification was done into 14 landuse/ landcover class categories. Taking control point from this imagery it has been checked with the ground truth using and topographic sheet of year (1975) and it is reduced to 4 broader categories during supervised classification using maximum likelihood classifier. These categories are vegetation, water bodies, open land (open area and barren) and built-up barren. The classified image is shown in figure 12

The landuse/landcover classification shows the area is covered by 8.2% by built-up area, 56.04% by open land, 25.47% by vegetation and 10.27% by water bodies.

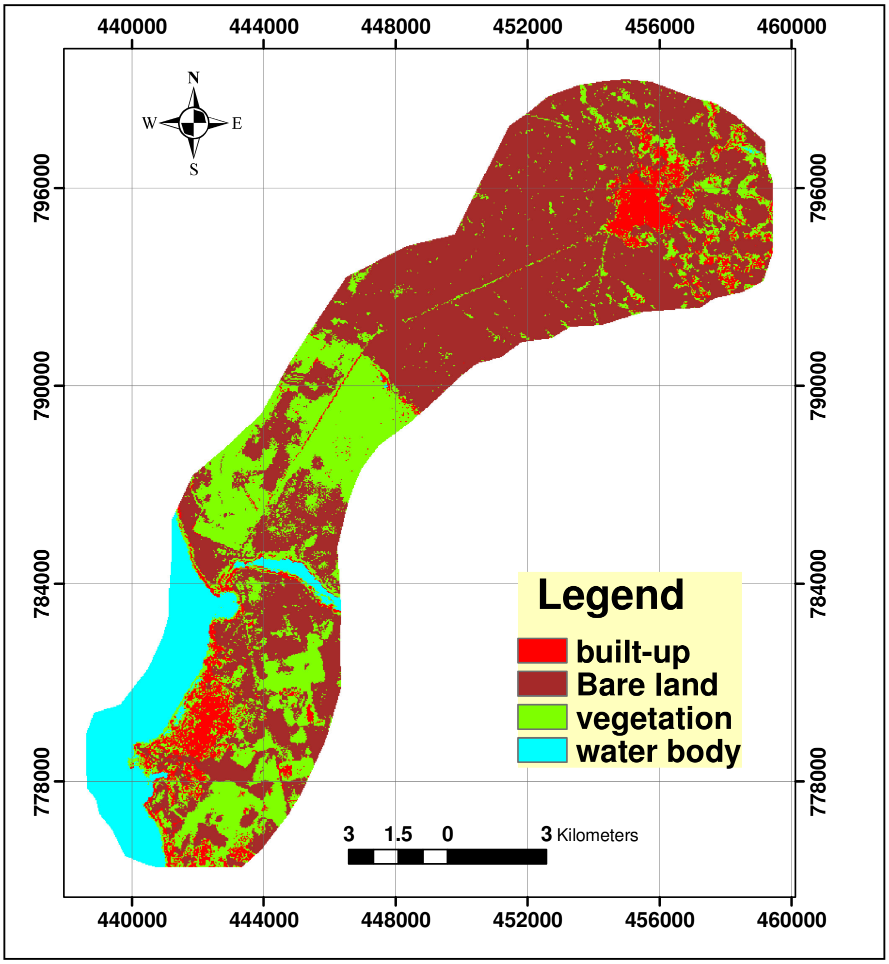

Figure 12 classified image of year 1986

The overall accuracy is calculated by summing the number of pixels classified correctly and dividing by the total number of pixels. The ground truth image or ground truth areas of interest define the true class of the pixels. The pixels classified correctly are found along the diagonal of the confusion matrix table which lists the number of pixels that were classified into the correct ground truth class. The total number of pixels is the sum of all the pixels in all the ground truth classes.

This classified image has an overall accuracy of 98.70%.

The kappa coefficient (k) is another measure of the accuracy of the classification. It is calculated by multiplying the total number of pixels in all the ground truth classes (N) by the sum of the confusion matrix diagonals (x_{kk}), subtracting the sum of the ground truth pixels in a class times the sum of the classified pixels in that class summed over all classes ($\Sigma x_{k\Sigma} x_{\Sigma k}$), and dividing by the total number of pixels squared minus the sum of the ground truth pixels in that class times the sum of the classified pixels in that class summed over all classes.

$$K = \frac{N \Sigma x_{kk} - \Sigma x_{k\Sigma} x_{\Sigma k}}{N^2 \_ \Sigma x_{k\Sigma} x_{\Sigma k}}$$

The kappa coefficient of this classified image is 0.98

Overall Accuracy=(1678/1700) 98.7059% Kappa Coefficient =0.9828						
Ground Truth (pixels)						
Class	Vegetation	water body	Built-up area	Open area	Barren	Total
Unclassified	0	0	0	0	0	0
Vegetation	553	0	7	1	1	562
Water body	0	199	0	0	0	199
Built-up area	1	0	388	0	2	391
Open area	0	0	2	438	2	442
Barren	0	0	0	6	100	106
Total	554	199	397	445	105	1700

Ground Truth (Percent)						
Class	Vegetation	water body	Built-up area	Open area	Barren	Total
Unclassified	0	0	0	0	0	0
Vegetation	99.82	0	1.76	0.22	0.95	33.06
Water body	0	100	0	0	0	11.71
Built-up area	0.18	0	97.73	0	1.9	23
Open area	0	0	0.5	98.43	1.9	26
Barren	0	0	0	1.35	95.24	6.24
Total	100	100.00	100	100	100	100

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
Vegetation	1.6	0.18	9/562	1/554
Water body	0	0	0/199	0/199
Built-up area	0.77	2.27	3/391	9/397
Open area	0.9	1.57	4/442	7/445
Barren	5.66	4.76	6/106	5/105

Class	Prod. Acc. (Percent)	User.Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
Vegetation	99.82	98.4	553/554	553/562
Water body	100	100	199/199	199/199
Built-up area	97.73	99.23	388/397	388/391
Open area	98.43	99.1	438/445	438/442
Barren	95.24	94.34	100/105	

Table3 confusion matrix of classified image of 1986

Similar procedures are followed to enhance the Landsat satellite imagery of year 1999. The true color composite blue, green and red (band3, band 2, band1) is shown in figure 13 and the histogram of this image of all bands is shown in figure 14.

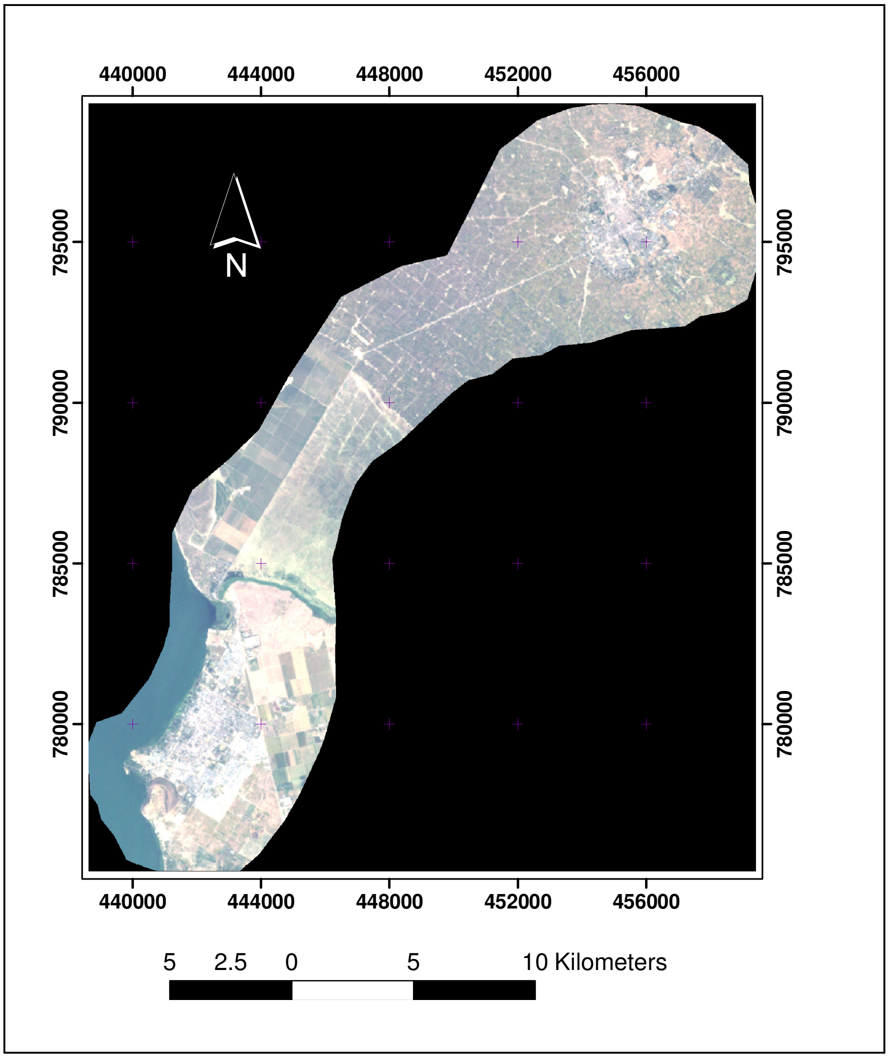

Fig 13 True color composite of study area in 1999

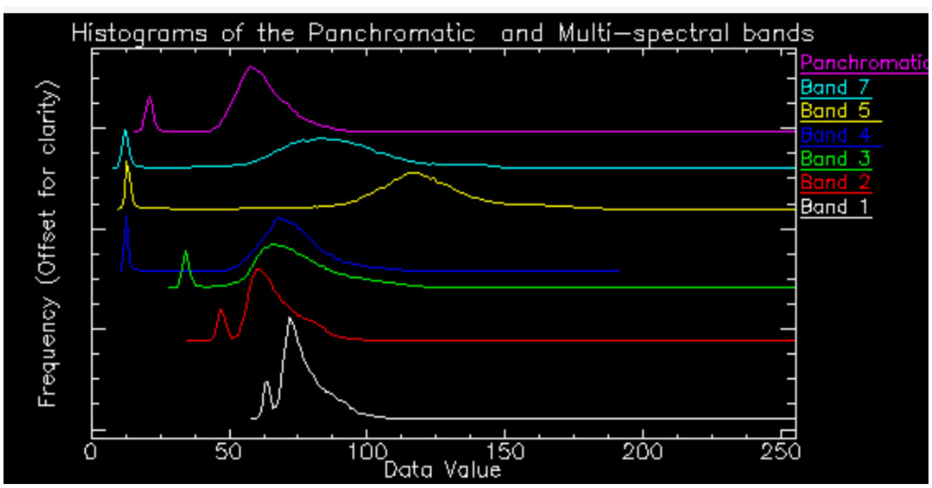

Fig 14 Histogram of the unstretched imagery of study area in year 1999.

To create the false color composite (FCC) of the study area, the original image was linearly stretched. Other image enhancements have resulted in no significant change of features identification as probably due to clear sky condition in the area during accusation of the images. And the false color composite is generated using band 7, band 4 and band 1. The imagery showing the false color composite is shown in figure and the histogram of this composite imagery is shown in figure 16 (see annexure for the statistics).

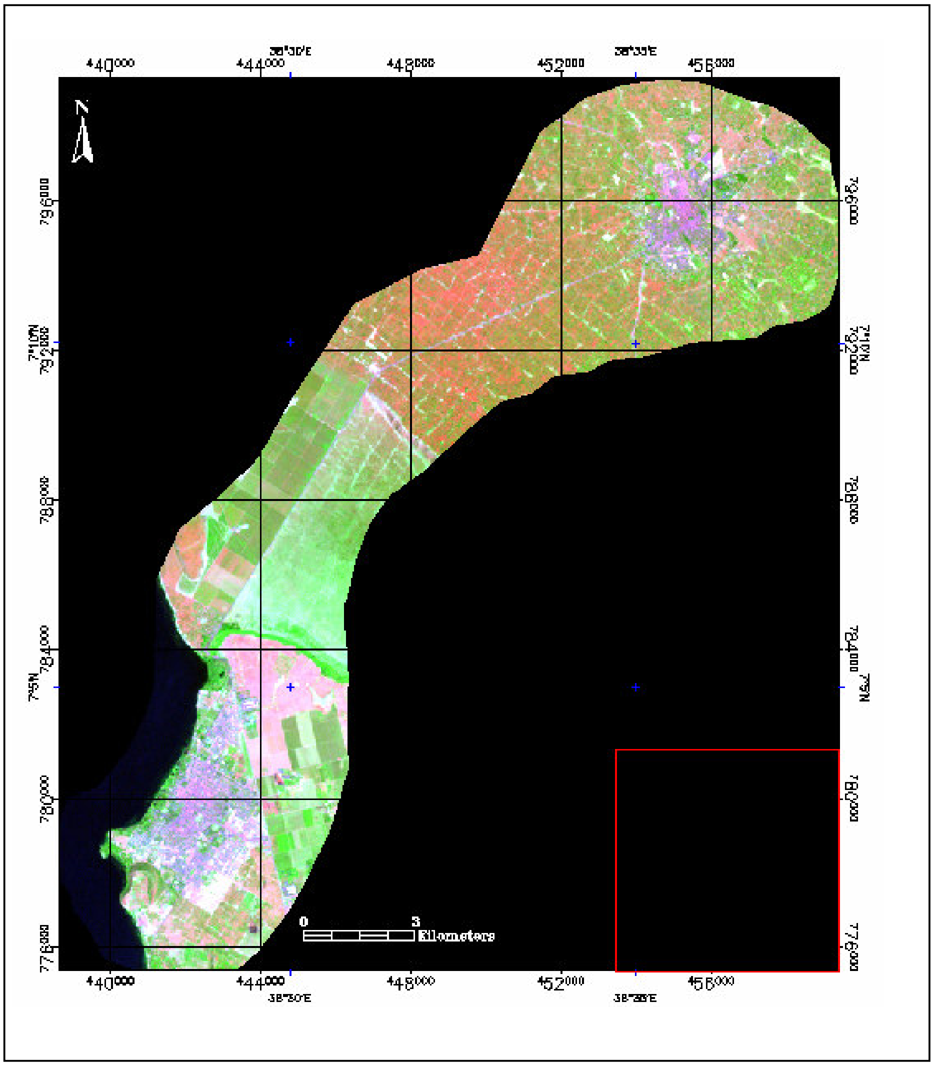

Fig 15 False color composite (FCC) of study area in year 1999

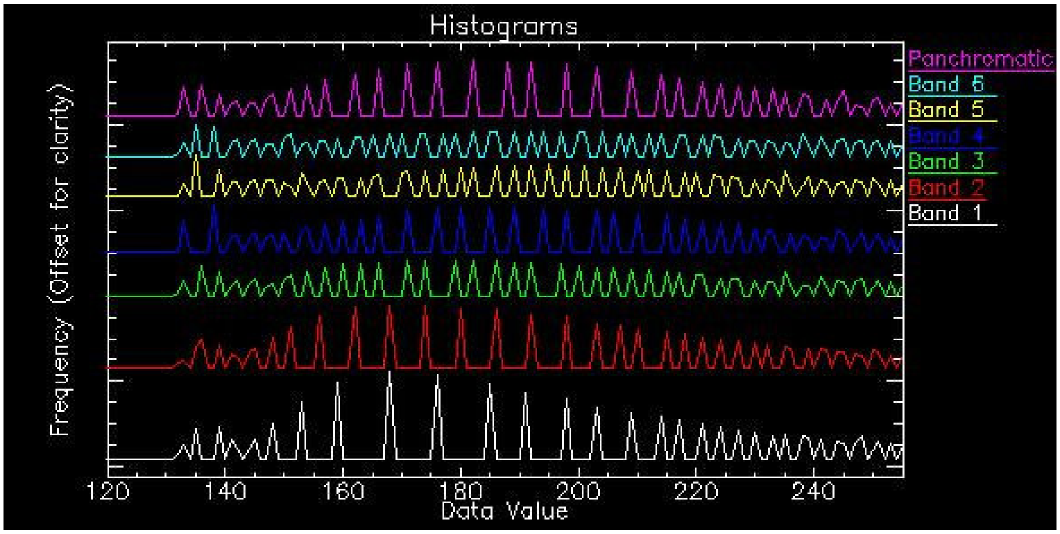

Fig 16 Histogram of linearly stretched imagery of study area in year 1999.

Using the false color composite unsupervised classification of is done into 12 landuse categories. Taking control point from this imagery it has been checking it with the ground using GPS. It is categorized into four broader classes using maximum likelihood classifier. The classification algorithm used is the maximum likelihood classification. These are built-up, open land, vegetation and water body. The classified image is shown in figure17.

The classification has overall accuracy of 98.9459% and Kappa coefficient of 0.9852. (See all the statistics in annexure)

The classified land use/ land cover imagery shows the study area is covered 16.96% by built-up area, 34.77% by, 8.13% by water body and 40.13% by open land.

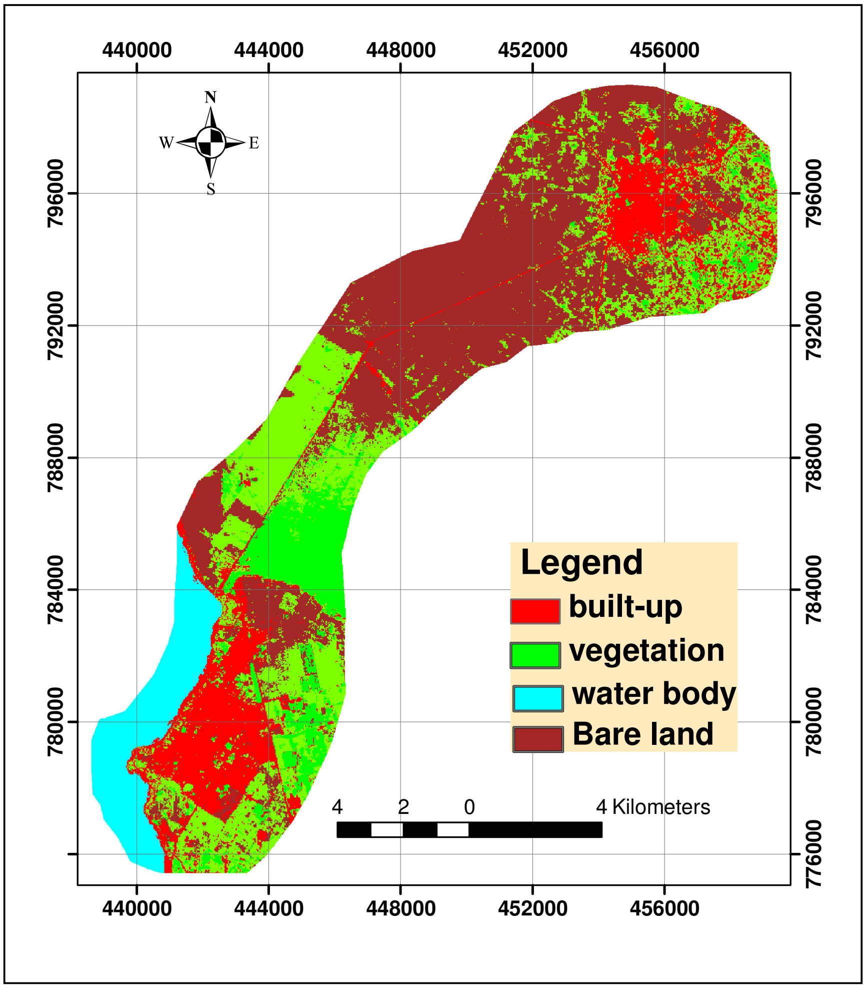

Fig 17 Classified imagery of year 1999

Overall Accuracy = (6477/6546) 98.9459% Kappa Coefficient = 0.9852						
Ground Truth(Pixels)						
Class	Built-up	grass land	plantation	open area	water	Total
Unclassified	0	0	0	0	0	0
Built-up	1393	0	2	25	0	1420
grass land [G	0	854	0	0	0	854
plantation [M	0	9	1220	0	0	1229
open area	33	0	0	2793	0	2826
water [Blue]	0	0	0	0	217	217
Total	1426	863	1222	2818	217	6546

Ground Truth(Percent)						
Class	Built-up	grass land	plantation	open area	water	Total
Unclassified	0	0	0	0	0	0
Built-up	97.69	0	0.16	0.89	0	21.69
grass land	0	98.96	0	0	0	13.05
plantation	0	1.04	99.84	0	0	18.77
open area	2.31	0	0	99.11	0	43.17
water	0	0	0	0	100	3.32
Total	100	100	100	100	100	100

Class	Commission (Percent)	Omission (Percent)	Commission (Pixel)	Omission (Pixels)
Built-up	1.9	2.31	27/1420	33/1426
grass land	0	1.04	0/854	9/863
plantation	0.73	0.16	9/1229	2/1222
open area	1.17	0.89	33/2826	25/2818
water	0	0	0/217	0/217

Class	Prod. Acc. (Percent)	User.Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
Built-up	97.69	98.1	1393/1426	1393/1420
grass land	98.96	100	854/863	854/854
plantation	99.84	99.27	1220/1222	1220/1229
open area	99.11	98.83	2793/2818	2793/2826
water	100	100	217/217	217/217

Table 4 confusion matrix of classified image of 1999

CHAPTER 5

5. Results and discussion

5-1. Built-up area

The percentage of an area covered by impervious surfaces such as asphalt and concrete is a straight forward measure of development (Barnes et al, 2001). It can be safely considered that developed areas have greater proportions of impervious surfaces, i.e. the built-up areas as compared to the lesser-developed areas.

Considering the built-up area as a potential and fairly accurate parameter of urban sprawl has resulted in making considerable hypothesis on this phenomenon. Since the sprawl is characterised by an increase in the built-up area along the urban and rural fringe, this attribute gives considerable information for understanding the behaviour of such sprawls.

Temporal data of Landsat satellite imagery of year 1999 and Landsat satellite imagery of year 1986 of built-up area is used to compare the sprawl. The built up area is calculated from each classified image of respective years. The classified image showing the built-up of 1986 and 1999 are shown in Figure 18 and 19.

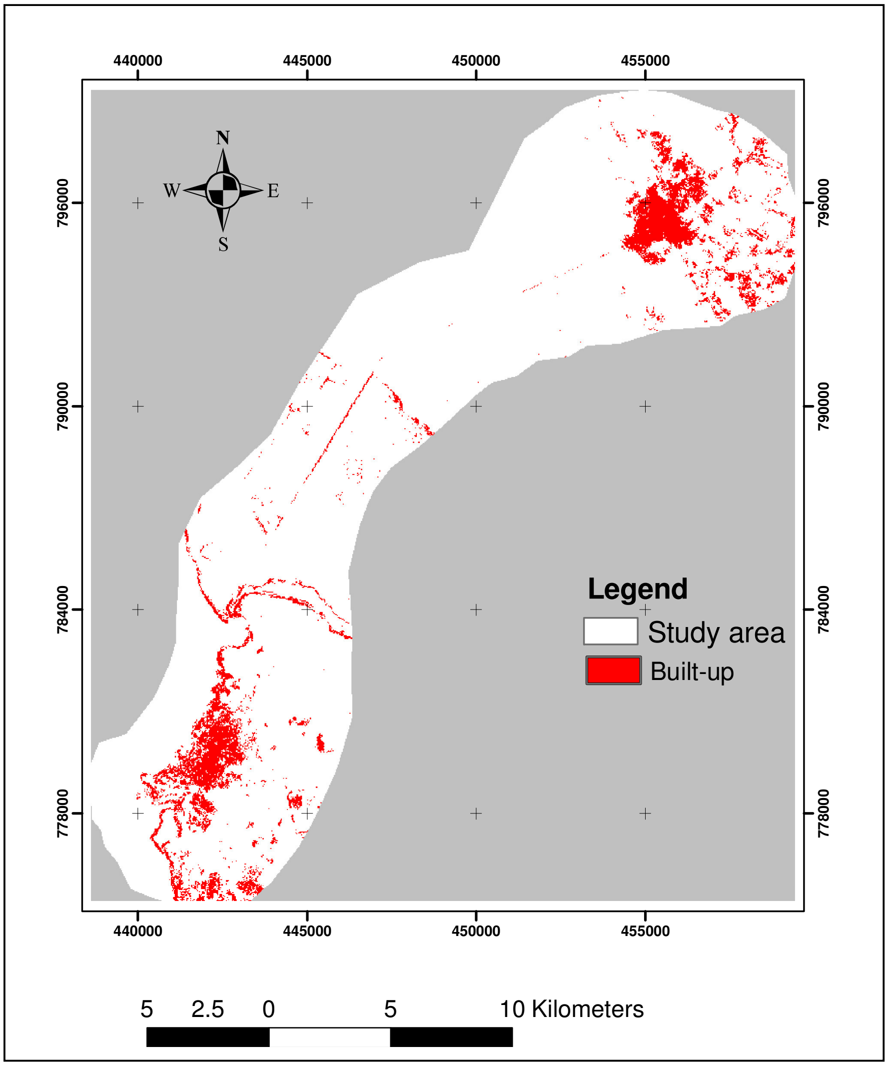

Fig 18 classified image showing built-up area of year 1986

From the classified built-up area it can be shown that the built-up area in the study area for year 1986 is $13.01Km^2$ while the built-up area for year 1999 is $26.79Km^2$.

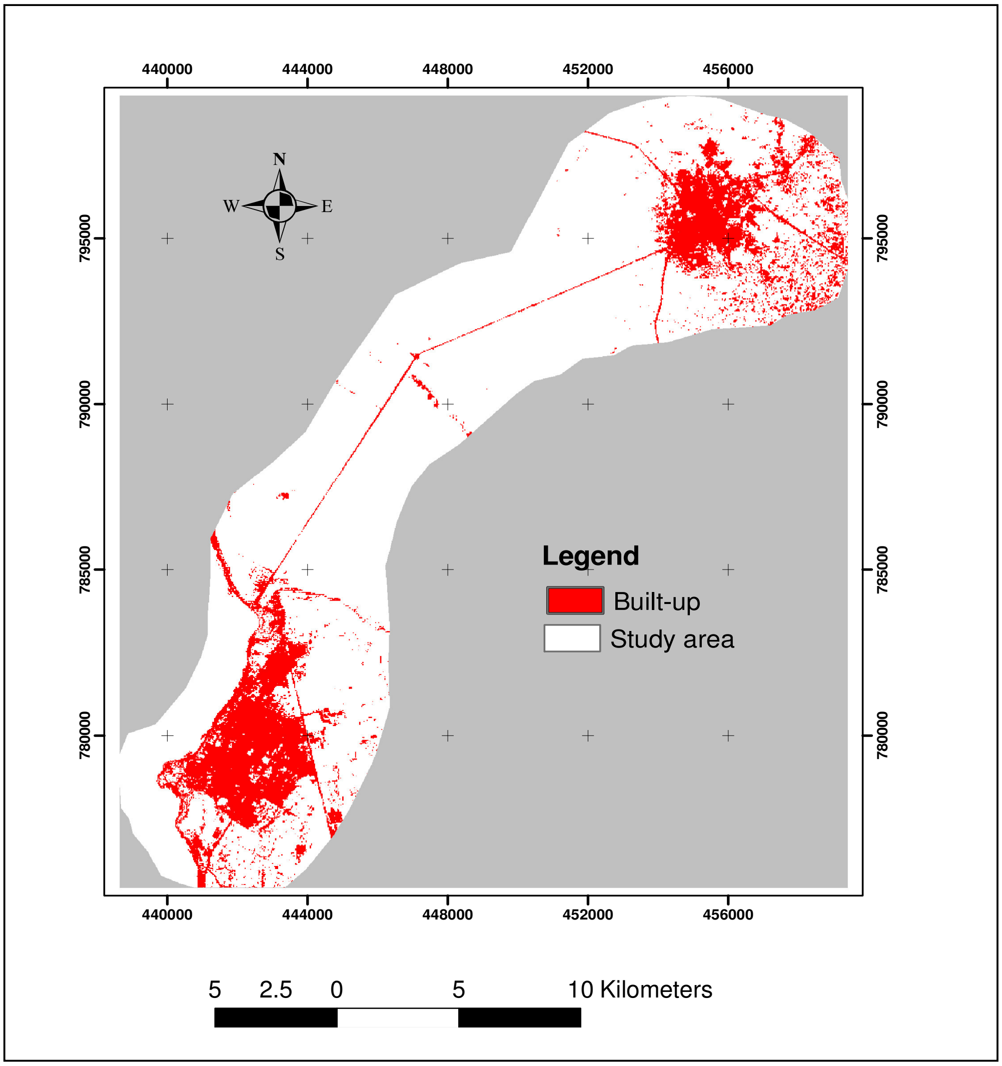

Fig 19 classified image showing built-up area of year 1999

From this temporal data it can be shown that the built up area change from the mid eighties to the late nineties there is 105.95% increase. This is shown in table 5.

Study area	Built-up of the area in Kilometer squares		Percentage change of built-up 1986-1999
	1986	1999	
Shashemene-Awasa	13.01	26.79	105.95%

Table 5 Details of Built-up Area for 1986 and 1999

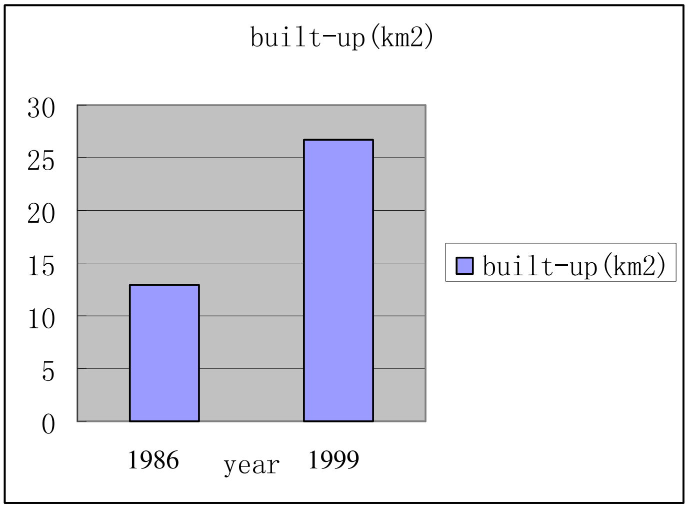

Fig 20 Graph showing built-up increase

5-2. Shannon¡¯ entropy

The built-up is generally considered as the parameter of quantifying urban sprawl (Torrens and Alberti, 2000; Barnes et al., 2001; Epstein et al., 2002). It is quantified by considering the impervious or the built-up as the key feature of sprawl, which is delineated using toposheets or through the data acquired remotely. Shannon's entropy reflects the concentration of dispersion of spatial variable in a specified area, to measure and differentiate types of sprawl.

The Shannon¡fls entropy (Yeh and Li, 2001) is computed to detect and quantify the urban sprawl phenomenon. The Shannon¡fls entropy, $_n$ is given by,

$$H_n = -\Sigma P_i \log_e (P_i)$$

Where;

P_i =proportion of built up area in each village

n = Total number of zones

The value of entropy ranges from 0 to log n. Value of 0 indicates that the distribution is very compact, while values closer to log n reveal that the distribution is highly dispersed. Higher values of entropy indicate the occurrence of sprawl

Shannon entropy was calculated. To calculate the entropy three zones were considered, the Awasa zone, Shashemene zone and the buffer region around the highway joining the cities of Awasa and Shashemene. And the proportion of the area in each zone is the ratio of the built-up area in the zone to the total area of the zone.

And the Shannon¡fls ertr opyrevealed that the distribution of built-up in the region in 1986 was slightly dispersed than in 1999. However, the degree of dispersion has come down marginally and that distribution is less dispersed or there is the less presence of sprawl when the entire stretch is considered. The values obtained ranges from 0.75 (in 1986) to 0.59 (in 1999) and log n for this region is 1.098. These are higher than the half way mark of log n (that is 0.55) and show some degree of dispersion of built-up in the region.

Study area	Built-up of the area in Kilometer squares		Shannon¡fls Ertr op	
	1986	1999	1986	1999
Shashemene-Awasa	13.01	26.79	0.75	0.59

Table 6 Built-up Area and Shannon’s Entropy for the Study

5-3.Identified pattern

It was seen that Shashemene was sprawling in radial direction from the city centre and linear growth was noticed along all five major roads connecting the city - spreading as five arms stretched outwards. The space between the arms or the major roads acts as the sinks for city development. Figure 21 is the false color composite (FCC) of Shashemene city showing the radial growth of the city.

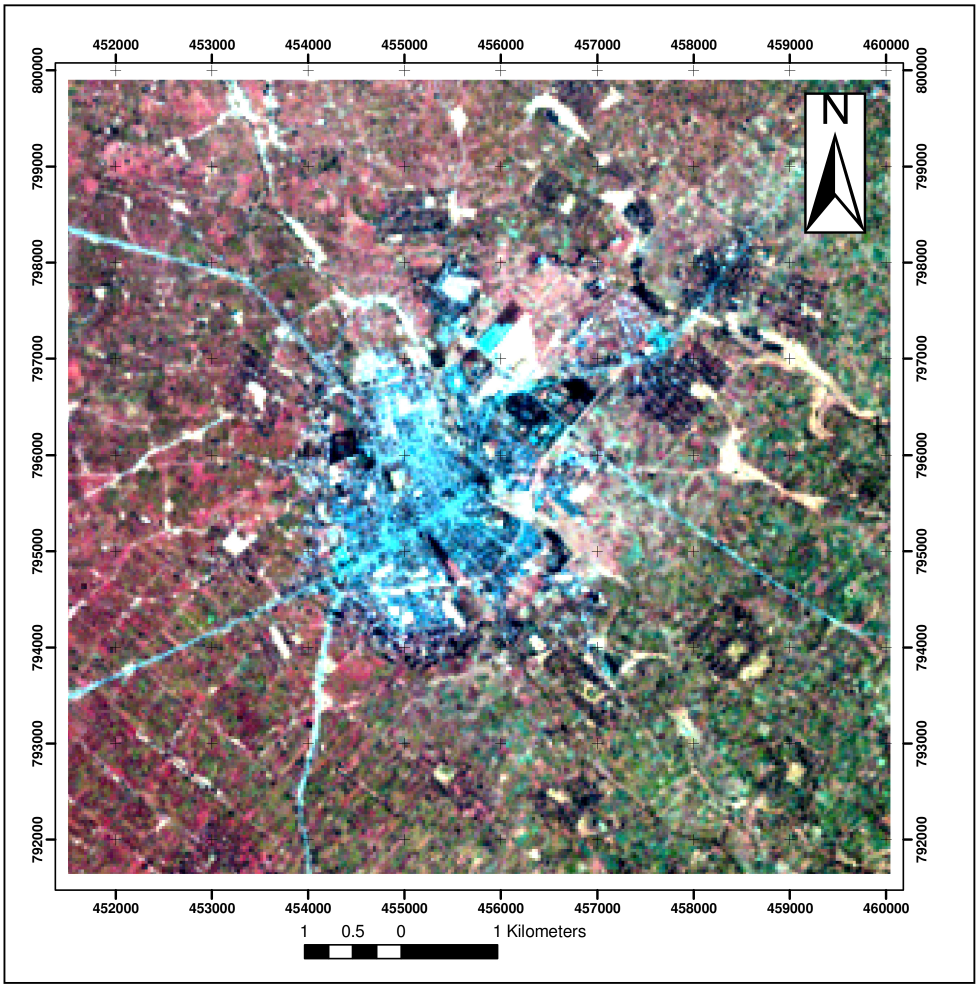

Fig 21 False colour composite of Shashemene city showing radial pattern of growth from the city centre and linear pattern along the highway

5-4.Modeling of urban sprawl

In the recent years, a lot of thrust in this field has been to understand and analyse the urban sprawl pattern. Various analysts have made considerable progress in quantifying the urban sprawl pattern (Theobald, 2001). However, all these studies have come up with different methodologies in quantifying sprawl. The common approach is to consider the behaviour of built-up area and population density over the spatial and temporal changes taking place and in most cases the pattern of such sprawls is identified by visual interpretation methods.

The causal factors affecting sprawl are population, distance from bigger cities, annual population growth rate, population density and etc.

The causal factors affecting the urban sprawl pattern were analyzed. For the analyses, the causal factors that were considered responsible for sprawl were:

- Population (POP),
- proportion of the population in each zone to the built-up area of that zone(POPBDEN)
- the proportion of population in each zone to the total area of that zone (POPADEN),
- Distance from Addis Ababa(DAA)
- Percentage of built-up(PCBUILT)

Thus the effect of the causal factors of urban sprawl of these sub-zones were analyzed by linear regression analyses with the parameter percentage built-up (the proportion of the built-up area to the total area of the zone) as dependent variable. The causal factors / parameters of urbanization were the independent variables. Table 5 shows the coefficients of causal factors and percentage built-up by linear regression analyses. The linear relationship between the causal factors and percentage of built-up is shown below.

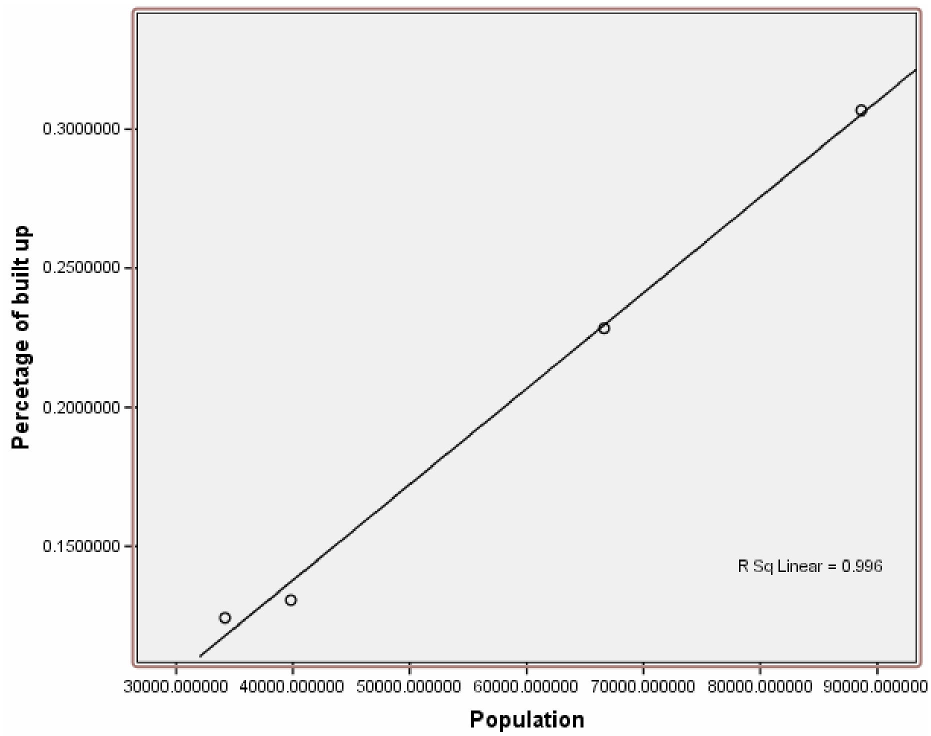

Fig 22 Scatter plot showing linear relationship between percentage of built-up and population

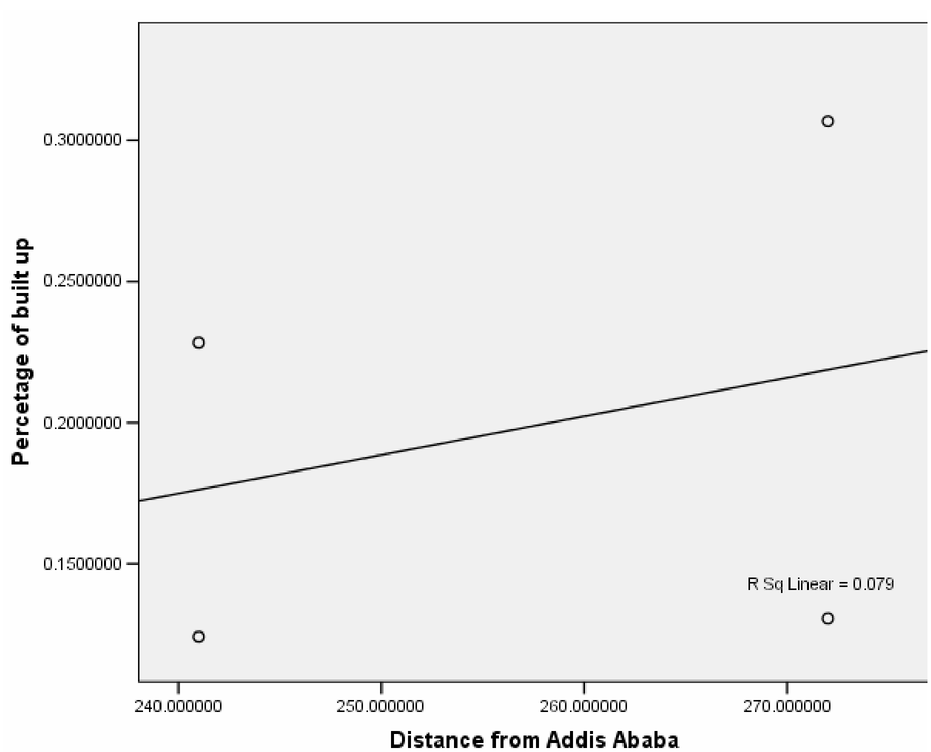

Fig 23 Scatter plot showing linear relationship between percentages of built-up and distance from Addis Ababa

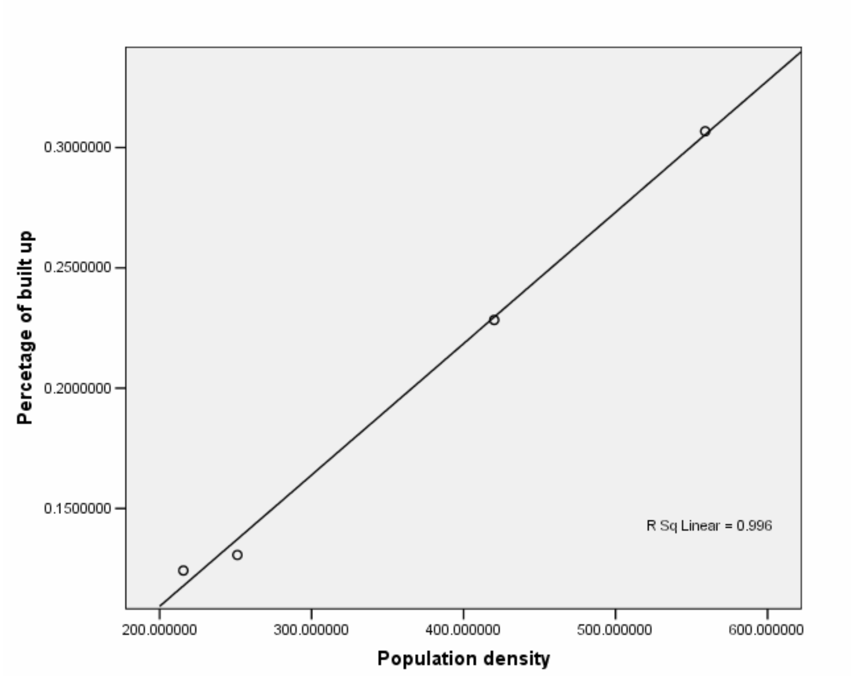

Fig 24 Scatter plot showing linear relationship between percentage of built-up and population density of the area

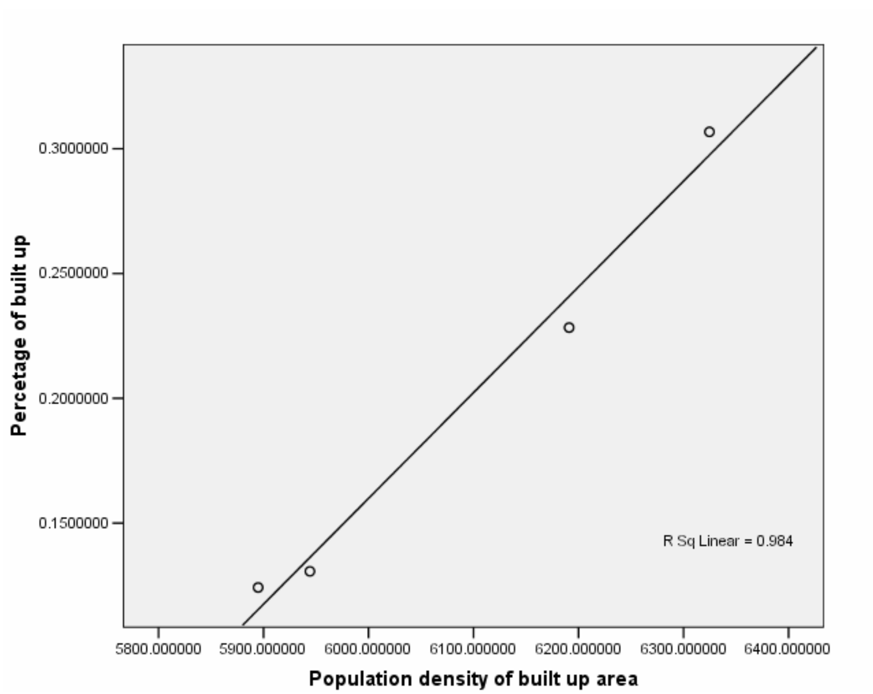

Fig 25 Scatter plot showing linear relationship between percentage of built-up and population density per built-up area

Dependent variable(Y)	Independent variable(X)	Linear equation Y=mX+b	Correlation coefficient(γ)
PCBUILT	POP	Y=0.00000344X+9.93116	0.99808
PCBUILT	POPBDEN	Y= 0.00042X -2.382	0.99221
PCBUILT	POPADEN	Y= 0.00054X+ 9.93117	0.99808
PCBUILT	DAA	Y= 0.00136X -0.154	0.28159

Table 7 Correlation coefficients among causal factors and percentage built-up by linear regression analyses

From the linear regression analysis population and population density of the zone play an important role in the sprawl phenomenon.(since the data is small the two causal factors have similar value).

Even though Shashemene is nearer to Addis Ababa than Awasa, this doesn¡ft have a significant effect on the sprawl phenomenon. The main reason is since Awasa is the capital city of Southern Nations, Nationalities and Peoples' Region (SNNPR) and this allows the city to have regional offices and various facilities, and hence more migration to the city and have a big population size, which has a major role in the sprawl phenomenon.

Multiple variable regression analysis was done to assess the cumulative effect of causal factors (except POPBDEN) and the probable relationship is,

PCBUILT= 1.76445+0.000003458POP-0.000394DAA+ 0.000296POPADEN---**1**

The correlation coefficient being, r = 0. 7972

5-5.Predicting the Scenarios of Urban Sprawl

The causal factors were considered for predicting the scenarios of urban sprawl. Considering the population growth rates 6.4(CSA 1994), the population of the zones was projected for 2030 and 2100. Using population of 2030 and 2100 (POP30 & POP100), the new POPADEN30 & POPADEN100 were calculated. Thus, substituting the values of POPADEN30 and POPADEN100 and the populations in equation 1.using equation 1 it was found that the percentage of built-up after 30 years becomes 22.60% while the percentage of built-up for year 2100 is 31.99%.This indicates that the pressure on land would continue to increase as ever and the agriculture fields, open grounds and water bodies would become prime targets for sprawl.

CHAPTER 6

6. Conclusion and scope for further research

The study investigated the urban sprawl phenomenon occurring along the Awasa A Shashemene. And this study found that found that there has been an overall increase in the built-up area by 105.95% between the year of 1986 and 1999. Further it was seen that Shashemene city is sprawling in radial direction (from the city centre) as well as linearly along the major roads.

Shannon¡¯s ntropy revealed that the distribution of built-up in the region in 1986 was dispersed than in 1999, however, the degree of dispersion has come down marginally and that distribution is less dispersed. The values obtained ranges from 0.75 (in 1986) to 0.59 (in 1999) and log n for this region is 1.098.

The study demonstrates GIS and remote sensing coupled with statistical analyses, such as arriving at Shannon's entropy help in spatial and temporal analyses for studying the sprawl and for delineating the regions with sprawl.

On the modelling studies, the study defines the sprawl phenomenon with respect to mathematical relationships. From these the possibilities of sprawl in terms of percentage built-up were estimated for years 2030 and 2100.

This study considers the whole city as a zone. The sprawl phenomenon can be viewed considering each village (kebele), and hence the effect can be seen in detail.

The future scope of this work would look into generating the images of further sprawl under different scenarios to understand any threat to natural resources and ecosystem.

With the development and infrastructure initiatives mostly around the urban centres, the impacts of urban sprawl would be on the natural resources and ecology. The wisdom lies in how effectively we plan the urban growth without hampering the natural resources and disturbing the rural set-up. Planning should also focus on a dispersed economic structure and aim at creation of balanced ecological, social, and economic system.

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