JIMMA UNIVERSITY

COLLEGE OF SOCIAL SCIENCES AND HUMANITIES

DEPARTMENT OF GEOGRAPHY AND ENVRONMENTAL STUDIES

GIS AND REMOTE SENSING BASED ANALYSIS OF URBAN SPRAWL CONDITIONS AND DEVELOPMENT: A CASE OF GIMBI TOWN, WESTERN ETHIOPIA.

BY

ABRAHAM REGEA GEBISA

A THESIS SUBMITTED TO JIMMA UNIVERSITY, COLLAGE OF SOCIAL SCIENCE AND HUMANITY, DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES IN PARTIAL FULFILLMENT OF THE REQUIRIMENT FOR THE DEGREE OF MASTER OF SCIENCE IN GEOGRAPHIC INFORMATION SYSTEM AND REMOTE SENSING

ADVISOR: Dr. KEFELEGN GETAHUN (Associate Prof., PhD)

CO-ADVISOR: Mr. GEMECHU DEBESA (MSc)

NOVEMBER, 2021

JIMMA, ETHIOPIA

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SEPTEMBER, 2021

JIMMA, ETHIOPIA

GIS AND REMOTE SENSING BASED ANALYSIS OF URBAN SPRAWL CONDITIONS AND DEVELOPMENT: A CASE OF GIMBI TOWN, WESTRN ETHIOPIA.

Thesis Approval Sheet Format

As a member of the Board of examiners of the MSc. Thesis open defense examination, we certify that we have read and evaluated the Thesis prepared by Abraham Ragea on the title; Analysis of Urban Sprawl conditions And identify suitable sites for further urban development based on GIS and Remote sensing integrated with Multi-Criteria Evaluation Technique in Gimbi Town, Western Ethiopia and recommended that the Thesis be accepted as fulfilling the requirement for Degree of MSc. in Geographic Information System and Remote sensing

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Acknowledgments

I feel deep sense of gratitude to my major advisor Dr. Kefelegn Getahun (Associate Professor) and Mr. Gemechu Debesaa (MSc) for their consistent supervision, precious advice, valuable suggestions, comments and systematic guidance to improve the content of this paper.

I also acknowledged the Ethiopian Agricultural transformation Agency, Ethiopian Mapping Agency and Ethiopian Geological Survey for their quality data of Soil, Satellite image and Geomorphology.

I would like to extend my sincere appreciation to Jimma University, School of graduate studies and Environmental Studies for their arrangement of this program and other assistance toward the Research.

I would like to express my warm appreciation to my families in helping me to fulfill my purpose by financial and moral support from the beginning to the end of this thesis.

Declaration

This is to certify that the Thesis prepared by Abraham Regea, entitled: “GIS and Remote Sensing Based Analysis of Urban Sprawl Conditions and Development: A Case of Gimbi Town, Westrn Ethiopia”. The thesis is submitted to Department of Geography and Environmental Studies, College of Social Science the Partial fulfillment of the Requirement for the Masters of MSc. Degree in Geography and Environmental Studies (specialization on GIS and Remote Sensing at Jimma University).

We deeply declared that this thesis has not been submitted to any other institution anywhere for the award of any academic Degree. We hereby certify that we have read and evaluated this Thesis entitled; “Analysis of Urban Sprawl conditions and Identify Suitable Sites for further urban development based on GIS and RS integrating with Multi-criteria Evaluation Technique in case of Gimbi Town, Western Ethiopia”. Therefore, we recommend that it can be accepted as fulfilling the Thesis requirement.

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Mr.Gemechu Debesa (MSc) ____________________ ____________________

Co-Advisor Signature Date

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Acronyms/Abbreviations

AHP	Analytical Hierarchy Process
CSA	Central Statistical Agency
DEM	Digital Elevation Model
EPA	Environmental Protection Agency
ERDAS	Earth Resource Development Assessment System
ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agricultural Organization
GIS	Geographic Information System
GPS	Global Positioning System
MCDM	Multi-Criteria Decision Making
MCE	Multi-Criteria Evaluation
MSS	Multi-Spectral Scanner
NASA	National Aeronautics and Space Administration
RS	Remote sensing
TM	Thematic Mapper
TM+	Thematic Mapper plus
UN	United Nation
UNFPA	United Nation Fund for Population Activities
USGS	United States Geological Survey

Abstract

Urbanization is one of the most impactful human activities across the world today affecting the quality of urban life and its sustainable development. Urbanization in Africa is occurring at an unprecedented rate and it threatens the attainment of Sustainable Development Goals (SDGs). Urban sprawl has resulted in unsustainable urban development patterns from social, environmental, and economic perspectives. This study attempted to analyze the urban sprawl conditions for the last two decades and identify suitable sites for further urban development based on GIS and Remote Sensing with multi-criteria evaluation technique. Satellite images of Landsat 2000, 2010 and 2020 years, digital elevation model and infrastructure related data were the major inputs for the study. GIS and RS integrating with Multi-Criteria Evaluation methods were employed to reach the final output. Finding from the study clearly reveals that the town has dramatically grown in all directions between the years 2000 and 2020. Built-up area increased a lot in the last 30 years by consuming a considerable amount of other land-use/land cover types. The major land use/land cover converted in to built-up areas is vegetation cover and farm lands. The current furthest expansion of built up area of the town is towards west and east; the main reason are plain topography and institutional factors like the Adventist hospital, Gimbi hospital in the west and Wollega University-Gimbi campus in the East. Finding from suitability analysis shows that from the total area of Gimbi town, more than 40 percent of the land falls under moderately suitable 847.1ha (42.1%) and about 612ha (30.4%) is categorized under suitable site for further urban development of the town. Modern technology of remote sensing and GIS which helps us to analyze the data spatially, offering possibilities of generating various options through modeling, thereby optimizes the whole planning process. It is in this context, the suitability analysis attempted in this study must be viewed as a basic "Prioritization of land for urban development."

Key Words: *Urban sprawl, urban development, MCE*

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

The highest urban population is found in developed world; whereas rapid urbanization and expansion is the main characteristics of cities and towns in developing world in the past few decades, taking a considerable non-built up area of their surroundings (UN, 2014). Urban area can be defined as places with the concentration of people engaged in non-agricultural activities with relatively high density than rural areas. According to European Union Regional Policy (2011), urban area refers to both cities and towns with an administrative unit or a certain population density and the population of towns is mostly smaller between 10,000 and 50,000 inhabitants whereas cities have larger population greater than 50,000 inhabitants. Urbanization is the increasing proportion of population living in urban areas whereas urban growth is the increase in the physical size of urban areas (Johns, 2006). United Nation indicated that the percentage of urban population in 1950 was 30 percent which increased to 54 percent in 2014 and estimated to be 66 percent by 2050. More recently, world's urban population is estimated to be about 54.5 percent (Sewunet, 2017).

Urban sprawl refers to an out ward spreading of a town and its suburbs to exurbs, to low density and often all too dependent development on rural land. Urban sprawl is a process usually expanding and growing to its surrounding areas at the expense of nearby agricultural farmlands. The process of urban expansion involves both the internal reorganization and outward expansion of the physical structure of urban areas. Such process of urban expansion is a worldwide phenomenon, which could see in the history of all urban centers. Sprawl in simple term 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 area and conditions (Haregewin, 2005).

Urban sprawl which has become an issue for many rapidly developing areas like Africa refers to the uncontrolled growth of an urban area resulting from poorly or totally unplanned urbanization. Urban sprawl always refers to the outgrowth of urban areas caused by uncontrolled, uncoordinated and unplanned growth. The inability to visualize such growth during planning, policies and decision making process has resulted in sprawl that is both unsustainable and inefficient. The rapid urbanization has impact of wildlife habitat, watershed land, farm land and open spaces cause many unexpected consequences including loss of prime farm land, loss of natural resources, increased environmental pollution, traffic congestion and many other physical, social and economy effect (Norzailawati, 2013).

Similarly, Ethiopia has a long history of urbanization that developed next to the ancient Egyptian civilization in East Africa. Urban sprawl in Ethiopia is changing following economic growth and establishment of universities and industries not only in Addis Ababa and regional cities but also in a number of other smaller towns in the country. On the other hand, linear strip development is expansion of cities following the development of main roads, on the lines of accessibility; this is the most common form of urban sprawl in Ethiopia (Sewunet, 2017).

Ethiopia is characterized by low level of urbanization even by African standard, where only 16% of populations live in urban area (PCC, 2008). Oromia region is one of Ethiopia regional states, which is consisted many suburban in the central part of Ethiopia, and of this suburban Gimbi town is one of the town (socio-economic and political center) of Oromia region, West wollega zone, Gimbi town which is also dynamic experiencing of rapid urban sprawl.

Therefore, GIS and remote sensing play a great role in assessing urban sprawl using various techniques of change detection based on Spatio-temporal satellite images. Hence, it is important to investigate the impact of rapid urban growth dynamics, developments of urban sprawl and quantifying the spatial extent of urbanization as it is helpful for decision makers. In this study an integrated approach of remote sensing and GIS was applied using Landsat to analyze urban sprawl. The approach was used to detect data obtained quantitatively detected change of Gimbi Town. Multi criteria evaluation with AHP method was used to detect further urban development in the study area.

1.2. Statement of the Problem

The basic problem is that rapid urbanization and urban sprawl have been two of the crucial issues of global change that affect the physical dimension of towns. In recent years, settlements that were small and isolated urban centers have become large and complex features, which are called metropolises (Satterthwaite et al., 2010). Moreover, population migration from rural to urban areas is one of the most important urban problems, resulting in regional imbalances and uncontrolled urban growth. The results of uncontrolled urban growth are urban sprawl, environmental damage, and the formation of informal settlements, which are followed by social, economic, and physical problems. Therefore, understanding the dynamics of urban systems and evaluating the impacts of urban growth on the environment is needed (Hakan *et al.*, 2011).

Ethiopia, one of the developing countries, has been intensified with the unplanned urban expansion and residential house sprawl in many of its towns and cities.

Gimbi town is one of the fastest growing urban centers in the west. The town has shown significant spatial expansion, increasing population growth, physical size, and developmental activities such as building, road construction, and many other anthropogenic activities. These development activities, in aggregate, lead to the spatial expansion of the town towards surrounding areas and the absorption of other land environments, i.e., agricultural lands, open spaces, and green areas. Gimbi town, spurred by rapid population growth and an unprecedented urbanization process over the past few decades, As a result, in recent years, the town has seen an increase in demand for residential areas as the population has grown.

Therefore, understanding the dynamics of urban systems and evaluating the impacts of urban growth on the environment is needed. Hence, there exists a definite spatial planning intervention for comprehensive urban development site identification in the town. Identification of possible sites for urban expansion in hilly terrain is one of the critical issues for planners and planning authorities. However, there is still a debate on how to uphold effective urban land use planning, on the one hand, and maintain proper natural resource conservation measures (Babu and Nautiyal, 2015).

Several studies have been conducted using GIS and RS techniques in many towns in the country. For instance, Lalisa (2017) conducted research on spatiotemporal analysis of urban land use and land cover dynamics in Gimbi town, and his finding shows that there has been an increased expansion of built-up areas in the last 31 years and the city has somewhat expanded in all directions. Similarly, Tolera (2018) argued that built-up areas have been increased from 1996 to 2016, resulting in a substantial reduction of forest area, cultivated land, grazing land, wetland, and riparian forest. Despite a number of studies on the issue of urban sprawl, the identification of suitable sites for its further development based on GIS and Remote Sensing integrated with a multi-criteria evaluation technique remains undefined in the study area. Therefore, this study was aimed at filling the existing research gap by studying the urban sprawl of Gimbi town through identifying suitable sites for its further development.

1.3. Objectives of the Study

1.3.1. General objective

The main objective of this research was to analyze the urban sprawl conditions and identify suitable sites for further urban development based on GIS and Remote Sensing integrated with a multi-criteria evaluation technique.

1.3.2. Specific objectives

- To analyze the urban sprawl conditions of the town between 2000 and 2020,
- To examine the major factors that affect urban development,
- To analyze suitable sites for further urban development using multi-criteria evaluation techniques.

1.4. Research questions

- What has been the urban sprawl condition of the town between 2000 and 2020?
- What are the major factors that affect urban development in the study area?
- Where are the suitable urban sites for further development?

1.5. Significance of the study

This study tried to detect the change in urban sprawl from 2000 to 2020 and map suitable sites in the study area. Therefore, the study is expected to

- Provide basic information on the extent of the urban land-use land cover of the area and the potential of satellite imagery for such purposes.
- Identify the rate at which urban sprawl changes at different times and consider the potential of GIS and remote sensing tools for measuring urban sprawl.
- The study of suitability analysis is critical for urban and regional planners and decision-makers to assess urban horizontal expansion areas. The study provides useful information on the complexities of urban development for local architects, urban planners, and policymakers, and it may serve as a reference for further studies.

1.6. Scope of the Study

The spatial extent of the study is the urban sprawl of Gimbi town, Western Oromia, Ethiopia. Temporarily, geographic information systems (GIS) and remote sensing techniques can assist in obtaining current information on urban sprawl with frequent coverage and at a low cost. Therefore, the main objective of the study is to map urban sprawl and land use changes in land cover using GIS and remote sensing techniques. In this research, focus was placed on urban sprawl mapping and change detection analysis by using temporal satellite images from 2000–2020. This study, which is geographically limited to Gimbi town, analyzes the suitable sites for future urban development by using an integrated GIS and AHP based multi-criteria suitability analysis.

1.7. Limitation of study

As it is common in many studies, there are some constraints on the study in relation to the availability of proper data. The main problem in conducting research in urban areas in developing countries like Ethiopia is the lack of correct satellite data. Most third world countries are not at the level of development to generate their own satellite data. Therefore, the countries as a whole or researchers from these countries mainly depend on external sources such as government agencies that provide data with acceptable quality at no charge or an affordable price and commercial organizations that provide high quality satellite data at a high and expensive price. Studies in urban areas that involve satellite images are deemed to have high spatial resolution. I tried to get high resolution satellite images both from internal agencies such as the Ethiopian Mapping Agency (EMA) and external sources, but that ended unsuccessfully because of both the unavailability (in the case of internal sources) and affordability (external sources) of data that covered the spatial and temporal extent of the study area. For these reasons, I was forced to look into another mechanism by which I could minimize the limitation of the data on spatial resolution by consulting my supervisor. Therefore, researchers used Landsat TM and ETM plus images (for the years 2000 and 2010) and Landsat 8 OLI images (2020) by pan sharpening all images and increasing the contrast to ease feature extraction in the classification process.

1.8. Organization of the paper

The research paper was organized into five chapters. The first chapter is about the introduction of the paper, dealing with background, objectives, statement of the problem, research questions, and scope of the study, as well as the organization of the paper. Chapter two is devoted to the literature review. The third chapter is about the methods and materials. It deals with the description of the study area, data sources, software used, image rectification, preprocessing, and classification. Chapter four is all about results and discussion. Finally, the conclusion and recommendations were forwarded and dealt with in chapter five.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Basic Concepts on Urbanization and Urban Growth

In the field of urban studies, the terms "urbanization" and "urban expansion" are frequently used interchangeably. It's important to remember that urbanization refers to the proportion of the country's population that lives in cities, whereas urban growth refers to an increase in the size of the urban population that is independent of the rural population (Haregeweyn, 2005). In contrast, depending on how it is used, the term "urbanization" can signify a variety of things. Clark (1982) defined urbanization as a spatial and social process involving changes in behavior and social connections as a result of people living in towns and cities (Nduwayezu, 2015).

(Oguz, 2009), argued that urbanization has been increasing since World War II, and has not shown any sign of decline and is likely to continue in to the twenty first century. Fast urbanization has led to a conversion of rural area in to built-up areas and loss of green spaces in cities. These changes in urban land-use concern loss of agricultural, water bodies, vegetation and loss of vacant areas. Urban population growth will be most important in low income countries, particularly in Africa and Asia. Among Africa countries, East Africa cities will experience urban population growth rates significantly higher than the African average. In descending order, Addis Ababa, Nairobi, Dares Selam, Antananarivo, Kampala and Moqadishu will remain the region’s largest cities in the foreseeable future. Comparing to the world cities, Dare Selam, Kampala, Nairobi and Addis Ababa already rank among the 31 fastest growing urban population (Zewdu, 2011).

2.2.Urban Sprawl

Urban sprawl is urbanization that takes place either in a radical direction around a well-established city or linearly along the high way over a given period of time. Obviously, radial and linear are just two types of map patterns that sprawl can take. Urban sprawl is considered by leap frog land-use pattern, strip commercial development a long high way, and very low density single use development all of which occur a relatively short period of time (Genemo, 2012). Urban sprawl can also be described as low density development occurring on the edge or outside of a municipal area that does not follow a specific growth pattern. It is an extent of urbanization mainly caused by population growth and large scale migration (Sudhira *et al.*, 2009). Urban sprawl is not considered as increasing of urban lands in a given area (Tahir, 2012).

2.3.Driving Factors of Urban Sprawl

At first urban sprawl has been a major - challenge in developed world but now it has already become a concern for cities in developing countries too. Urban sprawl is caused by different drivers and has in turn a wide range of consequences to the surrounding environment. Experts and institutions wrote about causes and drivers of urban sprawl (Handy, 2003).

The research classified major factors into seven categories that lead into urban sprawl: economic, both macro and micro factors, demographic factors related with population growth, more space and better housing preference, problems associated with inner city, transport related factors and factors related to regulatory frameworks (EPA *et al.*, 2013).

2.4. Impacts of Urban Sprawl

2.4.1. Negative Impact of Urban Sprawl

Urban sprawl also can have substantial economic impacts on communities through increased cost of services such as emergency response, utility, infrastructure, and public works. Environmental impacts of urban sprawl as pointed out by comprise the loss of arable land to development decreased aesthetic value of the town due to unauthorized developments and elevated air and noise pollution. In spite of the fact that advocates of urban sprawl argue that living in suburban areas outside of major cities is a matter of personal choice and freedom (Cheng, 2003).

The negative effect in Ethiopia, the urbanization was increased from 5% in 1950 to 16% in 2000, on average 4.3% per year. Furthermore, it is estimated that by 2025, the World's, African's, and Ethiopians' population rate will reach 58%, 52%, and 32%, respectively (Shishay, 2011). The reason for an optimistic prediction towards the urbanization growth. This negative effect of urban expanding on their peri-urban areas is more. When choosing your next residence, consider the negative effects of urban sprawl, and their impacts on you, your community and the environment due to undesirable consequences increased air pollution, loss of wildlife habitat, water over consumption’s and increased economic disparity. Common thought that urban sprawl is the growth of the urban area outside its border in to the suburbs. In most cases the development is single purpose and car dependent, agricultural and natural land gets lost and patches, enclaves, are created. Also, researchers have created arrangements of the different types of sprawl. As stated, the type of sprawl found in North America and Europe differs. In North America development is not contiguous but spread out, where as in Europe the density is higher but the form is more evenly equally scattered across the region, thus leaving more open spaces (Weijers, 2012).

2.4.2. Positive Impact of Urban Sprawl

Sprawl is not always seen as harmful. Some organization and planners see sprawl as a sign of economic vitality and not as ecological threat, one positive effects of sprawl is reducing housing costs. Besides that, they may present the various benefits of urban sprawl, such as the short-term economic and employment boost caused by new construction. However, urban sprawl is a growing concern in all of Ethiopia (Haregeweyn, 2005).

2.5. Application of GIS and Remote Sensing in Urban Sprawl

Remote sensing has been the best cost effective mechanism of data acquisition for a wide range of applications ever since the launch of landsat-1 in 1972 (Lo and Yeung, 2005). In remote sensing each sensor is designed for a specific purpose. Urban growth and the physical expansion of cities can be detected, mapped and analyzed using remotely sensed data obtained from mostly Landsat Multispectral Scanner (MSS) Thematic Mapper (TM) Enhanced Thematic Mapper Plus (ETM+), and SPOT (Ward *et al*., 2000).

Urban areas are complex geographic dimensions with a mixed combination of buildings, roads, gardens, soils, water etc. Such surface cover types, exhibit a unique radioactive and thermal moisture properties hence unique spectral signature. One of the most difficult problems we face in studying urban areas in developing countries is lack of reliable data. Most of the data obtained in developing count rise are outdated, unreliable or in some cases totally unavailable (Baudot, 2005). On the other hand, urban areas are the most dynamic features on the earth's surface and urban landscapes are the most complex combinations of various built-up and non-built up surface cover types. Therefore, both GIS and Remote Sensing (RS) have a wide range of applications (Melesse *et al.,* 2007).

2.6. Urban Development

Urbanization occurred as a result of industrial expansion, with accompanying demand for labor and growth in demand for more varied goods and services, according to the Western development trajectory. However, agricultural production in Ethiopia has not increased, and the country continues to face significant challenges due to geography, transportation, and natural resource constraints, such as diminishing soil fertility and the economic feasibility of using water for agriculture. This means that, while having access to a large pool of largely unskilled labor with little purchasing power, the urban economy lacks an optimistic source of domestic demand from the rural a strategy for state development (Kassahun and Tiwari, 1990).

2.7. Nature of Growth-driven Urbanization

Manufacturing company productivity and an increase in tradable services generate growth-driven urbanization. Manufacturing and tradable services use far less space than agriculture and have the potential for spatial concentration for a variety of reasons, including cheaper transportation costs, easier access to natural resource inputs, and higher returns (WDR, 2009). In rural locations, both sectors can absorb excess workers. Manufacturing productivity enhances agricultural production by delivering inputs and decreasing labor loads, in addition to increasing employment. Tradable services are distribution services with minimal transportation costs and a high return on investment (Tegenu, 2010).

2.8. The Context of Urbanization and Population Growth in Ethiopia

The demographic transition (with death rates decreasing first and fertility rates falling later after a period of extremely high population increase) and the urban transition (with populations becoming increasingly urban) have occurred at the same time in Ethiopia. The demographic shift began in the 1950s, with rapid urbanization following in the 1960s. When the quick periods of the two transitions collide, significant urban growth rates result. Ethiopia is currently experiencing a population shift. Ethiopia has had a high natural population growth rate since the beginning of the twentieth century, compared to preceding long periods of virtuous growth. (CSA, 2007).

The quick urban growth in major cities poses enormous opportunities and challenges for the future sustainable development of a country. For this reason, large towns are expected to be centers of innovation and wealth creation and need more resilient infrastructure and service resources as compared to smaller cities. This development, nevertheless, draws energy and materials from distant and nearby ecosystems. Presently, more than 54 percent of the world's inhabitants are living in urban regions (Zhang *et al*., 2016).

2.9. The Role of GIS and Remote Sensing in Urban Sprawl Studies and Planning.

RS and Geographic Information system (GIS) is a novel technology widely used to survey the land-use problem. The GIS assumes the numerical methods and spatial analysis tools to delineate land use. The approaches can yield the same results after repeatedly applying the same procedures. Furthermore, they reduce the manpower and time consumption for the delineation of land use. In contrast with the manual approaches, GIS is the most economic and objective methods. They can be used separately or in combination for application in studies of urban sprawl. The requests of Remote Sensing and GIS in urban studies at present is giving more weight on the acquisition of urban land use information and the comparison on the urban sprawl spanning most recent several decades, giving an image that remote sensing and GIS applications are located in the dynamic monitoring of urban growth only, therefore only in a few cases, we see GIS technology are applied in empirical analysis on the urban spatial structure (Herold et al., 2005).

"A geographic Information System (GIS) is a computer-based tool for mapping and analyzing things that exist and actions that happen on earth. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps.   Currently, the GIS field is characterized by a great diversity of applications including, agriculture, computer science, medicines, mathematics, surveying, statistics cartography, geology, geography, etc. GIS works with many types of data. The spatial data in GIS databases are predominately created from remote sensing through the direct import of images and classified images, but also through the generation of conventional maps (e.g. topographic maps) using photogrammetry. Nowadays, remote sensing is an integral part of GIS. Remote sensing data, such as satellite images and aerial photos allow us to map the variation in terrain properties, such as vegetation, water, and geology, both in space and time. Satellite images stretch a synoptic overview and deliver very useful environmental information for a wide range of scales, from entire continents to details of a meter (Longley *et al*., 2005).

Within the topic of urban sprawl research, the usage of GIS has become increasingly common. Modern remote sensing and geographic information systems enable us to acquire a large amount of physical data at a lower cost, at a faster rate, and on a more frequent basis than traditional ground surveys. The utilization of remote sensing data in conjunction with a geographic information system (GIS) allows us to examine data spatially, which is critical for making sound urban planning and land use management decisions. As a result, due of its ability to handle a wide range of geographical data, using a tool like a GIS as part of urban sprawl research is suitable.

2.10. Application of GIS and Remote Sensing in Suitability Analysis for Urban Development

GIS has been practiced in many disciplines including geography, forestry, urban planning, and environmental studies. Particularly, in suitability analysis, GIS has a great role in multi-criteria decision-making procedure (Malczewski, 2006). Suitability analysis is built upon the notion of multi-criteria evaluation. Multi-criteria decision making (MCDM) or multi-attribute decision making (MADM) techniques involve the evaluation of several criteria or datasets to meet a specific objective (Eastman *et al*., 2006). In the MCDM process, criteria or datasets are examined for assigning relative ranks and individual feature weights based on the land use type for which suitability being examined. The weighted summation is adequately straightforward to use GIS data. It will be incorporated into the land-use suitability analysis (Feizizadeh and Blaschke, 2013).

The suitability analysis procedure requires the identification of the appropriate locations for a particular land use activity by considering physical resources (elevation, slope, aspect, climate), natural resources (soils, geology, hydrology, vegetation and wildlife habitat, and environmentally sensitive areas), and existing land use and development of man-made facilities such as transportation systems, existing urban areas, and utility networks (Kuldeep, 2013).

2.11. Land Suitability Classification for Urban Development

According to FAO (2007) land suitability classification is divided into order, class, sub-class, and unit. Land suitability orders indicate whether the land is evaluated as suitable or not suitable for use under consideration. There are two orders symbolized in maps, tables, etc. by the symbols S and N respectively. Order S suitable land on which continued use of the kind under consideration is expected to benefits, without unacceptable risk of damage to land resources. Order N, not suitable land which has qualities that appear to preclude continued use of the kind under consideration. Land suitability classes reflect degrees of suitability. The classes are numbered successively, in a sequence of decreasing degrees of suitability within the order. Within the order suitable the number of classes is not stated. There might, for instance, be only two, S1 and S2. The number of classes documented should be kept to the minimum necessary to meet interpretative aims. Class S1 is highly suitable land having no important limitations to sustain application of a given use or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level. Class S2 moderately suitable land having limitations which in aggregate are moderately severe for continued application of a given use; the limitations will decrease productivity or benefits and increase required inputs to the extent that the overall benefit to be gained from the use, although still attractive, will be appreciably lower to that predictable on Class S1 land. Class S3 marginally suitable land having restrictions which in the aggregate are severe for continued application of a given user and will so reduce productivity or benefits, or increase required inputs, this expenditure will be only marginally justified.

Within the order not suitable, there are generally two Classes. Class N1 currently not suitable land having limitations which may be manageable in time, but which cannot be corrected with existing knowledge of current acceptable cost; the limitations are so severe as to preclude successful continued use of the land in the given manner. Class N2 is always not suitable land having limitations that appear as severe as to preclude any possibilities of successful sustained use of the land in the given manner. The Sub-classes are a more detailed division of classes based on land quality and characteristics (soil properties and other natural conditions). For example, Sub-class S3rc is land that is marginally suitable due to Rooting Condition (RC) as the limiting factor. Land appropriateness units are sections of a subclass. All the units within a subclass have an equal degree of suitability at the class level and similar kinds of limitations at the subclass level. The units vary from each other in their manufacture characteristics or minor aspects of their management necessity often defined as differences in detail of their limitations. Their recognition permits detailed interpretation at the farm planning level. Appropriateness units are distinguished by Arabic numbers following a hyphen, e.g. S2e-1, S2e-2. There is no limit to the number of units documented within a subclass (Yirgalem, 2021).

Schematically, the conceptual framework is depicted in Figure 1.

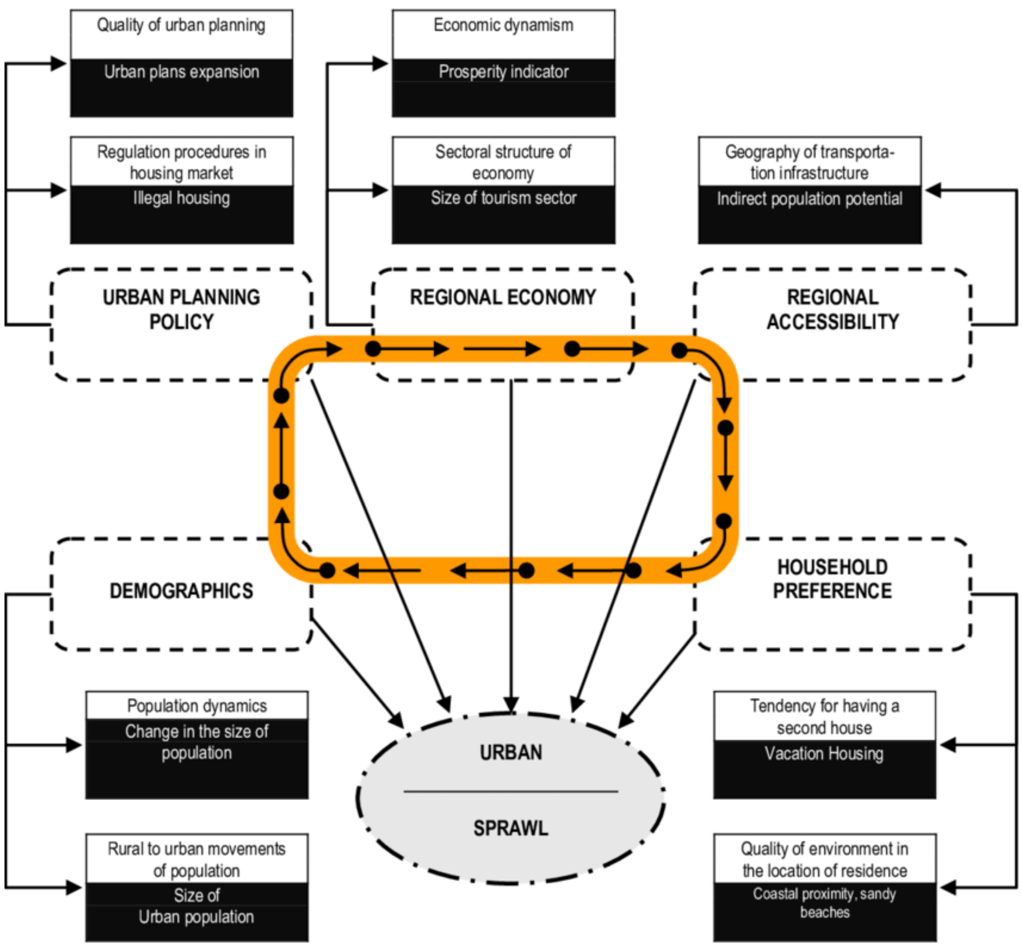

Figure 1: Empirical evidence of urban sprawl

CHAPTER THREE

3. METHODS AND MATERIALS

3.1. Description of the study area

3.1.1. Location

Gimbi Town is located in the western part of the Ethiopia at a distance of 441Km from Addis Ababa capital city of Ethiopia. Gimbi Town is located in western Wollega zone of Oromia Regional state, Ethiopia. It has total area of 2012ha and geographically positioned between latitude $9^0$09’00’’N to $9^0$12’00’’N and longitude $35^0$48’30’’E to $35^0$51’00’’E.

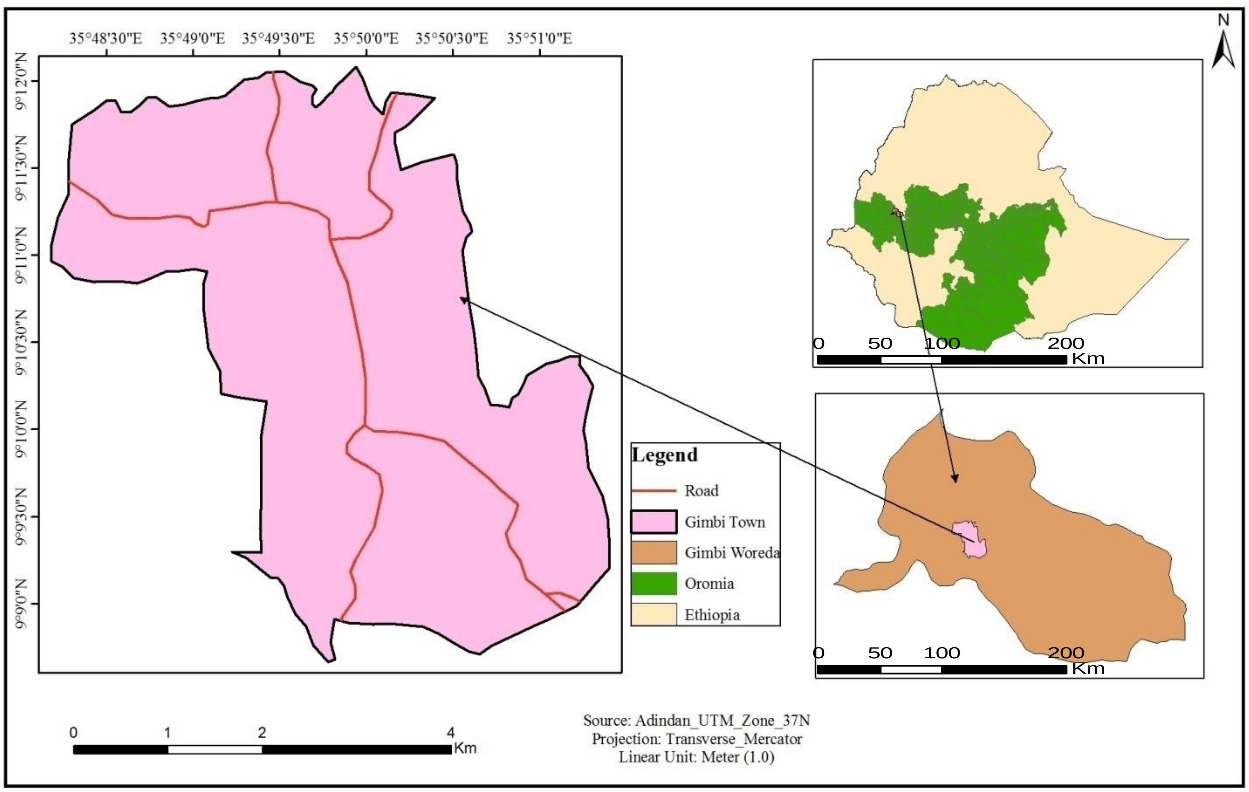

Figure 2: Location map of the study area

(Source: Ethio GIS, 2021)

3.1.2. Climatic Condition of the Study Area

The Gimbi town lays in semi- temperate 1976 – 2194m above mean sea levels with an annual mean temperature of 12.75 to 27.43^{0}C. The climate in Gimbi is Temperate. Gimbi is a town with a significant rainfall. Even in the driest month, there is a lot of rain. The average annual temperature is 14.56^{0}C min and 26.25^{0}C max in Gimbi. The driest month is December, with 6.47mm of rain. Most of the precipitation here falls in August; averaging 364.25mm. March is the warmest month of the year. The temperature in March averages 30.40^{0}C. August is the coldest month, with temperatures averaging 18.27^{0}C.

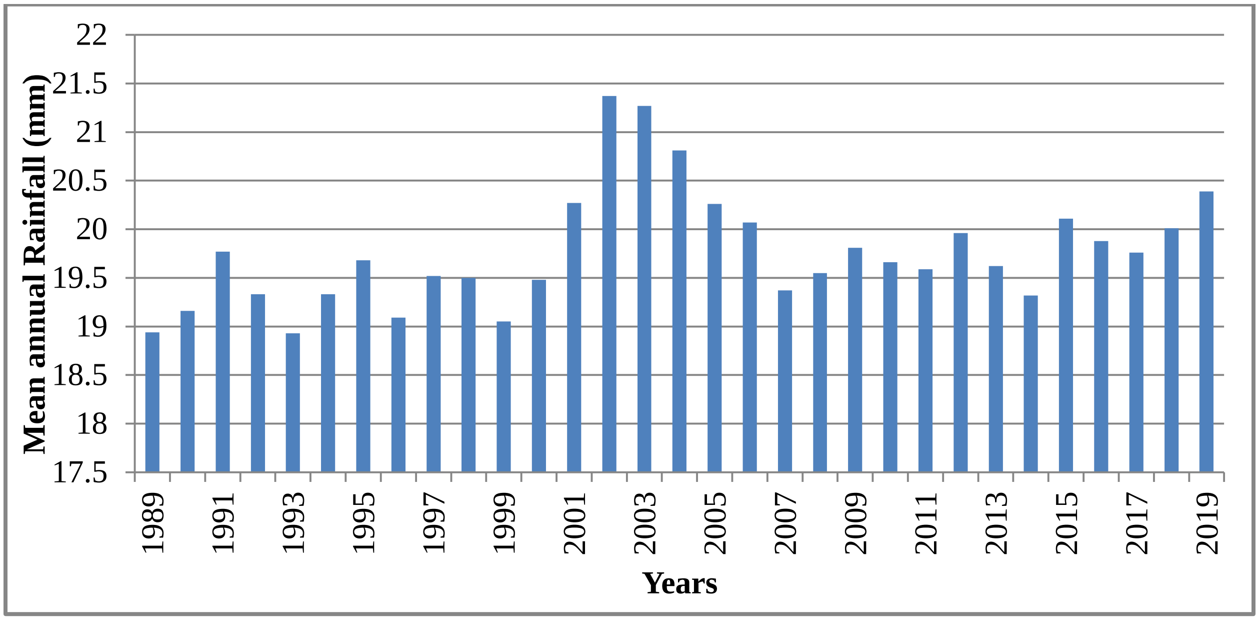

Figure 3: Annual rainfall of Gimbi Town

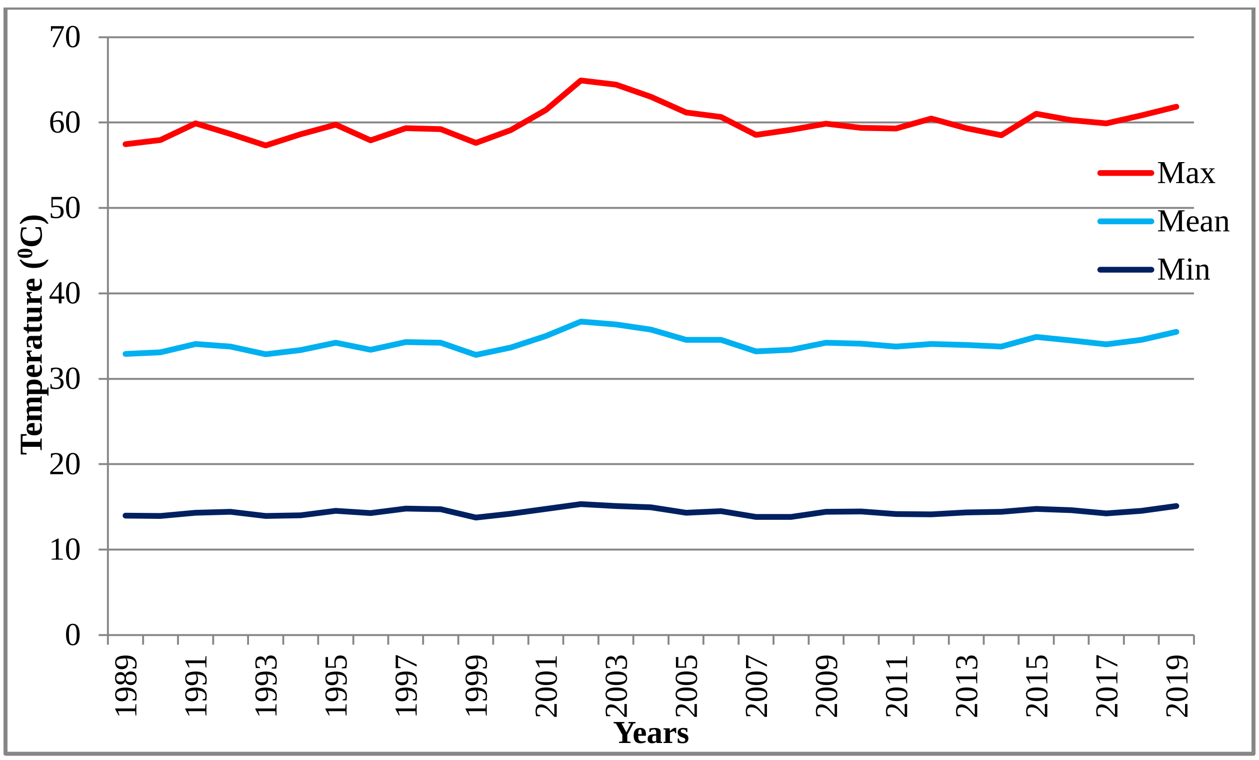

Figure 4: Minimum, Mean and Maximum Temperature of Gimbi Town

Population

According to CSA (1984, 1994, 2007 Census conducted and 2018 town made survey, the town has a total population of 53219, 75219,144861 and 216286), respectively. The detail information of projected population by Gimbi town statistics office is presented in Fig. below.

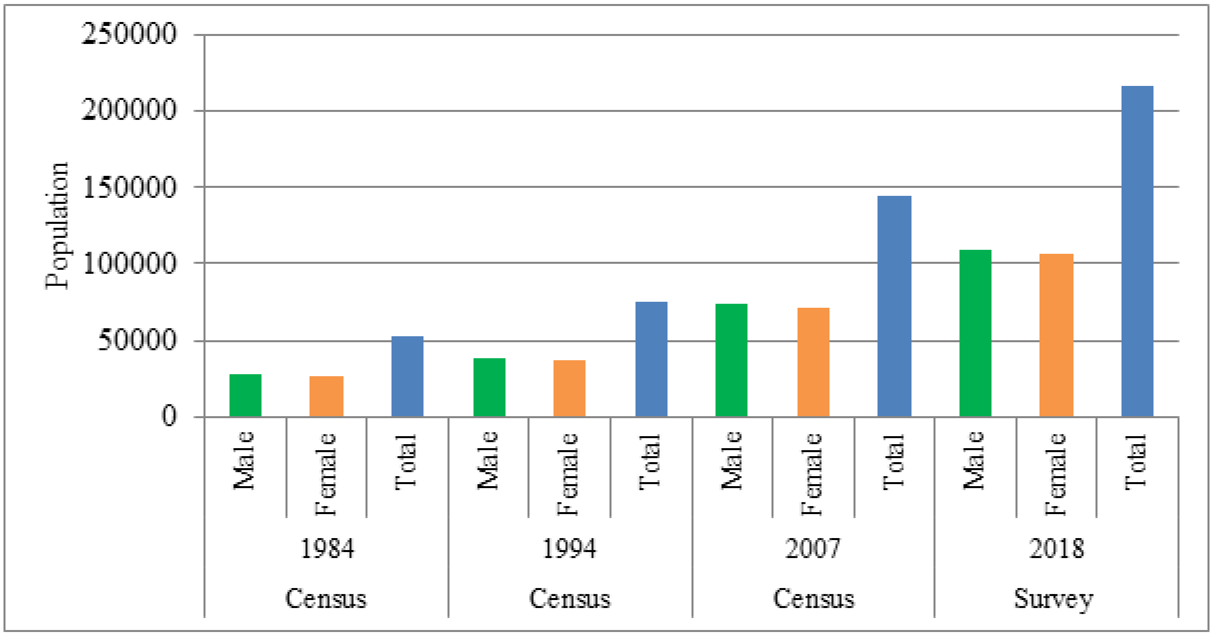

Figure 5: Population of Gimbi Town

(Source: Gimbi Town Statistics Office, 2013).

3.2. Research Design (Approach)

To conduct this study, explanatory research design with Different methods including GIS and remote sensing with the application MCE and quantitative method of data collection and analysis was used (Johnson and Onwuegbuzie, 2004). To attain the specific objectives of this study, researcher personal observation and document reviewing were used to get reliable data. Different methods such as satellite images processing were also applied. The result was interpreted depending on the analyzed data following scientific ways.

3.3. Methods of Data Collection

3.3.1. Data types and Source

The different data sources were applied for the analyses of urban land suitability for the study area because the most important thing in making research is the source of data. Data help to reach the final result, which was designed earlier in the objectives. Different types of data were utilized to achieve the objectives in this paper. Nowadays, a wide range of spatial data is available at various scale local, regional and national levels from various web sites, commercial and government agencies. The United States Geological Survey (USGS) is a gold mine of information and the known source of satellite image free of charge that covers wide areas. For this research, the Landsat image from the years 2000 to 2020 was obtained from USGS Earth Explorer (Table 1). For three years, a high-quality cloud-free image was selected from row 54 and path 170, full scenes. The season of the year was preferred to get cloud-free images for ease of classification and facilitate comparison in classification activities.

Table 1: Satellite images data sources

Dataset	Resolution	Source
Landsat TM (2000)	30m*30m	
Landsat ETM+(2010)	30m*30m	**USGS Website**
Landsat OLI/TIRS (2020)	30m*30m	
Shape files	_________	**EthioGIS**

Different data sets were referred to analyze the land suitability analysis for further urban development of the study area (Table 2).

Table 2: Key factors and parameters for urban development suitability evaluation

Data set	Sources
Soil	Agriculture Ministry of Ethiopia
Elevation (DEM)	Downloaded from Earth Explorer
Geomorphology	Agriculture Ministry of Ethiopia
Aspect	DEM data
Slope	DEM data
Urban center	GPS/Master plan
Land use/Land cover	Landsat (was downloaded from USGS)
River proximity	Generated from ASTER DEM 30m.
Road proximity	Developed by digitizing OSM.

3.3.2. Tools and Software

As the study is about urban sprawl measurement, mainly ERDAS Imagine 2015, and ArcGIS 10.5 software was used for data process and urban sprawl mapping in this research. ERDAS Imagine is important software for image preprocessing, enhancement, transformation, supervised classification and change detection analysis activities. The factors that are input for multi-criteria analysis were preprocessed following the criteria set to urban land suitability analysis. So, using spatial analyst and 3D Analyst extension, some relevant GIS analyses were undertaken to convert the shape files that were collected. IDRISI Selva 17 was also used for weight module determination. ArcGIS is important software to map urban sprawl by area calculation using classified images in the study area. As well as, the computer was used for writing and processing software for generating the final output.

3.4. Method of Data Analysis

In order to detect land use/land cover of Gimbi town during the year of 2000, 2010 and 2020 Landsat image were converted to thematic map. The methodology applied in this study was the calculation of spatial metric indices from categorical maps generated from satellite images to quantify urban sprawl. Therefore, the activities were conducted in this portion include acquisition of satellite images for three years, preprocessing, image classification and categorical map generation, accuracy assessment, reclassification, parameterization, change detection, and urban sprawl analysis. Finally finding site suitable for further urban development of the study area was performed (Seyoum, 2012).

3.4.1. Preprocessing

Preprocessing images is necessary because geometric and radiometric distortions are the subject of satellite images. The preprocessed level 1 satellite images were obtained from the NASA Earth Explorer website for this study. The images were downloaded from the web site and stacked layer of the USGS Landsat archive after the compiled file has been collected. Image collection and season choice was based free of cloud coverage and data availability. For Landsat 2000, 2010 and 2020 satellite images, pre-processing activities such as image sub-setting or clipping by study area, and image panning or resolution blending were carried out to be ready for use for all images. Study area image extraction or clipping the images using boundary shape files to get an image fit to the study area was made to all images in ArcGIS data management, Raster Processing 'Clip Tool'. To increase the interpretability and spatial resolution of the raw images, a resolution merge was performed by using the 15m panchromatic band (Band 8) for ETM plus and Landsat 8 images. First layers from 1–7 for ETM+ image and 2–7 for the Landsat 8 image were stacked for each year and then merged using the panchromatic band 8 as a high-resolution layer in ERDAS Imagine. Therefore, all preprocessing activities helped a lot to get a better quality image which improves the interpretation and classification processes in the later stages (Seyoum, 2012).

3.4.2. Image Classification

Image classification involves categorizing raw remotely sensed satellite images into a fewer number of individual LU/LC classes, based on the reflectance values (Adedeji *et al.*, 2015). This study used a maximum likelihood classification method involving supervised image classification techniques. Digital image classification is the procedure of assigning pixels to classes. Usually, each pixel is treated as an individual unit composed of values in several spectral bands. It is divided into supervised and unsupervised classification (Jensen, 1996).

Supervised classification is the process of using a known identity of specific sites (through a combination of fieldwork, analysis of aerial photography, maps, and personal experience) in the remotely sensed data, which represent homogenous examples of land cover types to classify the remainder of the image. To produce good quality classification results, it is deeply based on the quality and quantity of training samples. Training areas were carefully selected from each surface cover class of each category and the number of training areas were increased as the types of surface cover reflectance differs within the category. The classification process was started by selecting training areas within the images with careful observation of the images and feature cover types. The selection process for the training area also helps by combining true and false colors. Consequently, consideration was taken during the selection of the training area to include all pixels of objects found in the images.

3.4.3. Accuracy Assessment Procedures

Accuracy assessment is a compulsory activity after any satellite image classification analysis to know whether or not the classification process met its objectives. It is the degree of correspondence between observation and reality (Levin, 1999). It refers to assessing the accuracy level of the final categorical map generated by image classification. This can be done by generating a random set of points and comparing the land-cover map of the image with that of obtained in the field i.e. image map with reference data (Eastman, 2003).

Ground Truthing Points (GTPs) and ancillary data (Google Earth) were used to define training sites for the recent image (OLI/TIRS) classification. Training sites for classification of older images (TM and ETM+) were defined based on the result of unsupervised classification, spectral values of recent image and information obtained from elder peoples. In this study a total of 100 ground truthing points 20 from agriculture/farm land, 20 from vegetation, 20 from shurub land, and 20 from built up area and 20 from bare land were collected from the field using Google Earth/handheld Global Positioning System (GPS). The most commonly applied methods of accuracy assessment include producer's accuracy, user's accuracy, overall accuracy and Kappa coefficient (Lu *et al*., 2009). All of these techniques were applied to check the performance of classification activities for all years.

$$OAC = \frac{\Sigma Xij}{N} * 100 \qquad (1)$$

$$Khat = \frac{(Obs - exp)}{(1 - Exp)} \qquad (2)$$

Where: OAC is over all accuracy,

- PAC is producer accuracy,
- UAC is user accuracy,
- X_{i+} is the column total, and
- K_{hat} is Kappa statistics,
- X_{ij} is the diagonal values,
- N is total number of samples,
- X_{+I} is row total and obs=is (OAC),
- r is the number of categories,
- Exp. Represents correct classification.

3.4.4. Effective Criteria (Factor) Used in the Identification of Urban Suitable Sites

Determining the appropriate conditions for urban development was developed for urban suitability. In the present study nine criteria or parameters i.e. Slope, road proximity, land use/land cover, geomorphology, elevation, river proximity, town center, soil type and aspect were used in assigning weights based on Knowledge-based approach. Higher weight age was assigned according to its suitability for site suitability analysis and vice versa. Further, pair wise comparison matrix using Saaty's nine-point weighing scale was calculated and applied to generate a ratio matrix (Saaty, 1996). Thereafter calculation of the criterion weights was done after the creation of pairwise comparison matrix. AHP being a powerful tool in applying Multi-criteria Decision Analysis (MCDA) was developed by Saaty in 1980. Weights or priority vector for the alternatives or the criteria is required. For creating the pair wise comparison matrix (PCM), a system of numbers to indicate how much one criterion is more important than the other was designed by Saaty (1980). The value of λmax is required in calculating the consistency ratio (CR) (Han and Tsay, 1998):

Consistency Index (C.I.) = (λmax-n) / (n-1)………………………………...……… (3)

Where: n is the number of criteria and λmax is the largest eigen value (Han and Tsay, 1998; Malczewski, 1999).

The final consistency ratio is calculated by comparing the C.I. with the Random Index (RI) (Malczewski, 1999).

C.R. = C.I. / R.I……………………………………………………………………….. (4)

Where: R.I. depicts random index and in this case R.I. = 1.24 (Saaty, 1980).

The consistency ratio is designed such a way that shows a reasonable level of consistency in the pairwise comparisons if C.R. < 0.10 and C.R. ≥ 0.10 indicate inconsistent judgments. All criteria layers were converted into raster format for analysis because raster format is less complicated than vector data format (Chang, 2006). Thereafter all layers were multiplied by its weight for final site suitability map using raster calculator of ArcGIS. Voogt (1983) mentioned that the most relevant technique for multi-criteria evaluation is the weighted linear combination. In this technique, factors are combined by applying a weight value to each, followed by a summation of the results to yield a map of suitability (Eastman *etal*., 1995) as follows;

S = Σ (Wi * Xi) or Σ [criteria map * weight]………………………………………. (5)

Where: S is the final suitability map, Wi is the criteria map and Xi is the weight of the parameter. The final site suitability map describes that the study area was divided into four suitability classes.

3.4.5. Multi-criteria Decision Making

Decision making with multi-criteria is a method of correctly defining complex decision problems. It involves breaking complex decision problems into simpler and smaller parts, and objectively and systematically deciding each part of the problem to produce relevant results (Linkov, 2009). Determining the appropriate site selection factors for procedure, weights are then assigned to all parameters. Generating thematic maps of different land suitability to urban development, determine the region best suited for urban development.

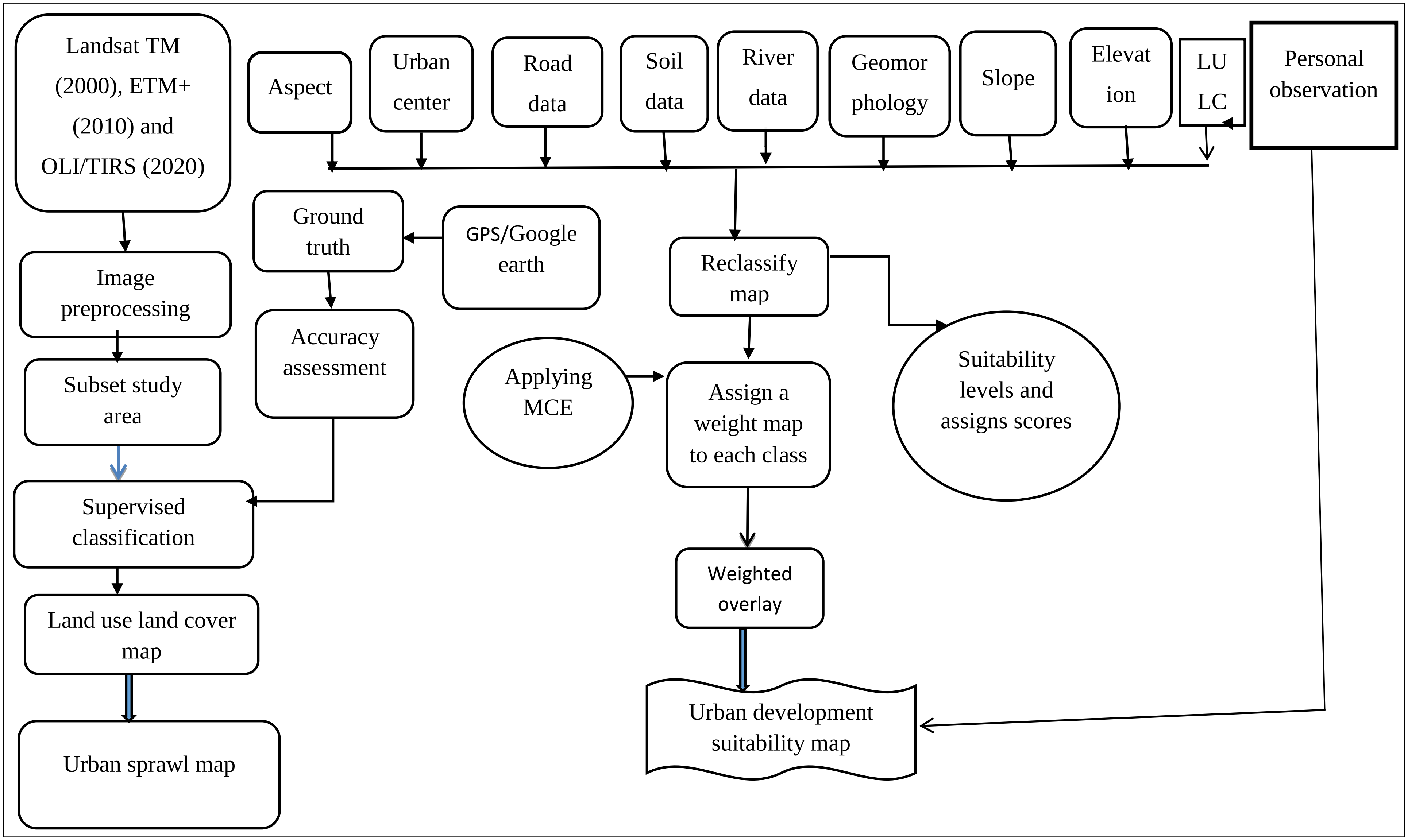

Figure 6: General work flow diagram

3.5. Effective Criteria (Factor) Used in the Identification of Suitable Sites for Urban Development with their Individual Importance

All the factors and constrains were internally classified in to five classes (very high, high, moderate, low and very low) with values ranging from1 to 5, where value of 5 denotes the most suitable and value 1 denotes the least suitable for all factors and constraints was considered.

A. Slope

Slope is an important criterion for hill terrain for finding suitable sites for built-up. Steep slopes are disadvantageous for construction purpose because the slope increases the construction cost. Slope is one of the most important parameter for finding new suitable sites for urban expansion. The slope less than 10^0 is high suitable than the slope more than 40^0 in study area (Figure 7).

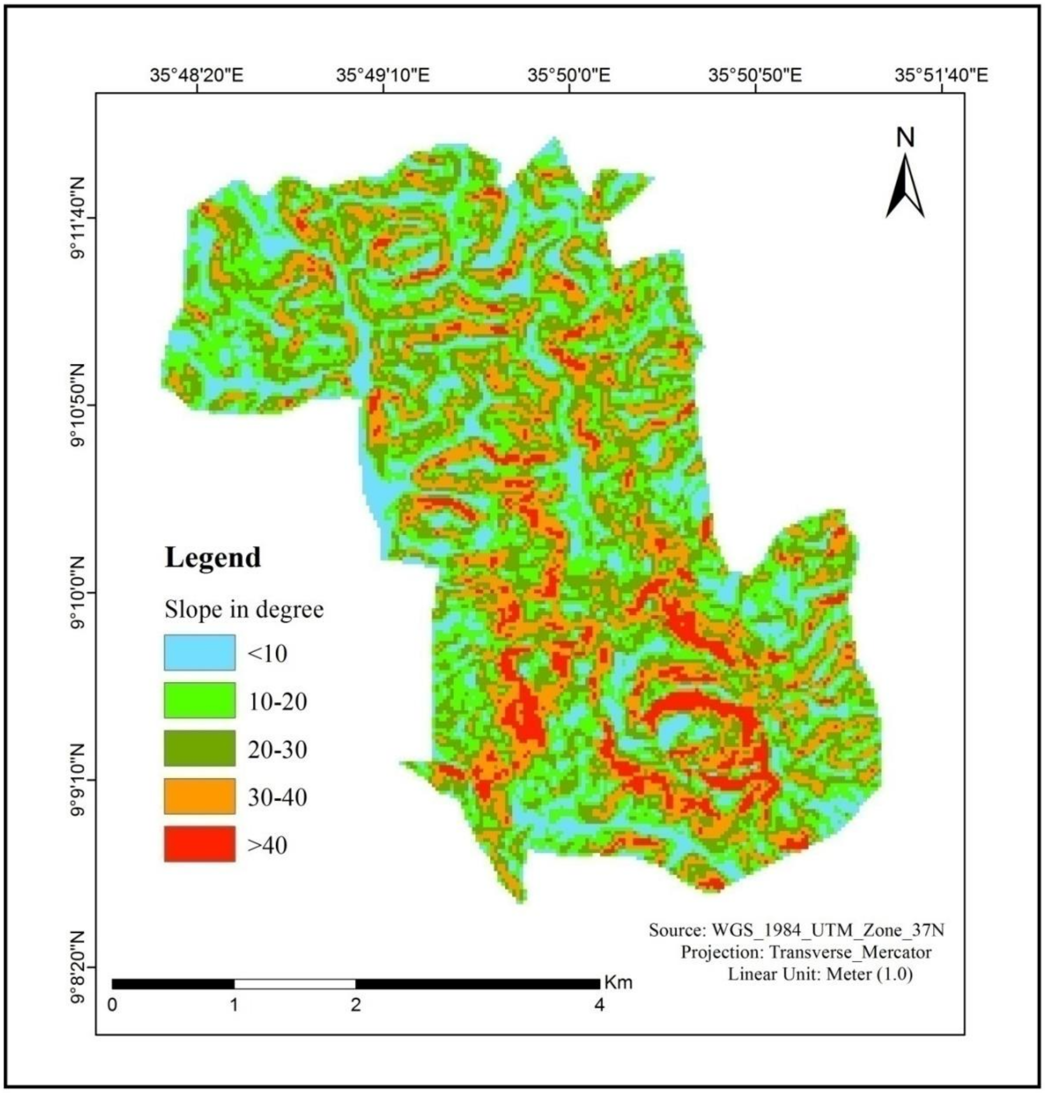

Figure 7: Map of slope factor of the study area

Table 3: Area and suitability of slope of the study area

S/No	Slope interval (degree)	Area(ha)	Area (%)	Suitability classes
1	<10	486	24.16	Highly suitable
2	10_20	399	19.83	Suitable
3	20_30	502	24.95	Moderately suitable
4	30_40	298	14.81	Less suitable
5	>40	327	16.25	Un suitable
	Total	2012	100.0	

B. Land use and Land Cover

Land use is the main basis for urban land suitability analysis; the distribution of various land-use types gives considerable constraints to urban land development. The land-use map of the study area will be prepared from Landsat 8 image acquired in 2020 and a supervised digital image classification technique will be employed using ERDAS IMAGINE 2015 software. Land use/land cover map of Gimbi town has been categorized as built-up area, farm/cultivated, bare land, and vegetation because once a building is constructed; it remains there (Santosh and Ritesh, 2014; Mesfin, 2019). Thus barren land or shrub land is considered to be the highest suitable for development purpose (Figure 8).

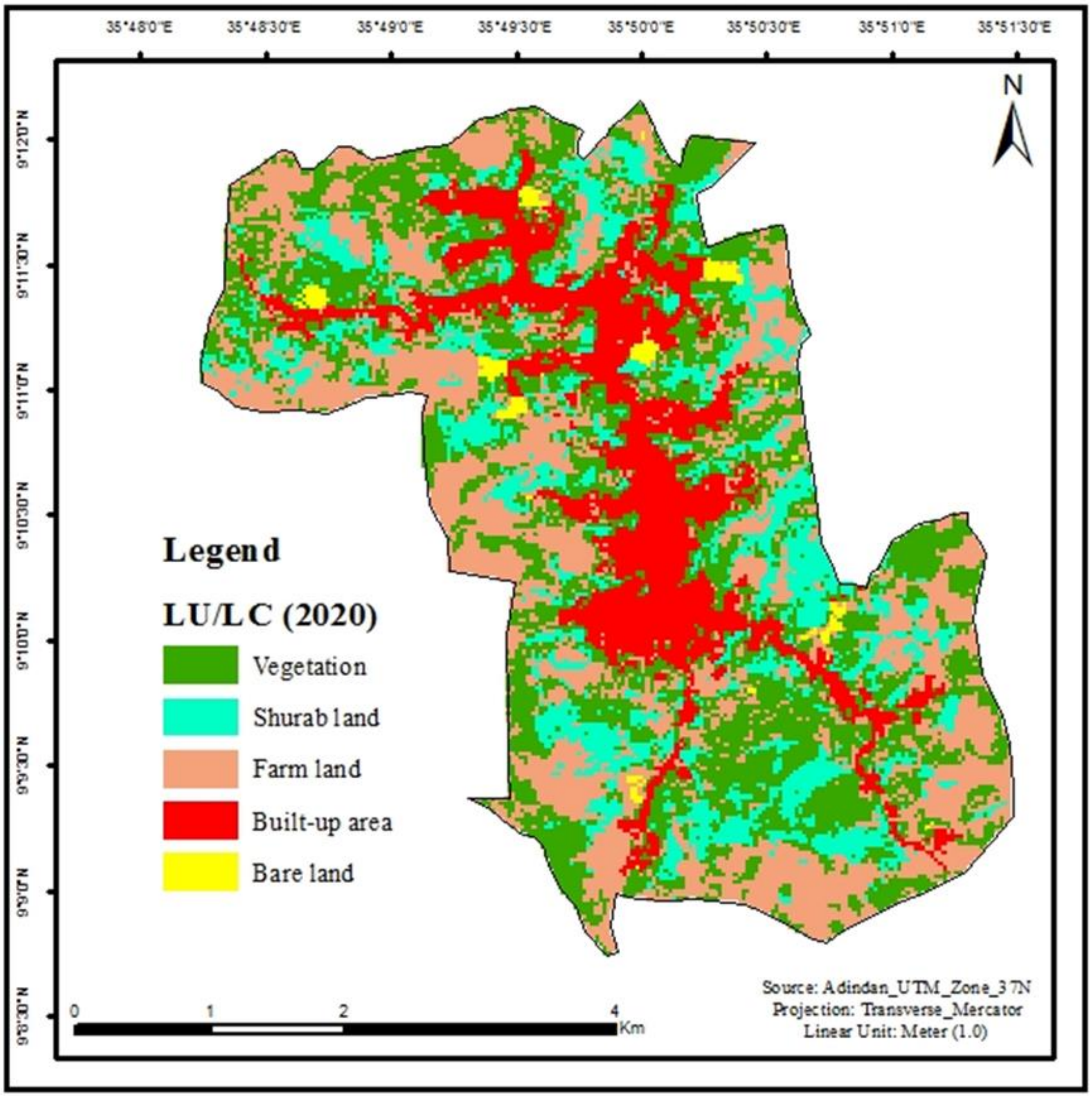

Figure 8: Land use/land cover map of the study area

C. Road Proximity

The road network plays a very important role in urban development. The road networks were digitized from Open Street Map. As more settlement develops near the road networks because of the transportation facilities and very easy access to the nearby places and town center. Easy access to road helps in movement and transportation at any place. However, the construction of new road is expensive especially in hilly regions. So effort is made to locate the site nearer to any existing road if possible. Moreover, in order to find out better accessibility to the existing road, buffer zones have been created by taking 1000-meter distance from the road (Road Proximity) (Figure 9).

The transport network is one of the main factors in determining urban development because the market, school, hospital, etc. connectivity to the road is required (Linkov, 2009). The road distance <1000m is high suitable than distance >4000m in the study area.

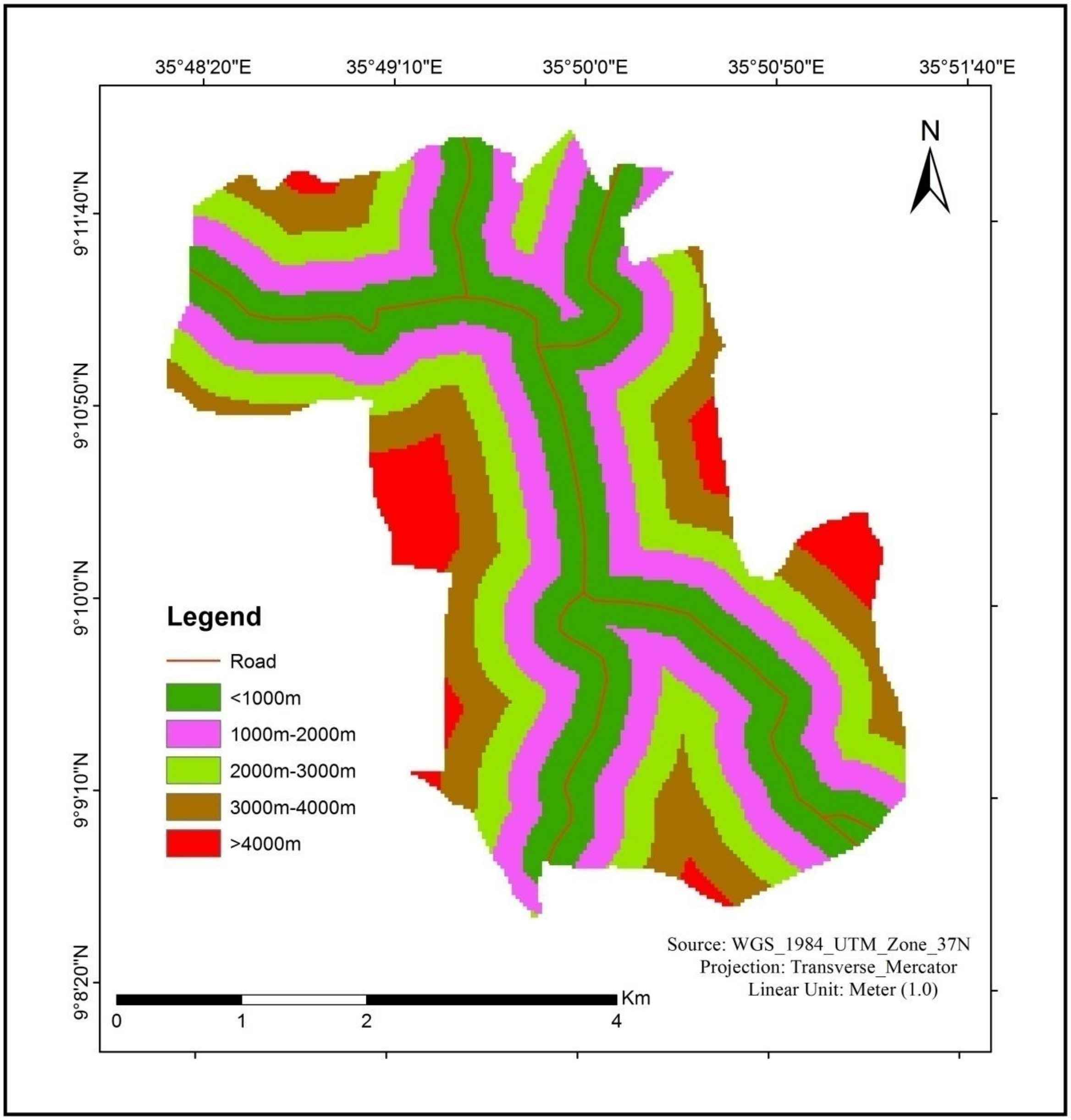

Figure 9: Map of Road factor of the study area

D. Soil factor

The characteristic of soil is a result of topography, climate, and type of parent material, age, and environment (Yhdego, 2007). Soil is the most important criterion for determining an area's suitability for urban construction. The identified soil types have high fertility, nutrient deficiency, and high water holding capacity and can be used for urban areas (Mesfin et al., 2019). Soil type essentially gives a comprehensive idea on the basic soil properties of a location. By knowing a soil type, broad implications could be drawn on its suitability for its construction. In the study area there is two type soils found from these dystric nitisols is classified as high suitable for urban development than dystric gleysols (Figure 10).

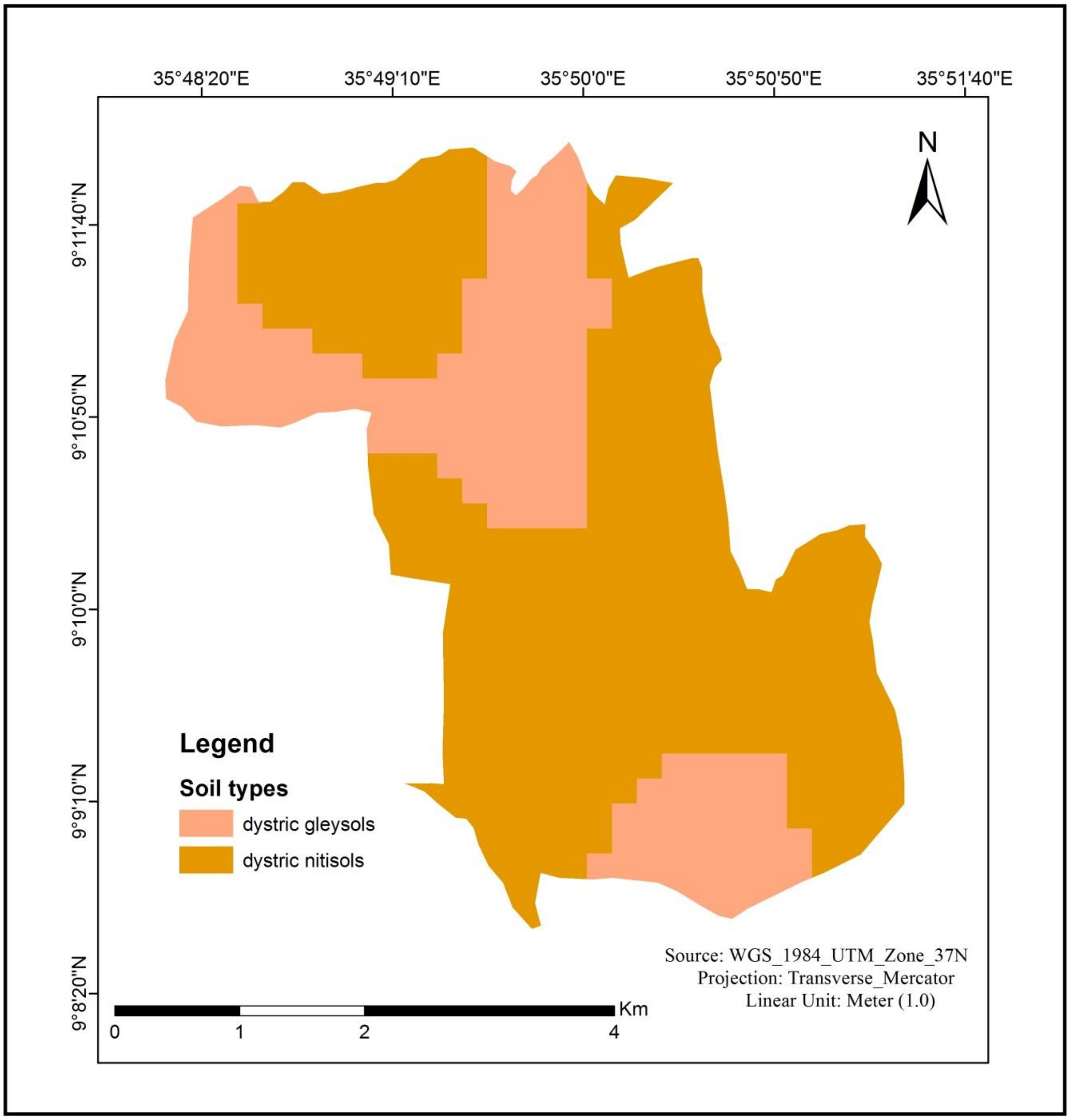

Figure 10: Map of soil factor of the study area

Table 4: Area and Suitability of soil types of the study area

S/No	Soil Types	Area(ha)	Area (%)	Suitability classes
1	Dystric gleysols	670.7	33.3	Less suitable
3	Dystric nitisols	1341.3	66.7	Highly suitable
	Total	2012	100	

E. Rivers Proximity

In this study, the rivers were generated from ASTER DEM 30m. The area near the water bodies develops more rapidly than the area which is away from the surface water bodies (Tesfaye and Degefie, 2019). Based on existing literature the river buffer classified into <200m, 200-400m, 400-600m, 600-800m and >800m. For urban development the place proximity to river is more suitable than the place far away from river (Figure 11).

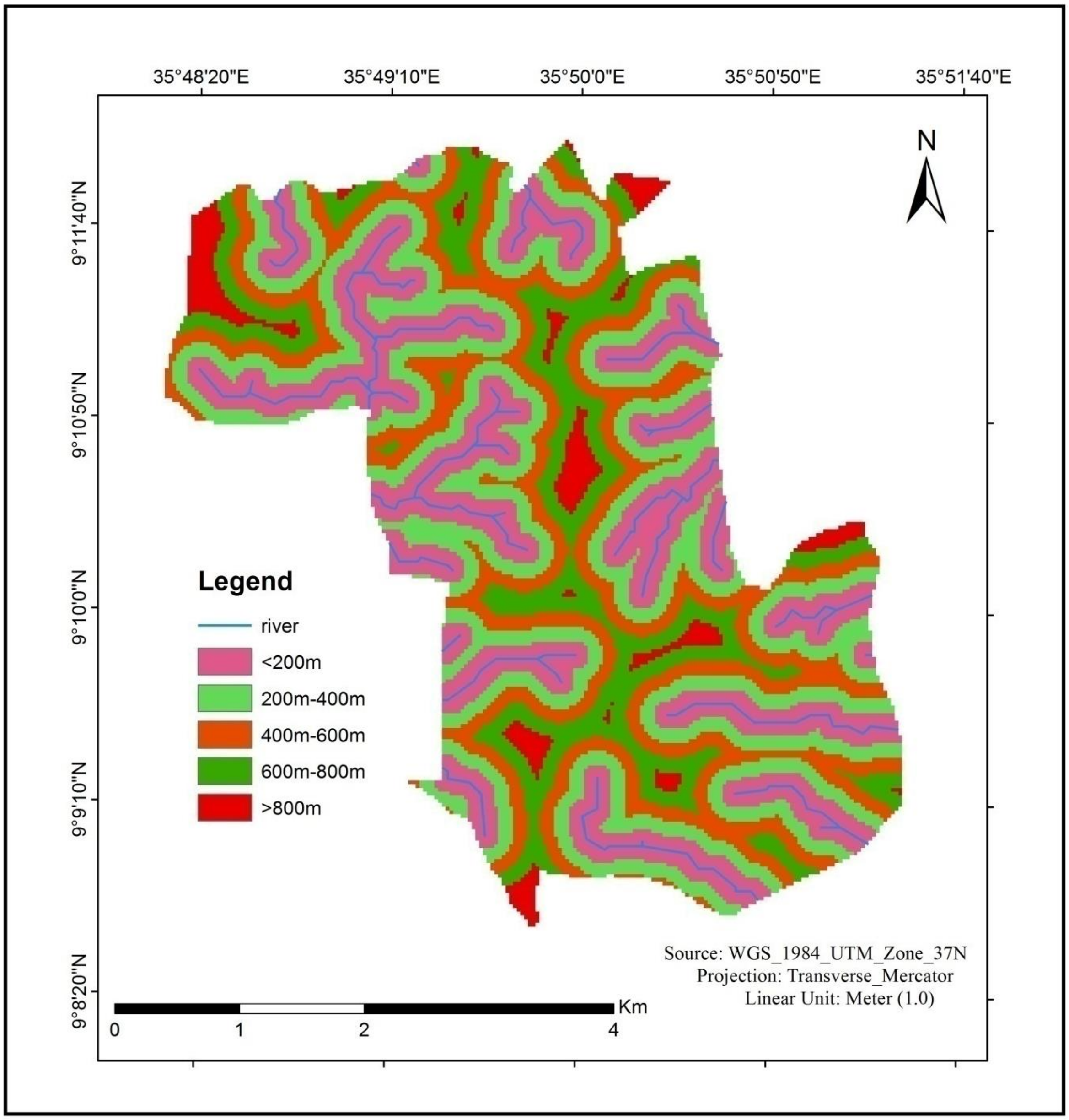

Figure 11: Map of River factor of study area

F. Geomorphology

Geomorphology can be defined as a science which studies the genesis and the causes of the evolution of land surfaces and their rate of change about nature and human. Geomorphologic studies describe the present nature of the topography and interpreting the causes of its formation. The residual landforms are identified based on stage of denudation, wherein, all the structure gets obliterated. Low dissected structural hills are given higher priority as compared to high dissected structural hills for construction. Based on literature residual geomorphology type of land form is high suitable than structural landforms (Figure 12).

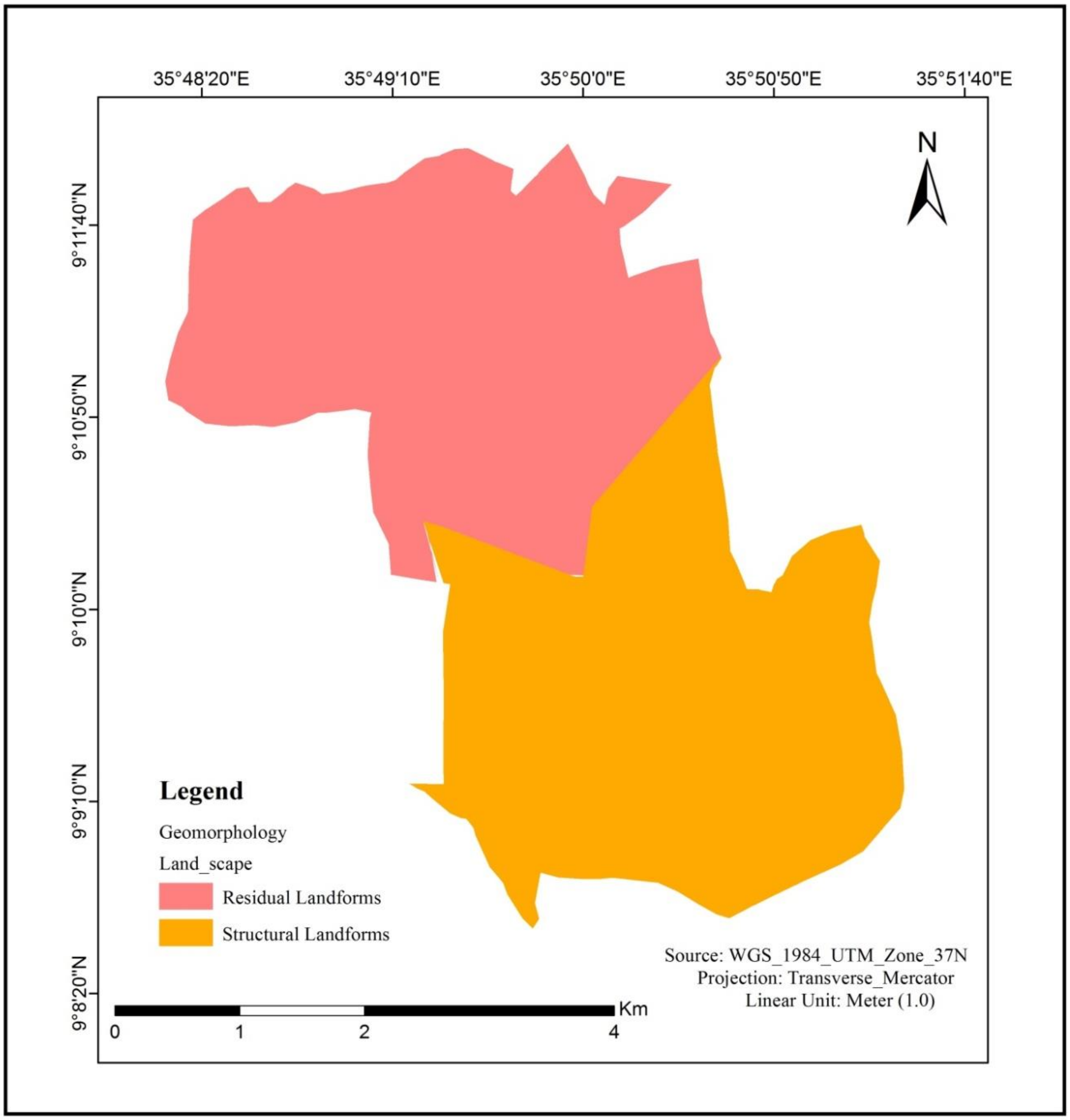

Figure 12: Map of Geomorphology factor of study area

Table 5: Area and suitability of Geomorphology

S/No	Land scape	Area(ha)	Area (%)	Suitability classes
1	Residual Landforms	1003	49.9	High suitable
2	Structural landforms	1009	50.1	Suitable
	Total	2012	100	

G. Urban Center

Gimbi Town has a very powerful but limited central zone and it is still empty spaces for development. Additionally, it has small zones that can be re-generated. Therefore, it is significant to first use a central zone for development than proximate areas should be developed. Since center of the town is already well constructed and developed, priority is expected to be given to the peripheries of the town for further development (Figure 13). Master plan/GPS point helps to digitize urban centers (Suraj *et al.*, 2014).

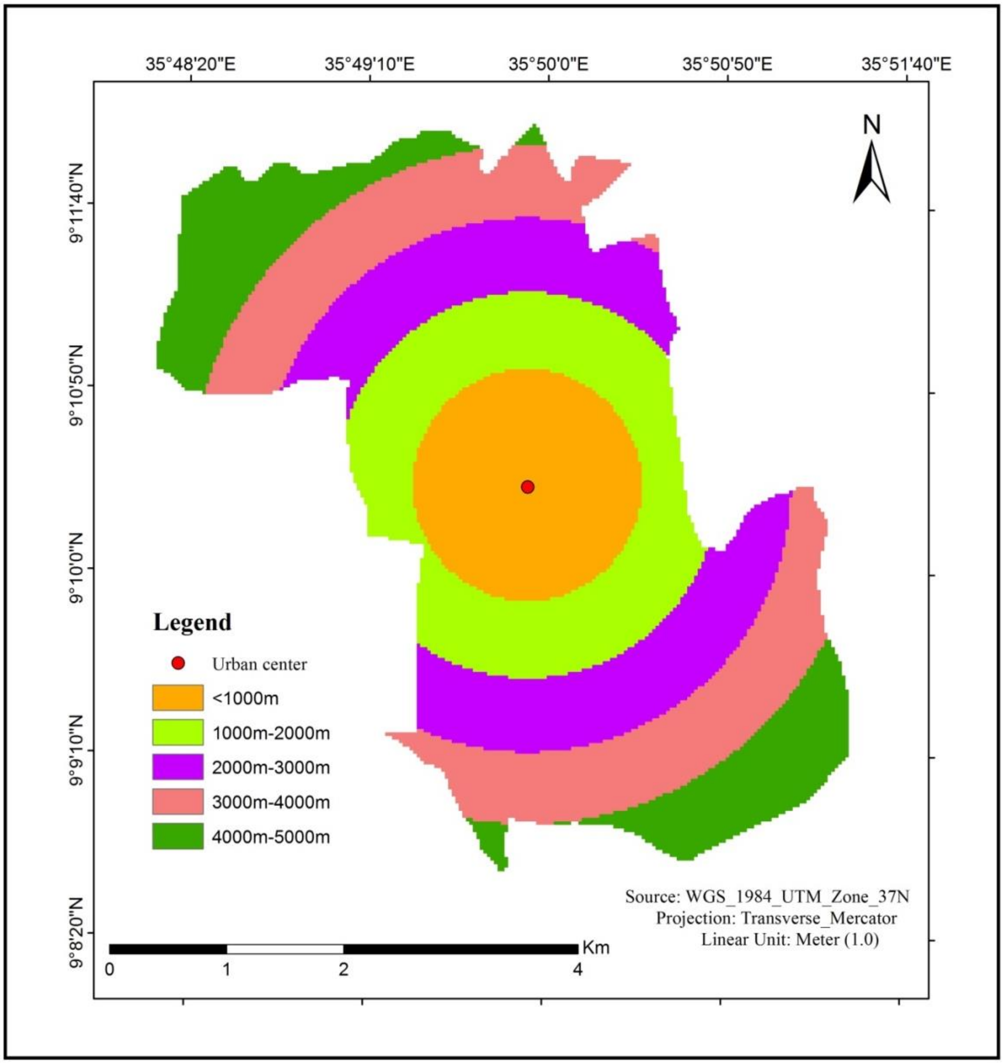

Figure 13: Map of Urban Center factor of study area

H. Elevation

In this study elevation factor was generated from the Digital Elevation Model (DEM) using the ArcGIS spatial analyst extension of surface module, which enabled to classify the area according to the level of elevation. Then, the elevation raster was reclassified in to five classes by examining the value and the frequency of elevation in the study area. According to Fard, (2012); town might be constructed in an area lower elevation in order to prevent the spread of contamination. It is convenient to locate town over low laying parts in order to minimize the effect of flooding hazard. Therefore, areas with high altitude ranked as least suitable, and areas with low altitude ranked as highly suitable for site selection. Elevation of study area classified into five classes that <1870, 1870-1935, 1935-2000, 2000-2065 and > 2065. The result of the reclassified elevation map is shown on (Figure 14).

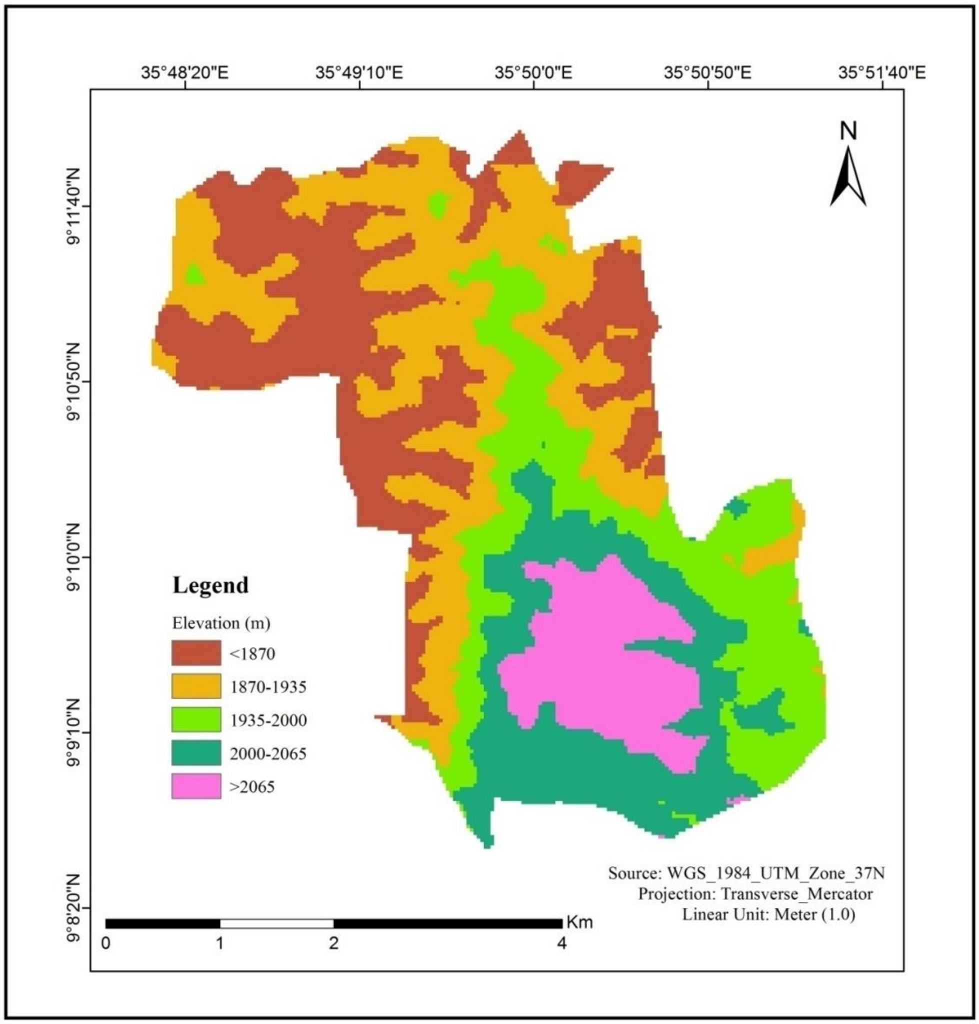

Figure 14: Map of Elevation factor of study area

I. Aspect factor

Aspect has a strong influence on temperature and affects the angle of the sun rays when they emanated in contact with the ground. Aspect generally refers to the horizontal direction which a mountain slope faces. In the mid-winter north facing slopes receive very little heat from the sun especially in the northern hemisphere. On the other hand, south facing slopes get much more heat rather than north facing slopes (www.fsavalanche.org/encyclopedia/aspect.html).

In the study areas with south facing slopes come under high suitability because in hilly terrain people prefer construction of houses in sun facing areas because in hilly terrain its cold during most part of the year. Only a few a people prefer construction of houses on east facing slopes because east facing slopes receive sun heat only during morning time (Nayama and Vinaya, 2016). Therefore in the study higher intensity of importance has been given to southern facing slopes rather than other slopes. East facing slopes are colder than west facing slopes as east facing slopes face sun only in the morning when temperatures are colder whereas at the same time west facing slopes take the sun in the warm afternoon mostly in hilly area (Figure 15).

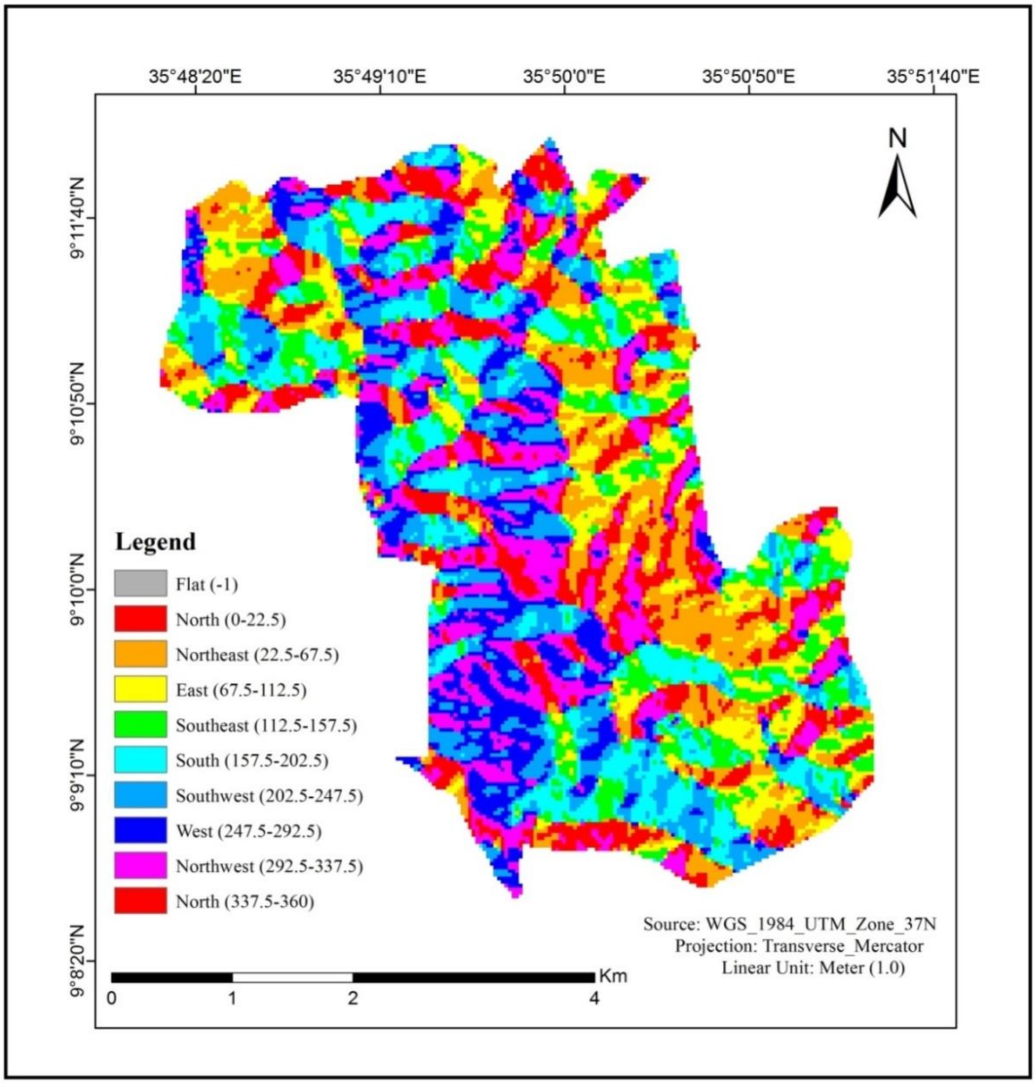

Figure 15: Map of aspect factor of the study area

3.6. Determining Relative Weight for each Criterion

After calculating the number of comparisons the pair-wise comparison is conducted, the selection criteria are rendered using a square matrix in one level relative to their importance to the study target. The diagonal elements of all square matrix compare to one matrix or unit matrix. The primary Eigenvalue and the respective own vector (Normalized Principal

Eigenvector) are also called priority vector (Saaty, 1987). As a consequence, if the value of the Consistency Ratio is greater than 0.1, the inconsistency is appropriate then validity is tested again.

3.7. Analytical Hierarchy Process

Analytic Hierarchy Process (AHP) was introduced by (Saaty, 1977) and is a commonly used process in MCDM. As one of the MCDM methods it is easy to implement. AHP is a decision support tool that was used to solve complex problem solving decisions. This uses a hierarchical multi-level system of priorities, requirements, sub-criteria, and alternatives. AHP also provides measures to determine the inconsistency of decisions mathematically. Based on the properties of reciprocal matrices, the consistency ratio (CR) can be calculated. CR < 0.1 indicates that the level of consistency in the pairwise comparison is acceptable. Saaty (1980) suggests that if CR is smaller than 0.10, then the degree of stability is fairly acceptable. But if it is larger than 0.10, then there are inconsistencies in the evaluation process, and the AHP method may not yield meaningful results. For this study researcher was used AHP for generating weight for each evaluation criterion according to the decision maker's pairwise comparisons of the criteria. All the criteria considered in this study can't have equal degree of importance therefore the importance of each criterion in relative to the other criteria was determined by AHP. The comparison is about whether the row criterion is equal, greater or lower importance that of column criterion and the higher the weight, the more important the corresponding criterion.

3.8. Weighted Overlay Analysis

The weighted overlay method uses one of the most commonly used methods for overlay analysis to solve multi-criteria problems such as site selection and models of suitability. The reclassified map assigns weight by AHP based on their suitability factors. At later stage, these analyses were reclassified using scoring values obtained from expert opinions and they were adapted to overlay. At the final stage, reclassified analysis were subjected to weighted overlay analysis in ArcGIS environment using weights from expert opinions. As a result of the process, the most suitable areas for urban expansion were identified and visualized (Gorsevski et al., 2012). Finally, they overlaid together than the most suitable urban development site of the study areas was selected.

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1. Land use/Land cover of Gimbi town from 2000 to 2020

The percentage of an area covered by impervious surfaces such as asphalt and concrete is a straight forward measure of development. 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 characterized by an increase in the built-up area along the urban and rural fringe, this attribute gives considerable information for understanding the behavior of such sprawls (Barnes et al., 2001). Temporal data of Landsat imagery of year 2000, 2010 and 2020 of built-up area were used to compare the sprawl. The built up area is calculated from each classified image of respective years. Land use/land cover maps of Gimbi town were produced for the year 2000, 2010 and 2020 (Figure 16, 17 and 18). Of the total area of Gimbi town, more than 40 percent of the LULC was covered by farm land in 2000.

From Table 5 in 2000 the highest area coverage of study area was farm/cultivation land (947.2 which is 47.1%) and the 2nd and 3rd large area coverage was vegetation and shrub land which were 652.3ha (35.7%) and 253.9ha (12.6%), respectively.

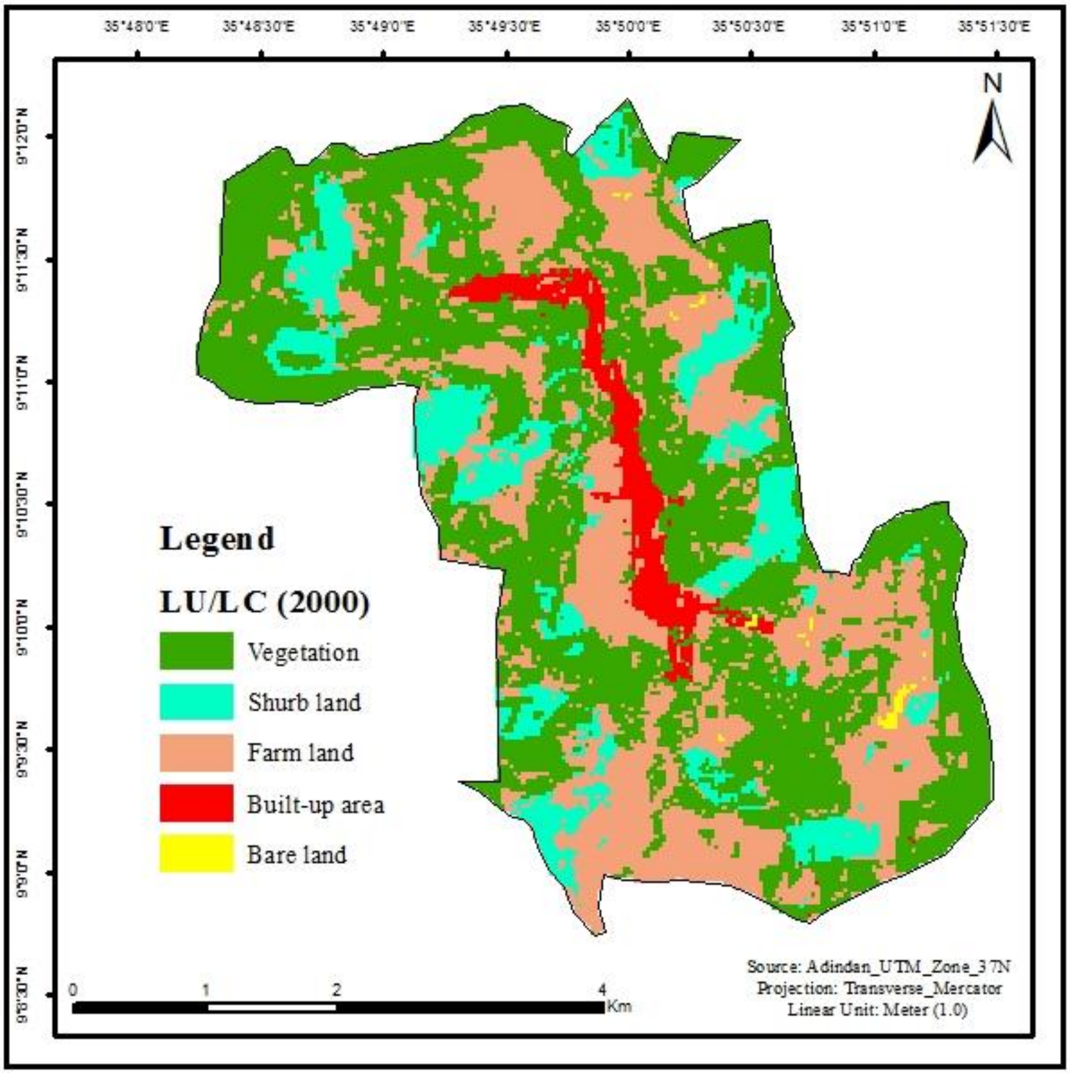

Figure 16: LU/LC map of the year 2000

Similarly, majority of the land use land cover of study area during 2010 was also the farm/cultivated land shares large percentage of total study area which covers about 43.9% of the total area (Figure 17).

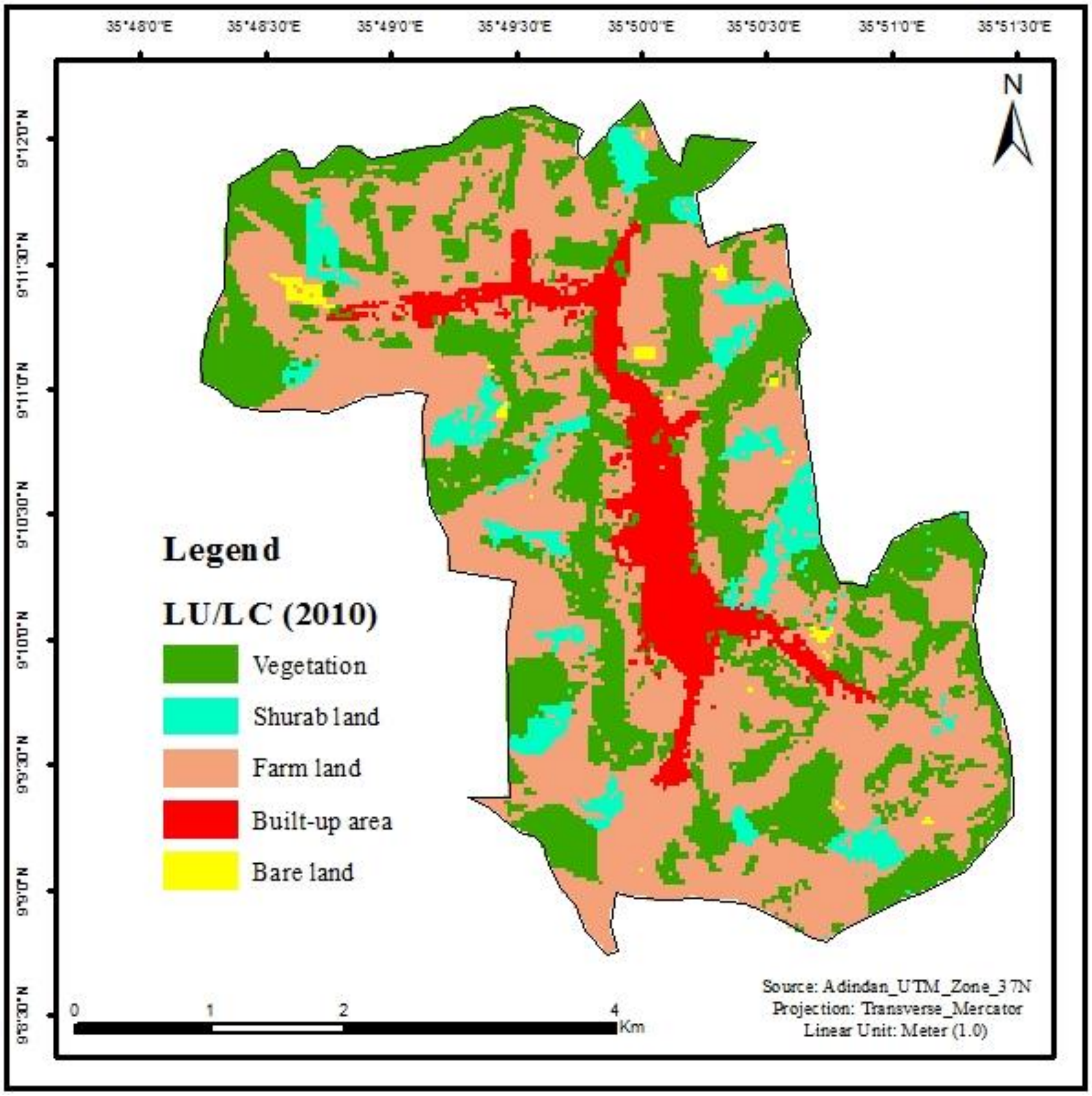

Figure 17: LU/LC map of the year 2010

The largest and least percentage share of land use and land cover of study area during 2020 was built-up areas (43%) and bare land (3.3%), respectively. Red color represents built-up area for Gimbi town.

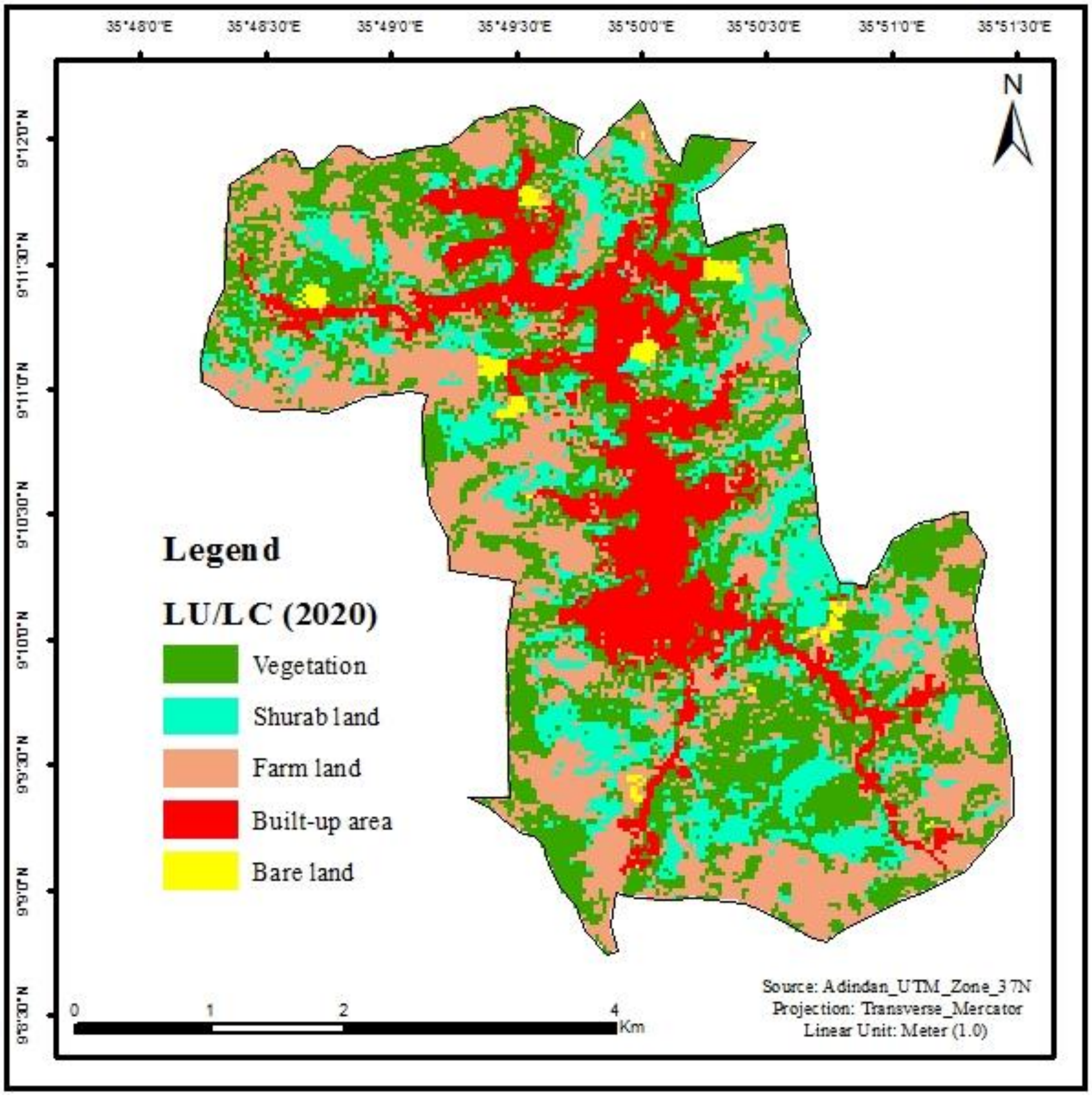

Figure 18: LULC map of the year 2020

Figure 18 shows the growth recorded in each land cover class across the Gimbi town urban municipality in 2020 as well as the corresponding impact on ecosystem services provision. Clearly, the maps reveal that highest rate of urban sprawl was recorded during 2020 especially for built-up area. This result is in line with (Shao et al., 2021).

Table 6: Area statistics of land use and land cover classes for 2000 to 2020

LU/LC types	2000		2010		2020	
	Area(ha)	area %	Area(ha)	area %	Area(ha)	area %
Built up Area	87.1	4.3	650	32.3	799.3	39.7
Bare land	5.5	0.3	12	0.6	66.5	3.3
Farm land	947.2	47.1	866	43	884	43.9
Vegetation	718.3	35.7	344	17.1	180.6	9
Shrub land	253.9	12.6	122	6.1	99.7	5
Total	2012	100	2012	100	2012	100

4.1.1. Accuracy Assessment for Land use/Land cover of 2000 to 2020

Land-use and land-cover accuracy assessment for 2000, 2010 and 2020 years produced for the study area and overall classification accuracy of each year were 98.8%, 97.8%, and 98.7%, respectively. The overall land-use and land cover classification Kappa statistics for the study periods were 0.97, 0.97 and 0.98, respectively. Details of each year land use/land cover class accuracy assessment for each year under investigation period was indicated in Table 6 below.

Table 7: Error matrix of land-use and land-cover for 2000, 2010 and 2020

LU/LC class	2000		2010		2020	
	Producers Accuracy (%)	Users Accuracy (%)	Producers Accuracy (%)	Users Accuracy (%)	Producers Accuracy (%)	Users Accuracy (%)
Built-up	93.8	99.6	89.4	85.5	98.9	98.9
Vegetation	94.5	98.3	99.3	99.8	98.6	99.8
Cultivated area	98.8	95.9	98.9	97.4	97.3	98.22
Shrub land	100	99.4	100	99.4	100	98.4
Bare land	99.5	99.5	43.2	97.2	92.6	98
Overall Accuracy	98.8%		97.8%		98.7%	
Kappa coefficient	0.97		0.97		0.98	

4.1.2. Land Use/Land Cover Change Detection

The change in LU/LC for the periods 2000 to 2020 was analyzed by using post-classification change detection technique in a GIS environment. The change in areal coverage for each category is clearly visible on the above maps. The result shows that there was no much change in years between 2000 and 2010 but the town began to expand a little bit towards the south, east and west following road outlets. The onset of growth seems to be after the year 2010 as the town and its surrounding grow dramatically after wards. The town has grown dramatically in all directions between the years 2010 and 2020. Built-up area increased a lot in the 30 years by consuming a considerable amount of other land use/cover types by 712.2ha (35.4) for last three decades (Table 7).

Table 8: Land Use/Land Cover Change

LU/LC types	LU/LC change from 2000 to 2020					
	2000-2010		**2010-2020**		**2000-2020**	
	Area (Ha)	Area (%)	Area(Ha)	Area (%)	Area(Ha)	Area (%)
Built up Area	562.9	28.0	149.3	7.4	712.2	35.4
Bare land	6.5	0.3	54.5	2.7	61.0	3.0
Farmland	231.7	11.5	-18.0	-0.9	213.7	10.6
Vegetation	-669.3	-33.3	-163.4	-8.1	-832.7	-41.4
Shrubs land	-131.9	-6.6	-22.4	-1.1	-154.3	-7.7

4.1.3. Land-Use/Land-Cover Change Matrix

In this study, Land Use Transfer Matrix (LUTM) and post classification method were used to detect land cover change from 2000 to 2020 (Figure 17). The LUTM method is derived from the quantitative description of state transition system analysis. In this study, from initial to final year transitional land cover matrixes were produced for each three periods of the studies in which column stands for the initial state of land use land cover categories and the row stand for the final state of land use/land cover categories. The rate of change for the two periods from 2000 to 2010 indicates that the trend of suburbanization is more and more increasing. The two largest percentage share of land conversion from one type to another are farm land 49.7ha and vegetation cover 49.9ha in to built-up areas (Table 8). This finding is in agreement with a number of studies. For instance; (Kumar *et al.*, 2014) and (Redman ad Jones, 2009) indicates that the process of rapid urbanization take place in developing countries significantly contributes to bring opportunities to new urban developments.

Table 9: Land-use/land-cover change matrix of the year 2000 and 2010

LU/LC types		2010					
		Bare land	Built up area	Farm land	Shrubs land	Vegetation	Total
2000	Bare land	0.2	0.3	3.9	0.0	0.6	5.0
	Built up Area		79.2	6.3	0.0	1.6	87.1
	Farm land	3.5	49.7	366.1	18.5	184.5	622.2
	Shrubs land	3.0	1.2	98.6	80.9	69.7	253.4
	Vegetation	4.5	49.9	513.7	32.4	444.1	1044.4
	Total	11.2	180.0	988.6	131.8	700.5	2012

Considering the land use/land cover matrix indicated in Table 9, shows that 141.6ha of farm/cultivated land in 2010 was changed to built-up area in 2020. The other largest percentage share of land conversion from one type to another is conversion of vegetation cover in to cultivated land i.e. farm/cultivated land class gained about 302.1ha from that of vegetation cover.

Table 10: Land-use/land-cover change matrix of the year 2010 and 2020

LU/LC types		2020					
		Bare land	Built up area	Farm land	Shrubs land	Vegetation	**Total**
2010	Bare land	6.2	0.2	1.1	0.2	3.5	11.2
	Built up area	0.0	157.5	12.1	0.4	10.1	180.0
	Farm land	11.0	141.6	497.3	14.6	324.8	989.3
	Shrubs land	0.8	1.6	42.5	44.3	42.8	131.9
	Vegetation	4.8	67.0	302.1	7.0	318.8	699.6
	Total	22.8	367.8	855.1	66.4	700.0	2012

The land use land cover matrixes indicated in Table 10 shows that built up area gained about 127.3ha and 151.4ha of extra land from vegetation and farm/cultivated land, respectively. This finding is in agreement with a number of studies. For instance; (Seid, 2007) pointed out that the major land use/land cover converted in to built-up areas are vegetation cover and cultivated lands.

Table 11: Land-use/land-cover change matrix of the year 2000 to 2020

LU/LC types		2020					
		Bare land	Built up area	Farm land	Shrubs land	Vegetation	**Total**
2000	Bare land	0.2	1.5	1.5	0.0	1.7	5.0
	Built up Area	0.0	80.6	4.5	0.1	1.9	87.1
	Farm land	12.4	151.4	275.5	7.2	176.2	622.7
	Shrubs land	2.7	7.0	104.2	41.1	98.5	253.6
	Vegetation	7.4	127.3	469.1	18.0	421.9	1043.7
	Total	22.8	367.8	854.9	66.4	700.2	2012

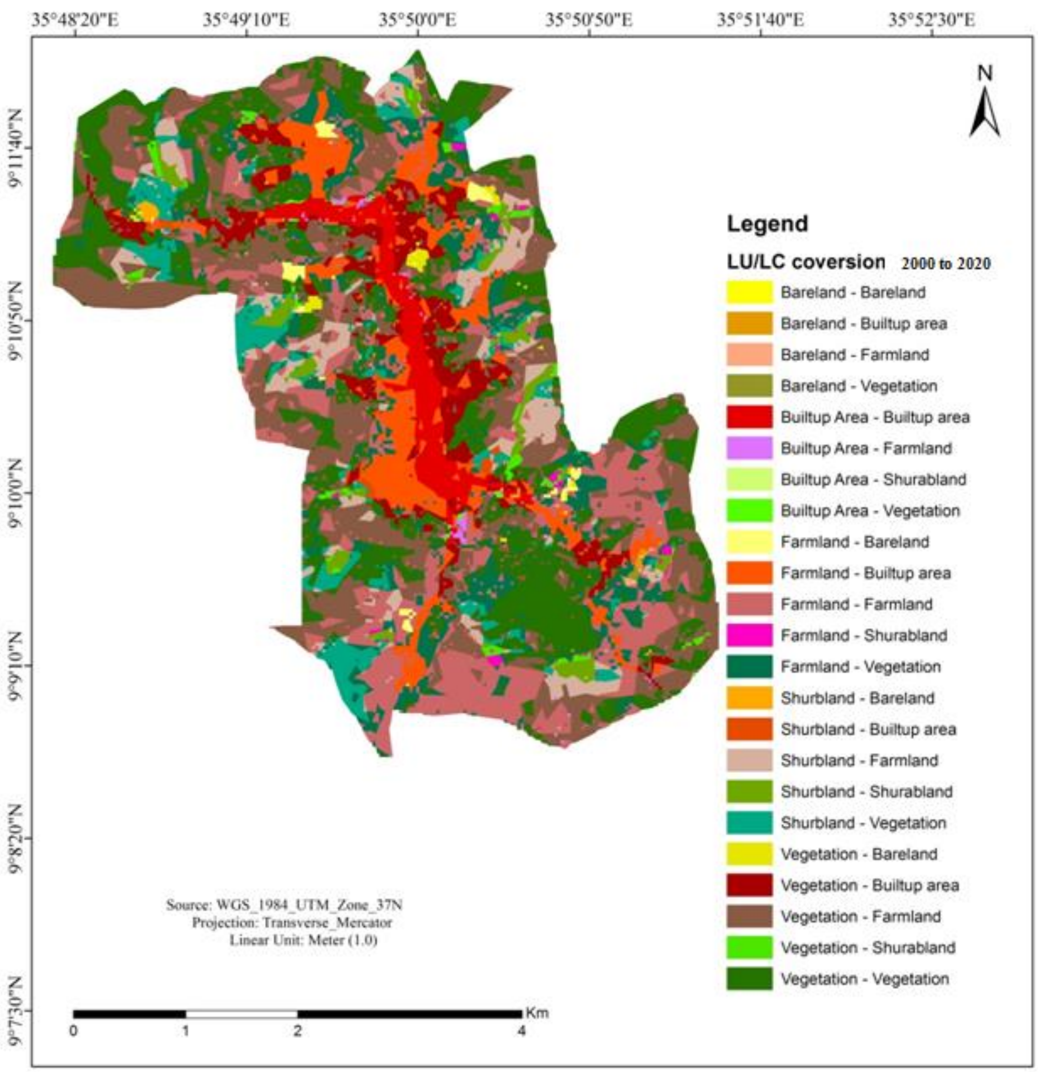

Figure 19: Map of LU/LC conversion from 2000 to 2020

4.1.4. Urban Sprawl Conditions of the Gimbi Town from 2000 to 2020

As displayed in (Figure 20), the built-up area of Gimbi town is highly expanded. The urban sprawl condition in Gimbi town clearly shows the area covered by built-up is grown from 4.3% in 2000 to 39.7% in 2020.

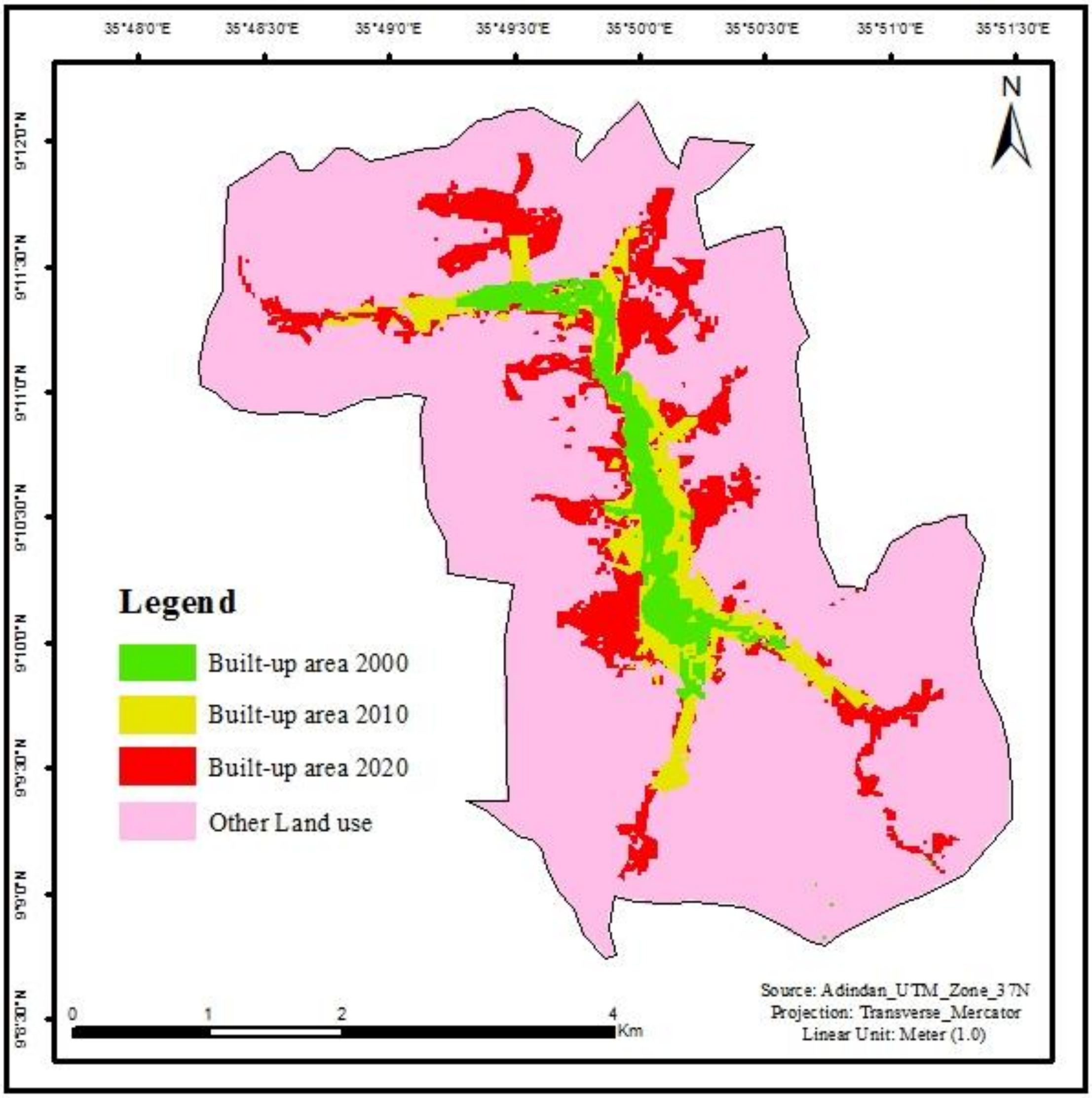

Figure 20: Map of urban sprawl from 2000 to 2020 of Gimbi Town

4.2. Analytic Hierarchy Process (AHP)

AHP is one of the most popular Multi-Criteria Decision Making Model (MCDM) techniques developed by Saaty (1980). It is used to identify the best one from a set of alternatives with respect to several criteria. The basic principle of AHP is to solve a problem by forming hierarchies. To ensure the credibility of the relative significance used, AHP also provides measures to determine inconsistency of judgments mathematically.

Based on the properties of reciprocal matrices, the consistency ratio (CR) can be calculated. CR < 0.10 indicates that level of consistency in the pair wise comparison is acceptable. Saaty (1980) suggests that if CR is smaller than 0.10, then the degree of consistency is fairly acceptable. But if it is larger than 0.10, then there are inconsistencies in the evaluation process, and AHP method may not yield meaningful results. The standardized raster layers were weighted using Eigen vector that is important to show the importance of each factor as compared to other in the contribution of urban land suitability analysis. Accordingly, the Eigen vector of the weight of the factors was computed in IDRISI 32 software in analysis menu decision support/ weight module. In this study, a pair of criteria were valued at the same time using the scale of nine points (degrees) ranging from1/9 to 9. Site suitability analysis for urban expansion for Gimbi town was performed through incorporating different parameters; these include slope, river, road proximity, land use/land cover, geomorphology, soil type, urban center, elevation and aspect in preparation of criteria maps.

4.3. Calculating Factor Weights and Overlaying the Identified Suitable Sites

Afterward preparation of maps of all features like road buffer, soil type, river buffer and geomorphology were converted to raster files and separate datasets were created using weightage and rank. Different layers having different scores were laid and the scores of each composite class were added. The larger the weight, the more important is the criterion in the overall function. The weights were developed providing a series of pair wise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated. The system by which the weights were produced follows the logic developed by Saaty (1980). Under the Analytical Hierarchy Process (AHP), weight rates were given based on pair wise comparison 9 point continuous scale (Table 11). These pair wise comparison were then analyzed to produce of weights that sum to 1. The factors and their resulting weights were used as input for the multi criteria evaluation part for weighted linear combination of overlay analysis. Finally, the suitability map was prepared.

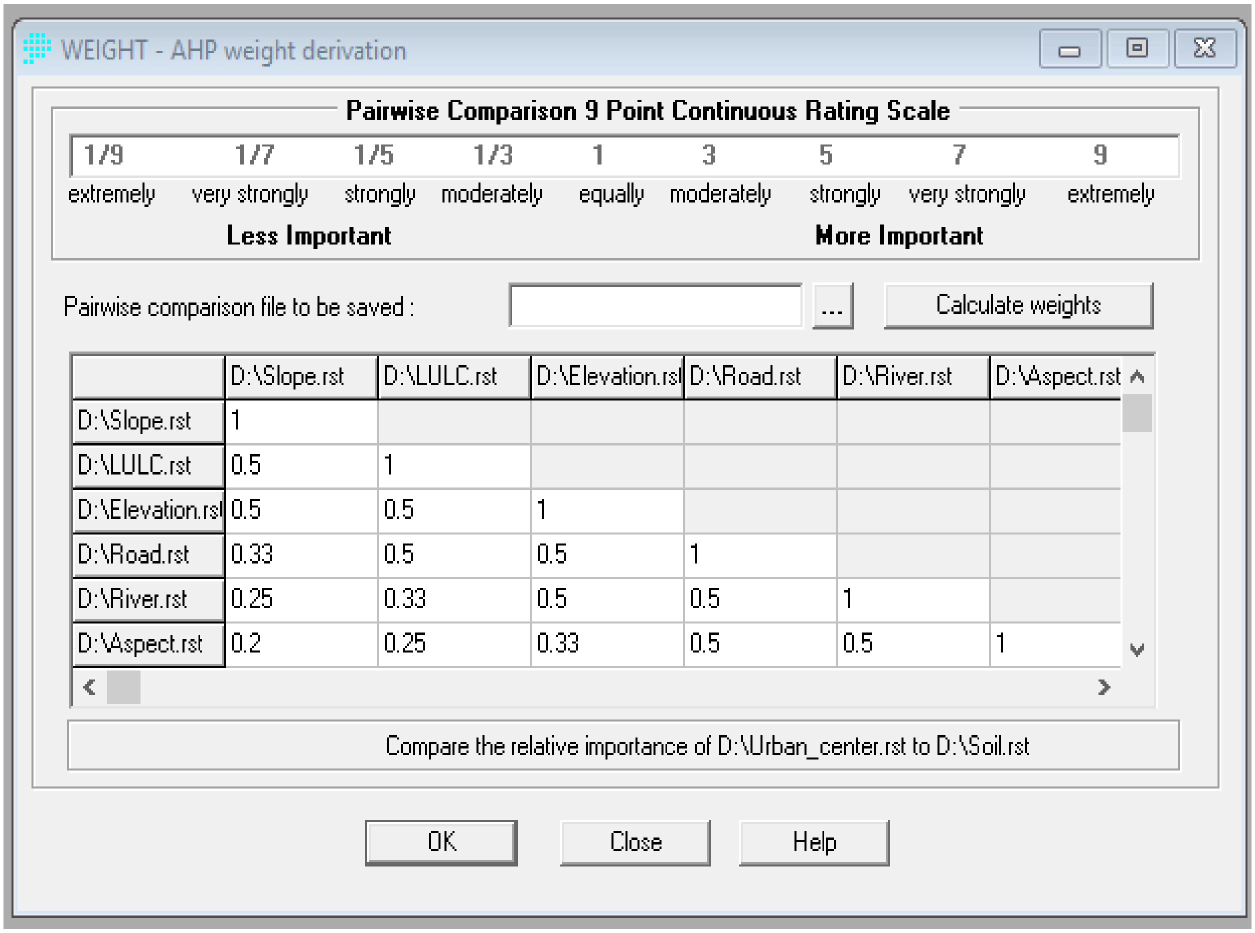

Figure 21: Pairwise comparison of different factor

Source: (Saaty, 1980)

Table 12: Weightages and parameters in determination of site suitability analysis

No	Spatial data (Layer Name)	Sub-Criteria class	Ranking	Level of suitability	Influence (%)
1	Distance from river	<200m	1	High suitable	8%
		200-400m	2	Suitable	
		400-600m	3	Moderately suitable	
		600-800m	4	Less suitable	
		>800m	5	Un suitable	
2	Geom orpho logy Lands cape	Residual landform	1	High suitable	3%

		structural landform	2	Suitable	
3	LU/LC	Bare land	1	High suitable	21%
		Shrub land	2	Suitable	
		Vegetation	3	Moderately suitable	
		Farm land	4	Less suitable	
		Built-up	5	Unsuitable	
4	Soil Types of Soil	Dystric gleysol	1	Suitable	4%
		Dystric Nitisols	2	HighlySuitable	
5	Aspect types	South	1	Highly suitable	6%
		South- West	2		
		South- East	3		
		West	4	Suitable	
		East	5		
		North- West	6	Moderately suitable	
		North- East	7	Less suitable	
		North	8	Unsuitable	
6	Elevation	<1870	1	Highly suitable	16%
		1870-1935	2	Suitable	
		1935-2000	3	Moderately suitable	
		2000-2065	4	Less suitable	
		>2065	5	unsuitable	
7	Slope (in degree) Slope	<10	1	Highly suitable	
		10-20	2	Suitable	

		20-30	3	Moderately	28%
		30-40	4	Less suitable	
		>840	5	Unsuitable	
8	Distance from Road (m)	0-1000m	1	Highly Suitable	11%
		1000-2000m	2	Suitable	
		2000-3000m	3	Moderately Suitable	
		3000-4000m	4	Less Suitable	
		>4000m	5	Unsuitable	
9	Distance from Urban Center	<1000m	5	Unsuitable	3%
		1000-2000m	4	Less suitable	
		2000-3000m	3	Moderately	
		3000m-4000	2	Suitable	
		4000-5000m	1	Highly suitable	

In the current study, the C.R. matrix of the nine important parameters in site suitability assessment for urban expansion is 0.02. Therefore the pair-wise matrix appears to have sufficient internal consistency to be considered acceptable.

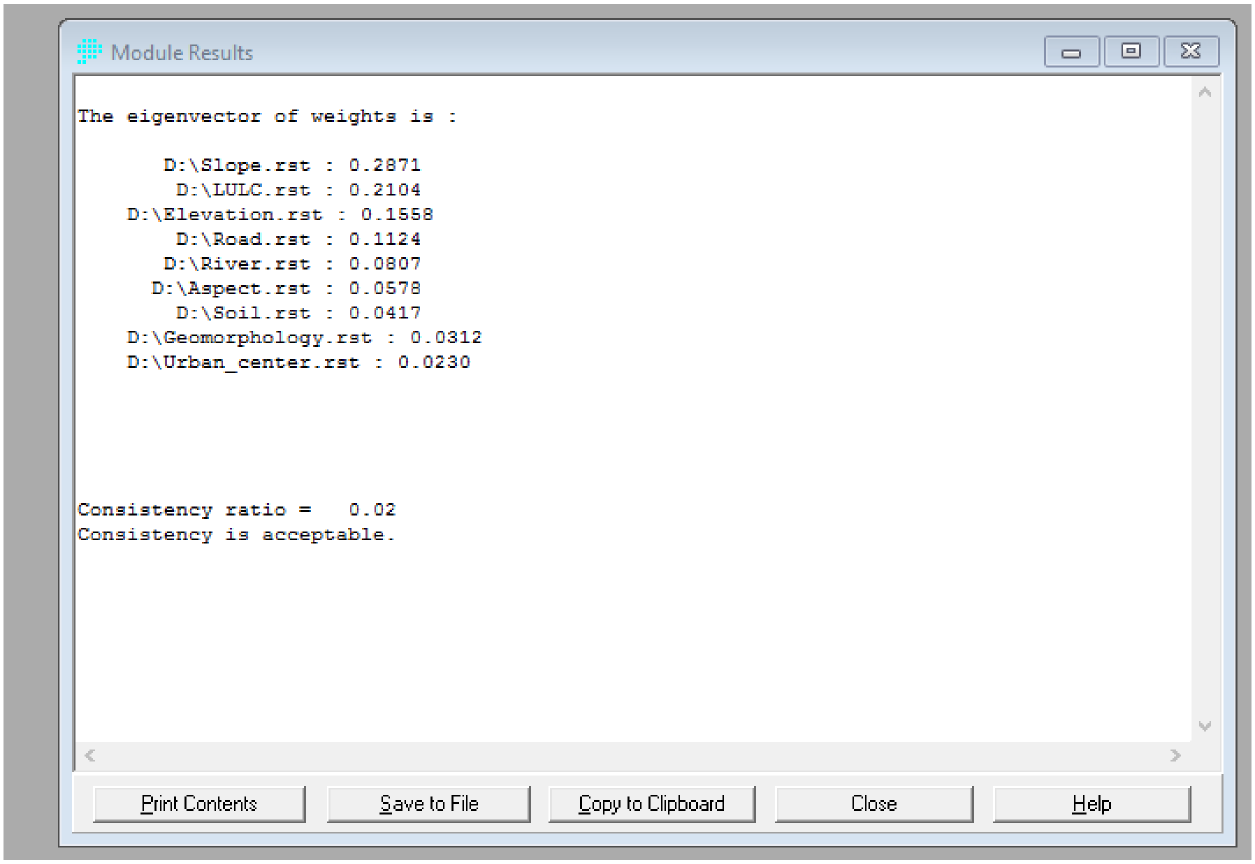

Figure 22: The eigenvector of weights

4.4. Suitable Sites for Urban Development

Land use/cover map of Gimbi town has been categorized as vegetation, farm/cultivated land, bare land, built-up area, and shrub land because once a building is constructed; it remains there for a number of years. Thus barren land/shrub land is considered to be the highest suitable for further urban development purpose. All criteria layers were converted into raster format for analysis because raster format is less complicated than vector data format (Chang, 2006). Thereafter all layers were multiplied by its weight for final site suitability map using raster calculator of ArcGIS. The final site suitability map describes that the study area was divided into four suitability classes (Figure 23). Deep green color represents suitable area and red color represents unsuitable area for further urban development in the town. This result is in agreement with result forwarded by (Effat and Hegazy, 2013).

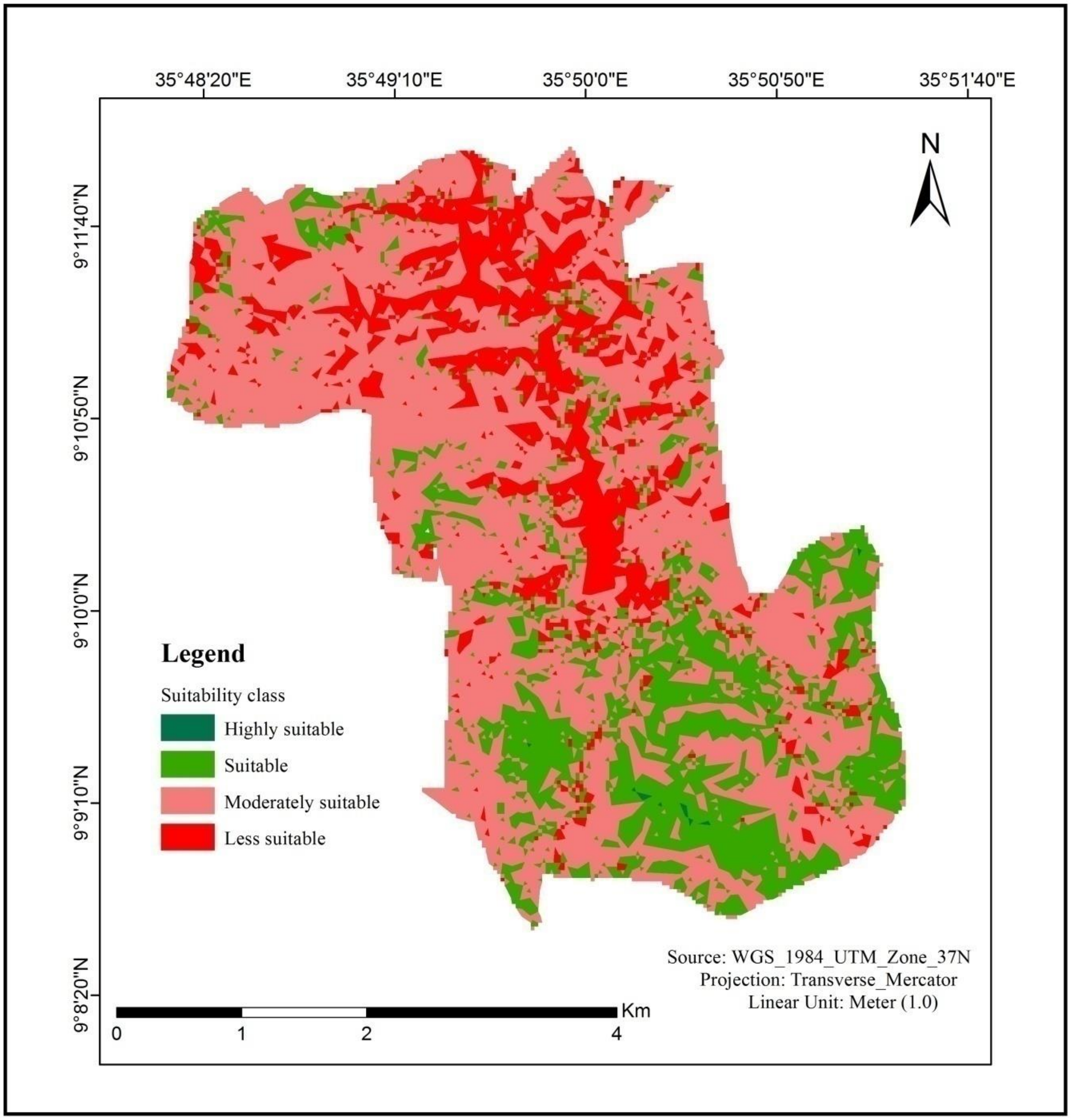

Figure 23: Suitability map

The spatial statistic result of the Landsat data of Gimbi town shows that out of the total area of 541.5ha, (26.9) are highly suitable for urban development, 847.5ha (42.1%) are moderately suitable for urban development and 612ha (30.4%) area suitable for urban development. This result is in line with (Yhdego, 2007 and Dong et al., 2008).

Table 13: Area under suitability class of each criterion

S/No	Suitable class	Area (Ha)	Area (%)
1	Highly Suitable	541.5	26.9
2	suitable	612	30.4
3	Moderately suitable	847.5	42.1
4	Less suitable	11	0.5
	Total	2012	100

According to the analysis results (Table 13) together with the urban planning policy in this area, it is found that the most suitable areas can meet the needs for future urban expansion. However, out of the total most suitable areas, about 60-80% were cropland. The future urban land use plan should be based on the utilization of limited the most suitable land together with the moderately suitable area.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

This paper focused on the integrated evaluation of urban sprawl and urban development suitability for Gimbi town by Remote sensing and Geographic Information System (GIS) techniques in providing information with regarded to urban expansion and suitability analysis for urban development are best methods for the study area.

The study clearly reveals that the town has dramatically grown in all directions between the years 2000 and 2020. Built-up area increased a lot in the 30 years by consuming a considerable amount of other land-use/cover types. The furthest built up area in 2000 was towards East direction following the main road to Addis Ababa. In 2010 the town became expanded and grown to both North and East. The main possible reason could be the flat topography that attracts residence since flat area created conductive condition for construction purpose. The current furthest expansion of built up area of the town is towards west and east, the main reason are plain topography and institutional factors like the Adventist Hospital on the east, Gimbi Hospital on the west and Wollega University-Gimbi campus on the East. The two major land use/land cover converted in to built-up areas in both specified time interval i.e. 2000 and 2020 is vegetation cover and farm lands.

Of the total area of Gimbi town more than 40 percent i.e. 42.1% falls under moderately suitable whereas about 30.4% is grouped as suitable site for further urban development. The remains 11% and 0.5% become grouped as less suitable and unsuitable area for urban growth in Gimbi town. The result of this study also indicated that integrated evaluation of urban development could be conducted in an operational way using remote sensing data, GIS spatial analysis technique and AHP modeling method.

5.2. Recommendations

Based on the findings obtained in this study, the following recommendations are forwarded for suitable urban land development:

- ✓ Modern technology of remote sensing and GIS which helps us to analyze the data spatially, offering possibilities of generating various options (modeling), thereby optimizes the whole planning process.
- ✓ Policy makers obey Land-use strategy by take account of urban land suitability in relation to the expected future needs and the possibility of meeting demands.
- ✓ The critical importance of land for specified uses should be known either physical or economic suitability. This means not only specific area of urban land should be used in particular way but also whether a particular area is physically suitable.
- ✓ Expansion of Gimbi Town brings a number of problems like, loss of vegetation and agricultural land. These problems require immediate attention of the urban planners, decision and administrators. Following are the suggestions which are to be given keen interest for sustainable growth and balance of the town.

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