ENVIRONMENTAL SUITABILITY ANALYSIS FOR VILLAGIZATION SITES USING ANALYTICAL HIERARCHY PROCESS, REMOTE SENSING TECHNIQUES AND GIS, THE CASE OF HOMOSHA WOREDA, BENISHANGUL-GUMUZ REGIONAL STATE (WESTERN ETHIOPIA)

A THESIS SUBMITED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY, IN PARTIAL FULFILIMENT OF THE REQUIRMENT FOR THE DEGREE OF MASTER OF SCIENCE IN REMOTE SENSING AND GIS

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May 2014

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This is to certify that the thesis prepared by Melkamu Dessalegn, entitled: ***"Environmental Suitability Analysis for Villagization Sites Using Analytical Hierarchy Process, Remote Sensing Techniques and GIS, The Case of Homosha Woreda, Benishangul-Gumuz Regional State, Western Ethiopia"*** and submitted in partial fulfillment of the requirements for the Degree of Master of Science (Remote Sensing and Geographical Information Systems) compiles with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the Examining Committee:

Examiner ---------------------------- signature__________Date_____________

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Advisor Dr. Getachew Berhan signature___________Date____________

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Chair of Department or Graduate Program Coordinator

Dedicated to

My wife Asnakech Tilinti Alago; your love and kindness will always be a much appreciated constant in my life.

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Abstract

Though Environmental Suitability Analysis for Villagization Sites of human settlement is a naturally complex multi-dimensional process, that involving multiple criteria and actors. However, Geographical Information System (GIS) integrated with Analytical Hierarchy Process (AHP) provide more reliable, flexible and accurate information to the decision makers by evaluating the criteria and factors for performing environmental suitability analysis. This study is aimed to develop a new environmentally suitable sites selection approach for villagization using AHP and GIS. The aim in integrating GIS and AHP is to provide reliable and quality information to the decision makers and other stakeholders in order to collect scattered households into selected nucleated villages. The study was carried out in Homosha Woreda, Benishangul-Gumuz Regional state, West Ethiopia. Major physical (Topography, Climate and Land use/land cover) and socio-economic (school, water points, health centers and distance from road) variables were considered for the environmental suitability analysis. All data were analyzed and stored in Arc GIS environment and the factor maps were generated. Pairwise Comparison Matrix known as AHP was applied and weights for criteria and factors were calculated. Weighted overlay techniques are applied to arrive at the final environmental suitability mapping. The results showed that 100% of Homosha woreda has warm temperate climatic condition. Similarly, 22.4 % and 51.2% of Homosha woreda has highly suitable socio-economic and topographic condition for human settlement respectively. In relation to land use/land cover, 37.5% of Homosha woreda is covered by forest and agriculture, which is marginally and currently not suitable for human settlement. The overall weighted environmental suitability analysis of the area indicates that only 1.2 % of the area has high suitability condition. The remaining 63.4%, 34.6% and 0.8% of the area are moderately, marginally and currently not suitable as villagization sites for human settlement.

Key words: AHP, Homosha woreda, Pairwise comparisons, Suitability Analysis, Villagization.

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Acronyms

AHP	Analytical Hierarchy Process
BGRG	Benishangul-Gumuz Regional Government's
BoFED	Bureau of Finance and Economic Development
CSA	Central Statistical Agency
DEM	Digital Elevation Model
ERDAS	Earth Resources Data Analysis System
FDRE	Federal Democratic Republic of Ethiopia
GCPs	Ground Control Points
GIS	Geographic Information System
GoE	Government of Ethiopia
LSA	Land Suitability Analysis
MCDM	Multi-Criteria Decision Making
MCE	Multi-Criteria Evaluation
mm	millimeter
REB	Regional Education Bureau
RHB	Regional Health Bureau
RS	Remote sensing
SDSS	Spatial Decision Support Systems
SMCE	Spatial Multi-Criteria Evaluation
VS	Villagization Scheme

CHAPTER ONE

1. Introduction

1.1. Background

Ethiopia is predominantly agrarian country that depend on rain feed agriculture production. She has about 51.3 million hectares of arable land but only about 11.7 million hectares are currently cultivated, that is about 23% of the total cultivable area (MoARD, 2010 cited in Bazezew et al., 2013). Even thought, agriculture sector is the backbone of the Ethiopian economy, making multifaceted contributions to the development of its economy, the performance of agriculture, however, in terms of feeding the population of the country, which is growing at about 2.6% per annum, is poor (CSA, 2007). A contributory factor to the widespread rural poverty and food insecurity in Ethiopia is the very low productivity of the smallholder agriculture, which employs over 80% of the Ethiopia .Smallholder farmers are the major producers of food through low-input, rain-fed and low-output farming systems (MoARD, 2010 cited in Bazezew et al., 2013). Drought, erratic rainfall, backward production technologies, small size of farmlands, and land degradation are the major causes for the low agricultural productivity in Ethiopia.

Thought like the governments of many developing countries Ethiopia is increasingly committed to providing basic social services such as drinking water, education, and health to their citizens (PANE, 2010).

Based on May 2007 census the projected figures for 2011 showed that the population of Ethiopia was 84,320,987(42,556,999 males and 41,763,988 females), of which 82.8% (69,818,432) were rural and 17.2% (14,502,555) were urban settler. During the same year (2011) there were 973 towns in Ethiopia and thus according to FAO (2008) ,Ethiopia is one of the least urbanized countries in the world.

In Ethiopia in 2011 the average population density which is the total population in a given area per square kilometer was about 113.7. Variations in population density exist from the higher administrative structure Region to the lower administrative unit kebele .These were recorded respectively as 119.1, 22.2, 121.9, 110.0, 19.4, 163.9, 13.0, 628.9, 5770.5 and 248.3 for Tigray, Affar, Amahara, Oromia, Benishangul-Gumuz, Southern Nations, Nationalities and peoples(SNNP), Gambella, Harari, Addis Ababa and Dire Dawa regions and city administration. The population densities are lower in the lowlands parts of Ethiopia, in particular western lowlands as in Benishangul-Gumuz and Gambella Regions, adjoining Sudan (CSA, 2007).

On the above, in general the distribution of the population in Ethiopia is related to altitude, climate, and soil. These physical and environmental factors explain the concentration of population in the highlands, due to the moderate temperatures, rich soil, and adequate rainfall, while lowlands are characterized by high temperature, relatively poor soil and low rainfall and hence scattered settlement pattern (BGRG, 2010). The dispersed nature of the population in the rural and lowland areas of the country makes addressing basic concerns such as health, education, extension services and food insecurity very challenging questions. Another concern is the rapid growing population, environmental degradation and low agricultural production and productivity.

In light of the socio-economic and food insecurity concerns in the rural and lowland areas of the country, the government of Federal Democratic Republic of Ethiopia (FDRE) has started implementing various actions based strategies and programs to overcome the challenges. One of these is the Villagization scheme which is accepted as the most feasible and practical solution to these challenges. Villagization scheme is aimed to collect scattered households into selected nucleated villages to improve their access to social, economic and administrative services (Ferede, 2012) as a support to effort being made to solve the food insecurity.

In Ethiopia, the need for this scheme is to ensure sustainable food security through ensuring sustainable supply of development vehicles (the socio-economic services and other infrastructures such as road, telephone and electric power). Moreover, Villagization is intended to improve agricultural production, to facilitate the delivery of basic social services to communities which were difficult to reach in their scattered homesteads, and to improve the land use of the peasants (BGRG, 2010).

In recognition of this, the Federal Democratic Republic of Ethiopia (FDRE) has launched a villagization scheme, which is a rural-based strategy primarily aimed at gathering on a voluntary basis pastoral and semi-pastoral communities in Afar, Somali, Gambella and Benishangul-Gumuz regions in nucleated village. The plan is to villagize 1.5million individuals by 2013 while the relocations which was started in 2010 (BGRG, 2010; HRW, 2011) is planned to supply basic rural infrastructures and socio-economic services, to help those communities to lead a sedentary way of life.

In Benishangul-Gumuz Region, Villagization scheme is under implementation in 18 Administrative Woredas'. None of the 17 woredas' villagization scheme utilized remote sensing techniques and Geographic Information System (GIS) technology in identifying suitable area for human relocation. It is therefore, this study focuses to integrate some of the physical and socio-economical environmental factors that directly or indirectly affect the suitability of areas for human relocation.

Homosha woreda is located in the western part of Benishangul-Gumuz Region and is one of the 18 woredas sites selected for the second round villagization scheme and is selected for this study of remote sensing techniques and GIS based analysis as it is the only woreda in the region where the villagization scheme will be implemented in the second round of the program.

1.2. Statement of the Problem

Collecting scattered households into selected nucleated villages is a Government strategy through which socio-economic and food insecurity challenges will be addressed, if it has volunteerism base (HRW, 2011). In recognition of this critical role, the government of Federal Democratic Republic of Ethiopia (FDRE) has given due attention to implement villagization scheme in four developing regions of the country: Afar, Somali, Gambella and Benishangul-Gumuz on a voluntary basis to address socio-economic and food insecurity challenges.

However, in Ethiopia the study on villagization scheme is not supported by GIS and remote sensing techniques at all levels (national, regional and local). The criteria set for site selection during villagization scheme in Benishangul-Gumuz Region was suggested to be based on the availability of ground and surface water, under-utilized/virgin land, sufficient construction and fuel wood, and the existence of sufficient rainfall in the area. In addition to this, free from malaria disease, natural hazards like flooding, existence of mineral deposits and accessibility to main road (BGRG, 2010) are major issues under consideration. However, the criteria set do not incorporate scientific measures/parameters such as GIS and remote sensing techniques provide support for decisions making process. Moreover, the criteria do not consider the benefit from the Analytical Hierarchy Process (AHP), which is essential for multi-criteria evaluation (MCE) and vital tool to analyze the major physical and socio-economical environmental factors that directly or indirectly affect the environmental suitability of sites for human settlement. Beside this, the criteria suggested are vulnerable to individual biasness or value judgment.

It is therefore, on the above, there is a crucial need to consider, evaluate and analyze the major sensible environmental factors that have direct and indirect effect on human relocation and to decide the environmental suitability of the villagization sites.

At present, this study is an attempt to evaluate, analyze and identify potential villagization sites using Remote Sensing techniques, GIS and AHP; a case study of Homosha Woreda, Benishangul-gumuz regional state. The integration of the AHP with GIS, combines decision support methodology with powerful visualization and mapping capabilities which in turn should considerably facilitate the creation of environmental suitability map.

1.3. Objectives

1.3.1. General objective

The general objective of this study is to develop a new environmentally suitable sites selection approach for villagization using Analytical Hierarchy Process (AHP), RS and GIS.

1.3.2. Specific Objectives

Specific objectives of this study are:

- To identify major factors for selecting appropriate villagization sites.
- To develop villagization sites selection approach using Analytical Hierarchy Process(AHP) and GIS
- To apply geospatial processing techniques.
- To identify environmentally suitable sites for villagization of human being in the study area.

1.4. Significance of the study

Effective implementation of villagization scheme is a key to tackle problems related food insecurity and socio-economic of vulnerable communities in the country, thereby establishing a nucleated villages and building social, economic and administrative institutions in those villages. Effective implementation of the villagization scheme is to make use of the powerful tools of AHP, Remote Sensing techniques and GIS which can integrate various environmental factors that directly and indirectly affect the ecological suitability of areas for human relocation.

AHP, Remote Sensing techniques and GIS provide the appropriate tools for analyzing both spatial and non-spatial data that fulfill all the set parameters, identify most suitable area and environmental potential sites for human relocation.

It is therefore, in general, the final outcome of this study is that using advanced analytical hierarchy process (AHP), remote sensing techniques and GIS to support planning and management, appropriate resource allocation and foster realistic decision making for governmental and non-governmental organization. In particular, the study will have special contribution in identifying nucleated villages that used to collect scattered households in Homosha Woreda, which the Regional Government of Benishangul-gumuz region will be able to utilize for successful implementation of the ongoing scheme of villagization.

1.5. Scope of the Study

Unless any research work is delimited to a manageable size, it cannot be conducted successfully. Therefore the study is confined to, Environmental Suitability Analysis for Villagization sites using Analytical Hierarchy Process, Remote Sensing techniques and GIS, the case of Homosha Woreda, Benishangul-Gumuz regional state, western Ethiopia.

1.6. Limitation of the Study

The research was encountered some constraints during the researcher work. Such as: lack of high spatial resolution satellite imagery and accessibility of road network in the study area. There was also lack of meteorological station recorded climate data of many years for the Study.

1.7. Attempted Works

Since the time of Emperor Haile-selassie resettlement and villagization program has been taking place in Ethiopia due to famine 1984-1985, resource scarcity and political concern. Following this, several studies have been conducted from social science aspect. For instance "Voluntary Villagization Scheme (VVS) for Transforming Semi-Pastoral Communities in Benishangul-Gumuz Region Northwestern Ethiopia" by Ferede (2011), and Resettlement of peasants in Ethiopia (Belay, 2004). In Homosha Woreda, however, no study was conducted regarding environmental suitability analysis for human settlement under Villagization scheme using remote sensing, GIS and AHP technique. Thus, this study is attempting to fill this gap by analyzing major physical and socio-economic factors that determine the suitability of environment for human settlement.

1.8. Organization of the Paper

The first chapter (Introduction) aimed to introduce the issues of Villagization scheme including background and statement of the problem, research objectives, the significance of the study, and scope of the study, limitation of the study and attempt works.

Chapter two (Literature Review) deals with the brief review of villagization scheme, Environmental Suitability of Villagization sites, Multi-Criteria Decsion Making for site selection.

Chapter three (Materials and Methods) introduces the materials and methods at a glance including description to the study area, data sources, materials, methodology and data processing.

Chapter four (Results and Discussions) presents the research findings.

Finally, chapter five (Conclusion and Recommendations) presents conclusion and recommendations remarks of the study.

CHAPTER TWO

2. Literature Review

2.1. General overview of Villagization

2.1.1. Definition of Villagization

The concept of villagization is seemed to overlap with resettlement research done. Mhando (2011) alternatively used them as if they were the same. Similarly, Mulugeta and Woldesemait (2011) used resettlement and internal displacement as if they were similar concepts joining them by conjunction, "or" while certain differences exist. In this conjunction, resettlement and villagization conceptually overlap while they differ in some aspects. However, villagization is an aspect of resettlement; it involves the relocation of scattered dwellings and settling in mostly similar geographic and administrative units. In this regard, the capacity of resettlers to readjust to the new environment is less complex than that in resettlement. Hilhorst and Leeuwen (2000) cited in Ferede (2011) use the concept of villagization without mixing it with resettlement. This seems more reasonable /appropriate utilization of the concept as it has its own defining identity that makes it different from resettlement although they overlap conceptually in certain uses. Meaning, there are points where they overlap and where they differ.

Theoretically, all forms of settlement readjustments, include villagization, inevitably involve resettlement, be it voluntarily or involuntarily, planned or spontaneous. Resettlement cited in literature in almost similar expression. Piguet & Dechassa (2004) cited in Ferede (2011) defined resettlement as a planned or spontaneous redistribution of population. Asrat Tadesse (2006) equates resettlement, land settlement, colonization, or transmigration all referring to the phenomenon of population redistribution, either planned or spontaneous. As Mengistu Wube(1992) cited in Dagnachew Shibru.(2011) , resettlement is the process by which individuals or groups of people leave spontaneously either voluntarily or involuntarily their original settlement sites to resettle in new areas; where they can begin new trends of life by adapting themselves to the biophysical, social and administrative systems of the new environment .In all cases, the movement of individuals or group of people and voluntarism in the definitions are the principles shared by resettlement and villagization. Although literatures on villagization are highly scarce, the existing ones defined it as the process of gathering scattered form of settlements into a predetermined center or site either voluntarily or forcibly (Sandra, 1987; Mhando, 2011; Mulugeta and Woldesemait, 2011). Here in after, this study will define villagization as it involves establishing nucleated villages to deliver social, economic and administrative services intended.

2.1.2. An overview of Villagization History in Ethiopia

The beginning of population relocation in Ethiopia as a strategy to transform rural population dates back to the period of Emperor Hail-Selasie I, most probably in 1958 (Messay, 2009 cited in Ferede,2012). However, others suggested the commencement of this strategy to be during the early 1960s. In both cases, it seems that the beginning of resettlement in Ethiopia revolves around the period 1960s. While resettlement program was launched in 1984 by the Derg regime and extensively implemented following the 1984 -1985 famine of Ethiopia (Sandra,1987), villagization was initiated one year later in 1985 (Mulugeta and Woldesemait, 2011) aiming to transform rural community by grouping the scattered farming communities throughout the country into small village clusters, to promote rational land productivity; conserve natural resources, and provide access to public services like clean water, clinics and schools, electricity, market and cooperatives. A village was, therefore, planned to host 200 – 300 households in an area of $100m^2$ (10m * 10m).Although Sandra (1987) argues that both resettlement and villagization equally began in 1984.

Accordingly, the Derg had extensively implemented both resettlement and villagization programs in Ethiopia since 1984. As Ofcansky and Berry (2002) cited in Mulugeta and Woldesemait (2011), by l986, about 4.6 million people in Shewa, Arsi, and Hararge had been relocated into more than 4,500 villages; by 1989, about l3 million people were villagized throughout the country with the exceptions of two administrative regions (the then Kifle-hagers) of Tigray and Eritrea in the process of villagization. During the same period (i.e. by March 1986), about 800, 000 people were, forced to move from their Northern highlands and, collected in a selected sites far in Southwestern part of Ethiopia (Sandra,1987). Villagization program which started in 1984 on a relatively small scale, had accelerated its pace due to national complain launched in 1985 and by February 1987, about 5.7 million people (15% of the rural population) had been moved into 11,000 new villages. In addition, by the end of that year, 10 million rural inhabitants (25 percent of the population) are expected to be villagized in 12 of the 13 provinces of Ethiopia with the objective of creating the necessary "preconditions" for agrarian socialism, and facilitating the provision of human social services by gathering scattered homesteaders into central communities (Sandra, 1987). Researches revealed that the resettlement and villagization programs were more of political than ecological and socio-economic arguments (Sandra, 1987; Lorgen, 1999).

The Federal Democratic Republic of Ethiopia has embarked the revitalization of population relocation strategies of resettlement and villagilization in the year 2003. The villagization program in Afar, Somali, Gambella and Benishangul-Gumuz regions focuses on collecting scattered households into selected nucleated villages as a solution to socio-economic and food insecurity challenges.

2.2. Environmental Suitability of Villagization Sites

Suitability site selection for specific purpose is a complex processes that requires critical decision to be made by decision-makers which affects a wide range of activities. Selection of appropriate site could significantly affect the profit and loss of the task under investigation. Environmental suitability sites assessment for human relocation is complex issue. The process of human relocation involves not only technical requirements, but also economic, social, environmental and political demands that may result in conflicting objectives. Moreover, suitability of environment for human being is more complicated compared to other species of flora and fauna. As a result poor environmental suitability especially for human being can increase the incidence and severity of natural hazards and make people more vulnerable to a wide range of consequent effects such as flooding, disease and famine.

Habitat of each species has its role in the ecology system, so does the human being. Despite the natural conditions, human settlement is affected by social and economic factors.

Land suitability assessment for human settlement unlike that for other living species it requires consideration of a comprehensive set of factors and a balance of multiple objectives in determining the suitability of a particular area for a defined land use. Thus, selecting environmentally suitable area for human settlement prediction variables should be carefully considered so as to assess both environmental factors such as: climate, topography, vegetation and socio-economic variables. These factors are major concerns in the process of environmental suitability site selection for human settlement. Taking into account that, consideration of parameters for environmental suitability assessment is affected by the availability of data (Jain et al., 2013).

Pareta(2013) describes environmental suitability in terms of land suitability , which is the ability of a particular type of land to support a specific use by considering physical resources (elevation , slope , climate) ,natural resources (soil ,hydrology , geology ,flora and fauna) and the existing land use and development (infrastructure) in the area under investigation. These different types of information constitute the criteria based on which the area under consideration should be weighted. These criteria are individually considered to identify areas of opportunity (suitable areas for intended work) and constraints (areas not suitable for intended work)

Land Suitability Analysis (LSA) is a GIS-based process applied to determine the suitability of a specific area for considered use. It reveals the suitability of an area regarding its intrinsic characteristics: suitable or unsuitable (Jafari and Zaredar, 2010). This analysis involved with considering wide ranges of criteria including physical (such as land-use, climate, soil and topography), social and economic factors. Criteria are detrimental to land suitability analyses for different land use types. Accordingly, land suitability analysis evaluates many alternative land use types under various criteria from various disciplines.

FAO (1993), environmental suitability analysis of land classification based on indigenous knowledge is vital to land use planning. The systematic analysis of environmental suitability of land, based on selected criteria helps to identify and put into practice future alternative land uses that best meet the needs of the people, while at the same time safeguarding resources for the future. Selecting the most appropriate land evaluation technique is therefore very important for current and future land use planning.

FAO (1976; 1993), the value of land quality is the function of the assessment and grouping of land types into orders and classes in the framework of their fitness. Land suitability is categorized as suitable (S) and not suitable (N).Whereas S features lands suitable for use with good benefits, N denotes land qualities which do not support considered type of use, or are not enough for suitable outcomes . Suitability orders could be further sub-divided.

Accordingly, three classes (indicate the degree of suitability within an order) S1, S2 and S3 are often used to distinguish land that is highly suitable, moderately suitable and marginally suitable for a particular use. Two classes of 'not suitable' can usefully distinguish land that is unsuitable for a particular use at present, but which might be useable in future (N1), from Land that offers no prospect of being so used (N2).

Skidmore (2002) environmental suitability is a key to sustaining human economic activity and well-being, for without a healthy environment, human quality of life is reduced. There are also many reasons to protect the environment for its own inherent worth, and especially to leave a legacy of fully functioning natural resources.

This study analyzes the environmental suitability sites selection for villagization against some environmental determining factors such as: topography, climate, Land-use/land-cover and socio-economic factors which were selected based on literature search, previous works , discussions with experienced experts and data availability. Eight causal factors, selected were; elevation, slope, temperature, land use/land cover, schools, health centers, water points and road networks. The casual factors were chosen based on the four main criteria but also under consideration of literature inputs and data availability.

2.3. Spatial Multi-Criteria Decision Making

Decision making is based on numerous data concerning the problem at hand. Decisions encountered problems that involve geographical data are referred to as geographical or spatial decision problems (Malczewski ,1999 cited in Drobne and Lisec,2009).Decision making is a sequence of activities starting with decision problem recognition and ending with a recommendation, and eventually with a final choice of alternative (Drobne and Lisec,2009). People often make spatial decisions, in both personal and professional matters such as what route to take on daily travel, where to locate a new office. Selecting an alternative usually requires trading off different considerations. Route selection, for instance, may be a trade-off among distance, driving time, and road quality. Different people facing the same problem may apply different values and motivations and reach at different conclusions. As decisions increase in complexity and importance, so does the need to formalize them using available information, and to document the rationale.

Various tools exist to support spatial decisions. Most important are Spatial Decision Support Systems (SDSS), Multi-Criteria Decision Making (MCDM), Multi-criteria Decision analysis (MCDA) and Spatial Multiple Criteria Evaluation (SMCE).

Spatial Decision Support Systems (SDSS) is computer assisted program that combines the application of GIS to locate the most suitable areas which satisfy the exclusion and preference rules that have been set by the decision makers. SDSS emphasis on the use of spatial data and in GIS it is on supporting decision makers in the decision-making process to choose the alternative (decision) which is the best solution to the problem that needs to be solved. The combination of multiple parameters, methods and decision making techniques, creates the foundation for a Multi-Criteria Spatial Decision Support System (MC-SDSS) (Drobne and Lisec, 2009). MC-SDSS integrate GIS based data processing and analysis techniques and multi criteria decision analysis.

Multi-Criteria Decision Making (MCDM) is systematic way to select the best available alternatives based on different opinions, conflicting priorities and values. Spatial multi-criteria decision making involves a set of geographically-defined alternatives (events) from which a choice of one or more alternatives is made with respect to a given set of evaluation criteria. The main aim of MCDM is to assist the decision-maker in selecting the 'best' alternative from the number of feasible choice-alternatives under the presence of multiple choice criteria and diverse criterion priorities (Jankowski, 1995 cited in Dagnachw Shibru., 2011).

The associated problem with the use of MCDM is how to establish weights for a set of activities according to their importance. Location decisions such as the ranking of alternative communities are representative multi-criteria decisions that require prioritizing multiple criteria. Saaty (2008) has shown that this weighting of activities in MCDM can be dealt with using a theory of measurement in a hierarchical structure. The analytical hierarchy process (AHP) is a comprehensive, logical and structural framework, which allows improving the understanding of complex decisions by decomposing the problem in a hierarchical structure. Moreover, AHP used to calculate values for a spatial and spatial multi-criteria decision analysis.

According to Shari and Retsios (2004), spatial multi-criteria decision analysis (MCDA)can be thought of as a process that combines and transforms geographical data (input) into a resultant decision (output) .The MCDA procedure are decision rules which define a relationship between the input maps and an output map. The procedures use geographical data, the decision maker's preferences, criterion values, and preferences according to decision rules. This means analysis results depend not only on the geographical distribution of attributes, but also on the value judgments involved in the decision making process. Malczewski (2004) thus, two considerations of critical importance for spatial MCDA are the GIS capabilities of data acquisition, storage, retrieval, manipulation and analysis, and the MCDM ability to combine the geographical data and the decision maker's preferences into one dimensional value of alternative decisions .

Generally, according to Shari and Retsios (2004), GIS and MCDM are tools that can support the decision makers in achieving greater effectiveness and efficiency in the spatial decision-making process. The combination of multi-criteria evaluation methods and spatial analysis is referred as spatial multiple criteria evaluation (SMCE). SMCE is an important way to produce policy relevant information about spatial decision problems to decision makers. Spatial multiple criteria evaluation can also play a very important role in the development and application of resource analysis, planning and evaluation process. A good example of SMCE application in planning and decision making is suitability site selection. It is, therefore, important to realize that environmental suitability analysis can be performed through the deployment of the GIS and MCDM techniques. In this regard, each component of environmental factors in a database is taken as an alternative to be evaluated for its quality or appropriateness for the purpose of human settlement (Dagnachew Shibru., 2011). Similarly, environmental suitability of villagization site can be analyzed using MCDM procedures in order to prove the appropriateness of the site for human settlement.

2.4. Analytical Hierarchy Process (AHP)

AHP is a widely used method in MCDM and was introduced by Saaty in 1980 (Triantaphyllou and Mann, 1995). It is easily implemented as one of the MCDM techniques. AHP is a decision support tool, which can be used to solve complex decision problems. It uses a multilevel hierarchical structure of objectives, criteria, sub criteria and alternatives.

AHP is based on three principles: decomposition of the overall goal (suitability), comparative judgment of the criteria, and synthesis of the priorities Ramanathan (2001).

AHP uses a fundamental scale of absolute numbers to express individual preferences or judgment (Table 4) that consists of nine points. In general, nine objects are the most which an individual can simultaneously compare and consistently rank. The score of differential scoring presumes that the row criterion is of equal or greater importance than the column criterion. The reciprocal values (1/3, 1/5, 1/7, 1/9) have been used where the row criterion is less important than the column criterion.

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 < 0.1 indicates that level of consistency in the pair wise comparison is acceptable. Dalalah et al. (2010) 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.

2.5. Role of Remote Sensing and GIS for Environmental Suitability of Villagization Sites

2.5.1. Remote Sensing for Environmental Suitability Analysis

Remote sensing (RS) is the technique of driving information about objects on the surface of the earth without physically coming into contact with them. This process involves making observations using sensors mounted on platforms (aircraft and satellites). RS is widely used as a tool for monitoring the gradual alteration of the dynamic environmental resources of the planet earth. This is done by sensing and recording reflected or emitted energy , processed, analyzed and applied to the question.

RS images have been used to produce local, regional, national, and global composite multispectral mosaics. Also, RS images have been used in mapping and monitoring various environmental resources. Similarly, changes observed from remotely sensed data can complement ecological assessments of settlement sites. Both restoration and long term management efforts require location and monitoring of the spatial patterns of changes.

Besides that, regional maps of natural resources provide environmental resource managers with information for settling long term and sustainable development decisions. Hence, it offers an efficient and effective means of collecting the required information in order to identify and map environmental suitability to human settlement.

2.5.2. GIS for Suitability Analysis

Drobne and Lisec(2009) Geographic Information System (GIS) is an organized collection of computer hardware, software, geographic data and personal designed programs to efficiently capture, store, update, manipulate, analyze and display all forms of geographically referenced information. GIS has the ability to perform numerous tasks utilizing both spatial and attribute data. Spatial data (georeferenced data) represents the geographic location of features, that is the location within geographic space where the features reside while attribute data is descriptive information of the map features.

GIS have the capacity to integrate both spatial and attribute data. Such functions distinguish GIS from other management information systems. Furthermore, GIS as an integrated technology allows for integration of a variety of geographical technologies (such as remote sensing, global positioning systems, computer-aided design, and automated mapping and facilities management) that can be in turn integrated with analytical and decision-making techniques. The way in which data are entered, stored and analyzed must mirror the way in which information will be used for analysis or decision-making tasks. GIS should therefore be viewed as a process rather than as merely software or hardware. The GIS possesses a set of procedures that facilitate the data input, data storage, data manipulation and analysis, and data output to support decision-making activities (Grimshaw, 1994 cited in Drobne and Lisec, 2009).

The selection of suitability site requires consideration of a comprehensive set of factors and balancing of multiple objectives in determining the suitability of a particular area for specific purpose. It is thus, GIS is a common tool used for suitability of site selection by providing the opportunity of overlay several data layers.

Drobne and Lisec(2009) the ultimate aim of GIS is to provide support for spatial decisions making process. In multi-criteria evaluation (MCE) many data layers are to be handled in order to arrive at the required suitability, which can be achieved conveniently, using GIS. Hence, the integration of multi-criteria methods of suitability assessments into a GIS environment offers the system spatial capabilities and analytical power for formal MCDM tools.

Finally, it is crucial to note, however, that GIS and MCE techniques are merely tools, which provide a mean to an end. Without knowledge and expertise of the operator and decision maker, and without appropriate data, such tools will not bring the required solution (Carver, 1991). Nevertheless, GIS and MCE applications appear to represent potentially fruitful areas for further research and development.

CHAPTER THREE

3. Materials and methods

3.1. Description of the study area

The study area, Homosha Woreda is one of the 20 woredas in Benishangul- Gumuz regional state, western Ethiopia. Structurally, the woreda belongs to Assosa administrative zone. The woreda is named following the establishment of the region in 1994 by the new constitution of Ethiopia; previously the area was belonged to Wolega (formerly known as kifel-hager). Homosha woreda consists of 15 kebeles (a small administrative unit), 14 rural and 1 urban kebeles. According to the Central Statistical Agency (CSA), the projected population of Homosha Woreda in 2013 was 27,617(14,257 males and 13,365 females) living in a total area of 705 km^2 which result in a population density of 39.2.

3.1.1. Physical features

3.1.1.1. Location

Homosha woreda is located in the western part of Benishangul-Gumuz regional state, in the western part of Ethiopia. It is entirely bordered by woredas of the Benishangul-Gumuz regional state. Kurmuk and Sherkole woredas in the north, Assosa woreda in the south, Kurmuk and Assosa woredas in the west and Menge woreda in the East.

The geographical location of the woreda lies within the coordinates of $34^0$26'E - 34^0 44'E longitude and 10^0 10'N - 10^0 29'N latitude. The woreda administrative town is situated in the urban kebele, namely Homosha town, which is 711 Km from Addis Ababa and 35km away from Assosa, the Regional capital of Benishangul-Gumuz (Figure 1).

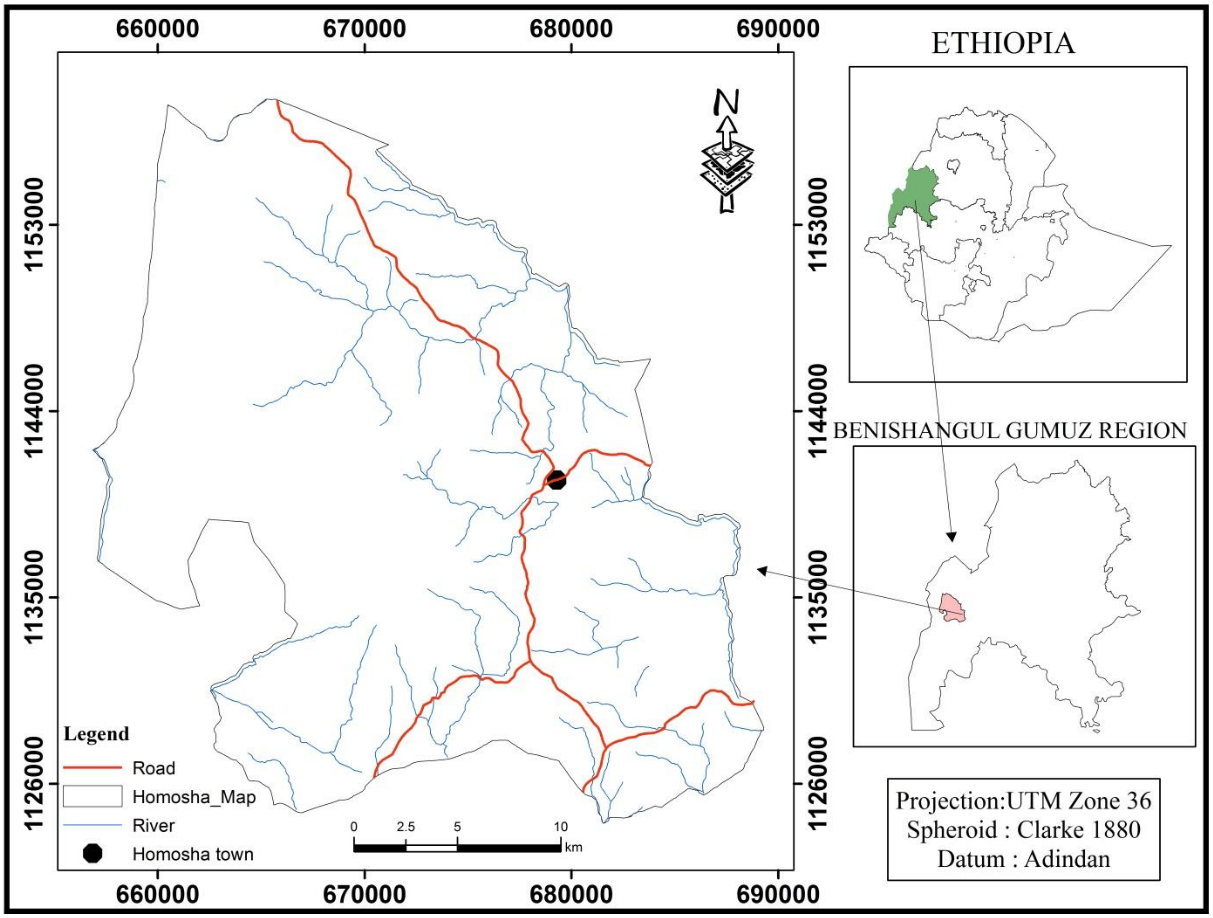

Figure 1: Map showing study area of Homosha Woreda

3.1.1.2. Topography

The study area is not characterized by different land features. The area has slope variation that ranges from 0^0-64.6^0 and physiographically dominated by lowlands. The altitude/elevation range is generally between 758-1942m.a.s.l. The highest peak is at Famatsere-gule Mountain and the lowest is the extreme western lowland near the Kurmuk and Assosa woredas boundary.

3.1.1.3. Climate: Temperature and Rainfall

Rainfall and temperature are the most important elements in characterizing the climatic condition of a given area.

3.1.1.3.1. Rainfall

The area is characterized by a unimodal rainfall pattern and obtains high rainfall during May to October. The highest rainfall record is in August. Unimodal rainfall phenomena are characteristics of whole Western part of Ethiopia. The mean annual rainfall of the area is 84.5mm. The mean of 2008/12 annual rainfalls of the five metrological stations during different months of a year are presented in Table 1and Figure 2.

Table 1: The mean monthly rainfall (2008-2012GC) in mm

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Assosa	1.2	6.5	0.6	61.4	132.5	211.4	114.4	173.1	215.8	140.2	23.1	9.5	90.8
Homosha	0.0	0.0	0.0	0.0	60.9	131.6	163.9	365.3	267.4	25.1	0.0	0.0	84.5
Kurmuk	0.0	0.0	0.0	12.0	48.4	154.8	161.5	234.8	226.4	119.0	89.3	56.4	91.9
Menge	0.0	0.0	29.6	54.2	72.3	111.8	101.2	160.8	59.8	63.1	0.0	0.0	54.4
Sherkole	0.0	2.5	0.0	78.1	147.8	196.9	132.0	112.5	124.9	82.1	11.8	0.0	74.1
Monthly average	0.2	1.8	6.0	41.2	92.4	161.3	134.6	209.3	178.9	85.9	24.8	13.2	79.1

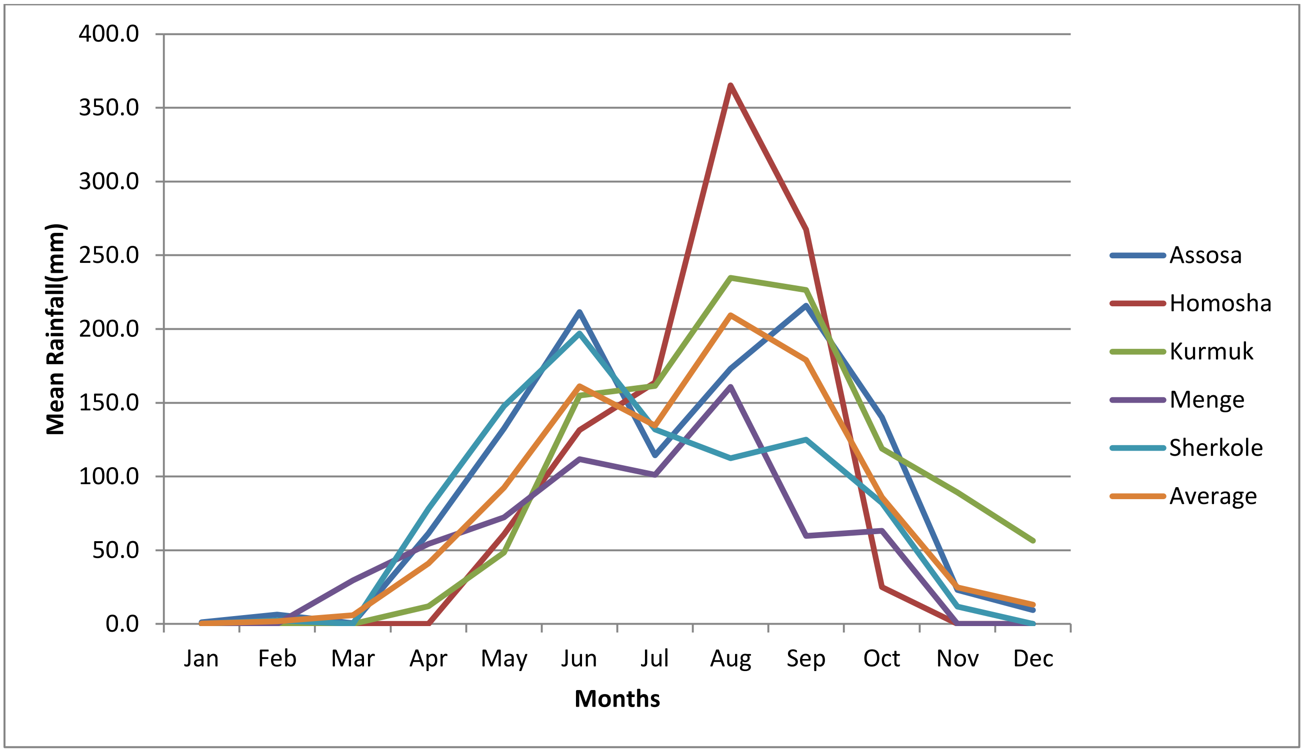

Figure 2: The mean monthly rainfall of the five metrological stations

3.1.1.3.2.Temperature

The area is of high temperature. This is due to the fact that, the temperature has inverse relationship with altitude. The area altitude is most dominantly low. This factor determines the mean local temperature ranging from 21.5^{o}C - 24^{o}C. The mean monthly temperature of the five metrological stations from 2008-2012 is shown in Table 2 and Figure 3.

Table 2: The mean monthly temperature (2008-2012GC) in ^{o}C

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Assosa	21.5	23.1	24.0	24.2	22.8	20.7	19.9	20.0	20.4	20.8	20.9	21.0	21.6
Homosha	23.1	22.8	22.0	22.3	21.7	22.5	23.3	21.5	22.0	22.7	24.0	23.1	22.6
Kurmuk	26.8	28.3	28.4	28.6	27.2	27.1	26.3	25.8	26.6	24.2	26.1	26.1	26.8
Menge	25.4	28.2	28.5	29.0	27.4	24.2	22.6	21.1	23.8	24.4	24.9	27.2	25.6
Sherkole	24.6	27.2	27.2	25.6	23.6	24.8	24.9	25.7	24.5	25.6	25.4	26.1	25.4
Monthly average	24.3	25.9	26.0	25.9	24.6	23.9	23.4	22.8	23.5	23.5	24.3	24.7	24.4

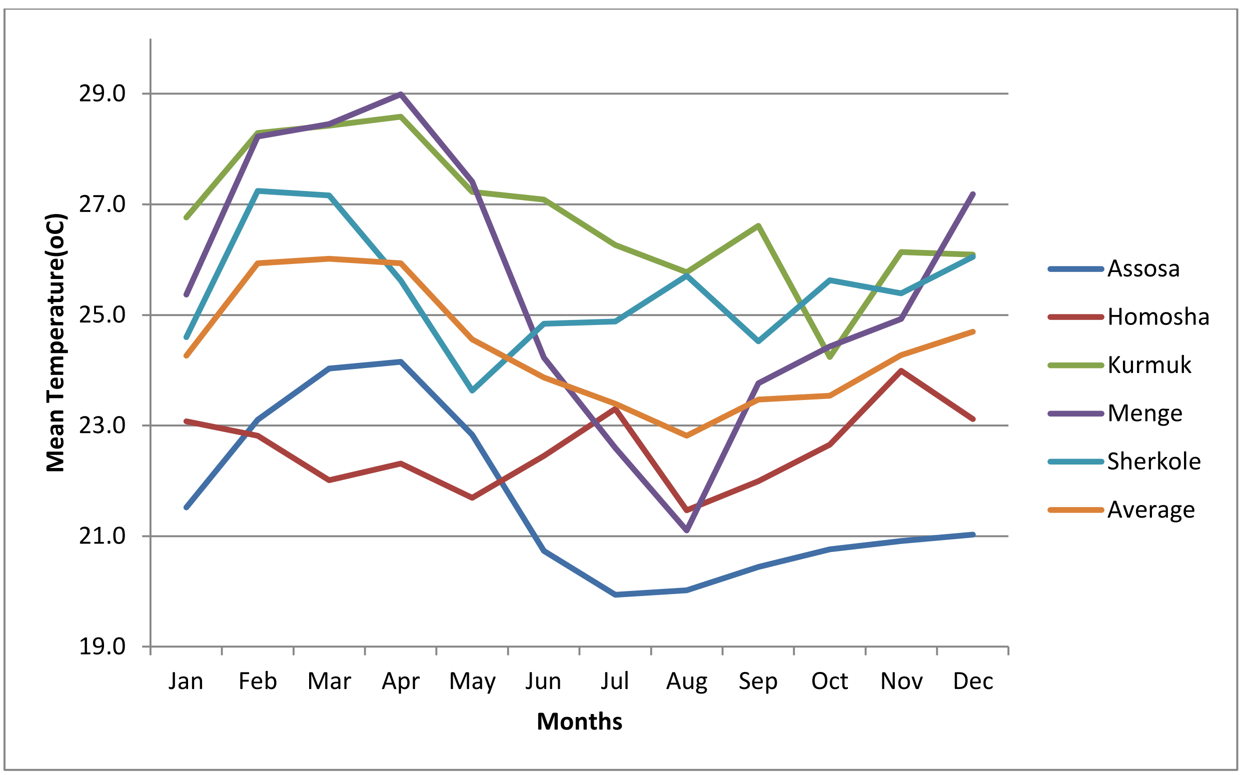

Figure 3: The mean monthly temperature of the five metrological stations

3.1.1.4. Soil
Soil is a mixture of mineral particles, organic matter, water and air. The classification of soil may be based on texture and mineral constituent. The types of major soil found in Homosha Woreda, as extracted from Soils and Geomorphology of FAO are Nitosols, Vertisols,Luvisols and Acrisols.

3.1.2. Socio-Economic Description

3.1.2.1.Economic Activities
The people in the study area "Homosha woreda" derive their livelihood from cultivation of crops (major cultivated crops are sesame, sorghum and maize), rearing of livestock, gathering wild foods, sale of fuel wood, charcoal and pottery, daily labor. Most income-generation activities are geared towards satisfying daily needs (to supplement food gaps). Goat rearing and traditional gold mining are also common practice in the area.

3.1.2.2.Population and Demography
According to the Central Statistical Agency (CSA, 2007), projected population of Homosha Woreda in 2013 is 27,617(14,257 males and 13,365 females) having annual growth rate of 3%. Among the total population of the area 26,146 are rural settler and 1,471(743 males and 728 females) are urban settler. Population density is 39.2 person km^2. The sex ratio, which is the number of males per 100 females, is 107 %. This indicates the excess of males over females. The corresponding figure of sex ratio for urban and rural population was 102 and 107. The variation in number of males and females affects the contribution made to socio-economic development of a community in defined area.

3.1.2.3.Infrastructure
In comparison to the past few years both the coverage and the quality of services are improved in Homosha woreda. The asphalt road from Addis Ababa via Assosa to Kurmuk border of Ethiopia passes through the woreda town. The Homosha town is connected to her neighboring woredas by asphalt and all-weather road networks. However, the road networks joining the city with rural kebeles are seasonal roads, which are functional only during dry seasons. In spite of this fact, the major means of transpiration in rural areas are human portage and pack animals (donkeys).

Through the effort made to improve access, quality, efficiency and equity of the education system, education institutions are constructed ,inputs fulfilled and upgraded as a result enrollment increased, gender gap decreased and girls' participation in schools are improved. According to BGRS (2013) data, 15 primary and 1 secondary school exist. The total number of student are 4,662(2,531 males and 2,131 females), and 317(251 males and 66 females) are enrolled in primary and secondary schools respectively. The Net Enrollment and Gross Enrollment Rates for primary (1-8) are 63.0 % (66.1% males and 59.7% females) and 83.0 % (87.8% males and 77.9% females) respectively. The Net Enrollment figure show 37 % school age children are out of school. This reveals that the current education institutions are not sufficient to address the effort toward achieving Millennium Development Goals (MDG) by 2015. Besides, education institutions are not well located.

The number and quality service of health centers are crucial to decrease Mortality rate of mothers and children and to create health expertise. To combat the health problem priority is given to the prevention of communicable diseases by expanding and updating the health centers. In the study area, there are three clinics and four health posts at the boundary of the area, which is not easily accessible for majority of people due to its physical distance and lack of all-weathered road network. In addition to this, lack of skilled health expertise and electricity are other challenges.

Concerning the water coverage, there are about 80 water points that are providing portable water for the people in the study area. Of these, 58 are hand dug well, 19 shallow well and 3 deep well. These water points are again concentrated around main road and schools sites.

Telecommunication and postal services are also at their lowest level of development in the area. There is no digital telephone station in boundary of the woreda. Only one desktop telephone systems exist in Homosha town. In the other hand all kebeles' of the woreda have access to wireless and/or mobile conductivity.

3.2. Data Sources, Material and Method

3.2.1. Data Sources

Effective utilization of large volumes of spatial data depends upon the existence of an efficient geographic data handling and processing systems that will transform these data into usable information.

To address the objective set by this study various data sets of both primary and secondary; raster and vector data were collected and used. Primary geographic data sources by direct measurement are captured specifically for use in GIS, while, secondary sources are those reused from earlier studies or obtained from other systems (longly et al, 2005).

Accordingly, Primary data: Landsat ETM+ satellite imagery having spatial resolution of 30 meter of the year 22 December 2013(path 171 and row 053) was used for land use/land cover classification. Digital Elevation Model (DEM) 30 meter spatial resolution data of Shuttle Radar Topographic Mission (SRTM) was used for slope and elevation analysis. They were obtained from U.S. Geological Survey (USGS) (*http://www.earthexplorer.usgs.gov).* Moreover, Ground Control Points (GCPs) were collected during field data gathering for all health centers, some missed water points and ground verification for the accuracy assessment of land use/land cover classification. GCPs were collected using Garmin 72 GPS satellite signal receiver.

Furthermore, secondary data: climate, population and infrastructure (road network) data sets were gathered from various sources. Mean monthly temperature and rainfall data for 5 stations were collected from National Meteorological Service Agency (NMSA) Assosa branch. These Climatic data were recorded for the last five years (2008-2012) at five different metrological stations, namely Assosa , Homosha , Kurmuk , Menge and Sherkole that are found surrounding the study area. Also, twenty years (1993-2012) hybrid mean annual temperature of satellite and meteorological station recorded data, known as gridded data, for 25 points having 10km distance within each other were collected from NMSA. Population and infrastructure (road network) were collected from Central Statistical Agency (CSA) and Regional Bureau of Finance and Economy Development respectively.

The socio-economic data sets were obtained from the respective regional Government Bureaux working on the area. Education Institutions and distribution were obtained from the regional Education Bureau. Similarly, infrastructural data about the water facility gathered from Regional Water, Energy and Mineral Bureau whereas Homosha Woreda shapefile (boundary 2007) collected from Regional Bureau of Finance and Economy Development.

3.2.2. Materials

In order to achieve the intended objective, Digital camera (14mp) and GPS 72 satellite receiver are used during the field work for gathering primary data. In addition, satellite imagery and diverse ancillary data have been used. Summary of materials used in this study is given in Table 3.

Table 3: Materials and softwares and sources

No	Type	Description	Source
1	Maps	Digital Soil map	FAO
		Woreda and Kebele boundary shape files	BG-BoFED
2	Softwares	ArcGIS, ERDAS-IMAGINE 9.2, Expert Choice software, 3DEM,MS-Excel ,MS-Access and GPS Utilities	AAU ,GIS Lab
3	Equipment/Instruments	Digital Camera(14mp) and GPS satellite receiver(GARMIN 72)	BG-REB

3.2.3. Methods

This study focuses at environmental suitability analysis for villagization of human being with respect to physical components and socio-economic constituents. Hence, it is important to consider all the major factors that affect collecting the scattered households through analysis of environmental suitability in a newly founded human settlement sites. It is vital considering of all variables results in better environmental suitability sites identification; however, huge financial input, data availability and time constraints would make it difficult for a private researcher to carry out the study. Hopefully, remote sensing techniques and GIS environment provide utility to treat every variable individually and reflect its relative influence through the weight assigned to it compared to other variables.

In this research work climate, land use/land cover and topography factors were considered as major factors of the physical environment while schools, health centers, water points and access to road networks were considered from the socio-economic environment.

Gridded temperature data having 25 sample points were interpolated using the kriging technique in the spatial analyst tool of ArcGIS to analyze temperature and to produce climate suitability mapping. This element of climatic variables was reclassified and standardized.

Land use /land cover were mapped from Landsat ETM+ satellite imagery of the year 22 December 2013 to classify the land use/land cover pattern of the study area. Image classification was carried out in two ways using ERDAS IMAGIN 9.2 software that is unsupervised classification before field visit and supervised classification after field survey by incorporating ground control points/truth collected during field work. Then land use / land cover map produced.

Slope and elevation data were derived from DEM of the Shuttle Radar Topographic Mission (SRTM) having spatial resolution of 30 meter. A slope in degrees was derived from DEM using the spatial analyst tool of ArcGIS. Both were reclassified in a GIS Environment using Spatial Analyst's Tool in order to produce slope and elevation suitability map of the study area.

The socio-economic data used in this study were analyzed based on the standard set by respective bureaux working on the area for the coverage / access of infrastructure in the study area. The schools, health centers, water points and road networks data were buffered using the multiple ring buffer technique in the analysis tools of ArcGIS to analysis infrastructure coverage/accessibility. They were reclassified and standardized using the spatial analyst tool of ArcGIS to produce infrastructures suitability mapping.

The pairwise comparison matrix was applied to produce the land use /land cover, combined topographic and infrastructure suitability maps measuring variables using a pairwise comparison method of Analytical Hierarchy Process (AHP). Actual factor weight and class weight (or rating) for parameters involved in the study were determined systematically based on the AHP. The priority of each factor involved in the AHP analysis is determined based principally on the villagization steering committee of Benishangul-Gumuz Regional state opinions. The method is implemented using the pairwise comparison technique that simplifies preference ratings among decision criteria. The first step of this procedure is to make pairwise comparisons between the vendors for each criterion. The standard scale for making these comparisons is shown in Table 4.

Table 4: The fundamental scale for pairwise comparison

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective.
3	Somewhat more important	Experience and judgment slightly favor one over the other.
5	Much more important	Experience and judgment strongly favor one over the other.
7	Very much more important	Experience and judgment very strongly favor one over the other. Its importance is demonstrated in practice.
9	Absolutely more important	The evidence favoring one over the other is of the highest possible validity.
2, 4, 6, 8	Intermediate values	When compromise is needed.
Reciprocals of above nonzero	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.	

Source: adapted from “Saaty” (2008)

Questionnaire is designed, developed and distributed where the villagization steering committee of Benishangul-Gumuz Regional state was asked to determine the relative importance of the involved criteria and factors through intensive group discussions. Results of the comparison (for each factors pair) were described in term of integer values from 1 (equal value) to 9 (extreme different) where higher number means the chosen factor is considered more important in greater degree than other factor being compared with. Moreover, to ensure the credibility of the relative significance used, AHP also provides measures to determine inconsistency of judgments mathematically. In this study, the questionnaires were distributed to experts and follow up interviews were conducted in all cases, to ensure that the respondents understood the contents of the questionnaire.

Finally, Weighted Overlay Analysis (WOA) in a GIS environment was used to map the Environmental suitability map of the study area after weights are calculated in Analytical Hierarchy Process (AHP). Figure 4 below indicates the general methodology flow chart followed throughout the work of this study.

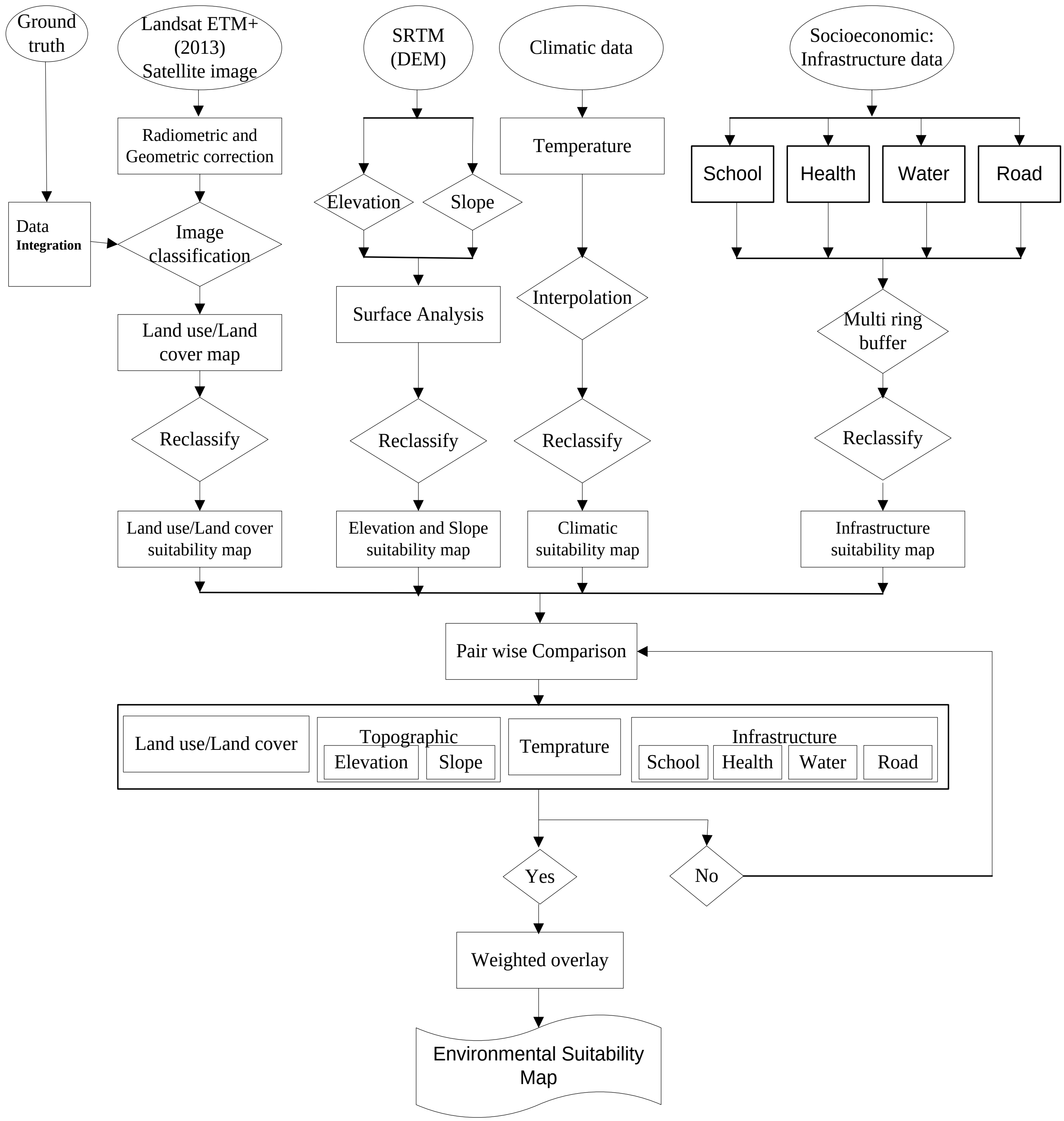

Figure 4: General methodology flow chart.

3.3. Data Processing and Analysis using GIS and AHP

The input environmental variables were projected to the same coordinate and extracted by Homosha woreda boundary to make sure that all inputs had the same extent. Image pre-processing operation such as rectification or restoration are done for the image used in this study so as to correct the radiometric and/or geometric distortion caused by sensors during data acquisitions before any analytical process on image. Cloud free Landsat ETM+ imagery (path 171 and row 053) that were acquired on 22 December 2013 were analyzed to classify the land use/ land cover of the study area.

3.3.1. Environmental Suitability Factors and Data Analysis using GIS

Based on the acquired information from literature search, previous works and discussions with experienced experts, there were four criteria determination and eight factors classification for identifying and prioritizing the potential villagization sites as presented in Table 5. These are land use/cover, topography (elevation, slope), socio-economic accessibility (proximity to schools, Health centers, water points, and distance from roads) and climate (temperature). These are the most important criteria and factors in determining what areas are best suited for villagization sites of human being.

Table 5: Criteria and factors for environmental suitability analysis for villagization sites

Factors	Units	Factors suitability rating					Reference
		High suitability	Moderate suitability	Marginal suitability	Currently not suitable (N1)	Permanently not suitable (N2)	
Slope	Degree	0-8^0	8^0-15^0	15^0-25^0	25^0-35^0	>35^0	Wei et al.(2013)
Elevation	m	>2000m	1500-1999m	1000-1499m	<1000m		MoH(2011)
Temperature	^{0}C	10^0 -16^{0}C	16^0 -21^{0}C	21^0 -32^{0}C	>32^{0}C	NMA(2012) and *www.EthioDemographyAndHealth.Org*	
Schools	Km	<3km	3-7km	>7km			BGRG (2011)
Water points	Km	<0.5km	0.5-1.5km	>1.5km			GoE(2010)
Health centers	Km	<10km	10-15Km	>15Km			BGRG(2012)
Distance to road	Km	<2 km	2-3Km	3-4Km	4-5Km	>5km	GoE(2013)
Land use/cover	class	Built up	Shrub	Agriculture	Forest	Questionnaire	

3.3.1.1.Physical Factors

3.3.1.1.1. Topographic Factors

3.3.1.1.1.1. Slope

The complexity of the area in terms of slope is a vital factor in the suitability analysis for human settlement. This factor shows the variation nature of earth surface with respect to degrees/percentage of rise. Slope determination of certain land type will benefit in various ways; in reducing construction cost, minimizing risks of natural hazards such as flooding and landslide. Slope is a safety indicator implying the gentler the slope the higher the safety factor and vice versa. The flatter the slope, the higher is the suitability of the area. On other hand, slope steepness will reduce the suitability of the area and surface materials on an area.

The study area has slope variation that ranges from 0^0 to $64.6^{\,0}$. According to Wei et al. (2013), systematic surface slope classification for human settlement in the study area was grouped in to five classes. The $0\text{-}8^0$ are highly suitable, $8^{\,0}$ - $15^{\,0}$ are moderately suitable , $15^{\,0}$ - $25^{\,0}$ marginally suitable , $25^{\,0}$ to $35^{\,0}$ are currently not suitable and greater than $35^{\,0}$ permanently not suitable.

The slope function calculates the maximum rate of change from every cell to its neighbors. The function is calculated over a 3x3 set of cells. If there is a cell location in the neighborhood with a NoData z-value, the z-value of the center cell will be assigned to the location *(http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/)*.The flatness or steepness for each cell can be evaluated either in degrees or percent. The rates of change (delta) of the surface in the horizontal (dz/dx) and vertical (dz/dy) directions from the center cell determine the slope. The basic algorithm used to calculate the slope in degrees is:

$$\textbf{Slope-degrees} = \arctan\left(\sqrt{\left(\frac{dz}{dx}\right)^2 + \left(\frac{dz}{dy}\right)^2}\right) * K \quad \text{------------------------------------- Equation 1}$$

where, K=constant, K =57.29578

The values of the center cell and its eight neighbors determine the horizontal (dz/dx) and vertical (dz/dy) deltas. The neighbors are identified as letters from A to I.

A	B	C
D	E	F
G	H	I

Surface window

$$\frac{dz}{dx} = \frac{(C+2F+I)-(A+2D+G)}{(8*X_{Cellsize})} \quad , \quad \frac{dz}{dy} = \frac{(G+2H+I)-(A+2B+C)}{(8*Y_{Cellsize})}$$

The reclassified slope map was given from the degrees measurement unit for human settlement requirement. Flat landform is the most suitable for human settlement because of good drainage, reasonable cost for construction and other environmental issues (Figure 5 and Table 6).

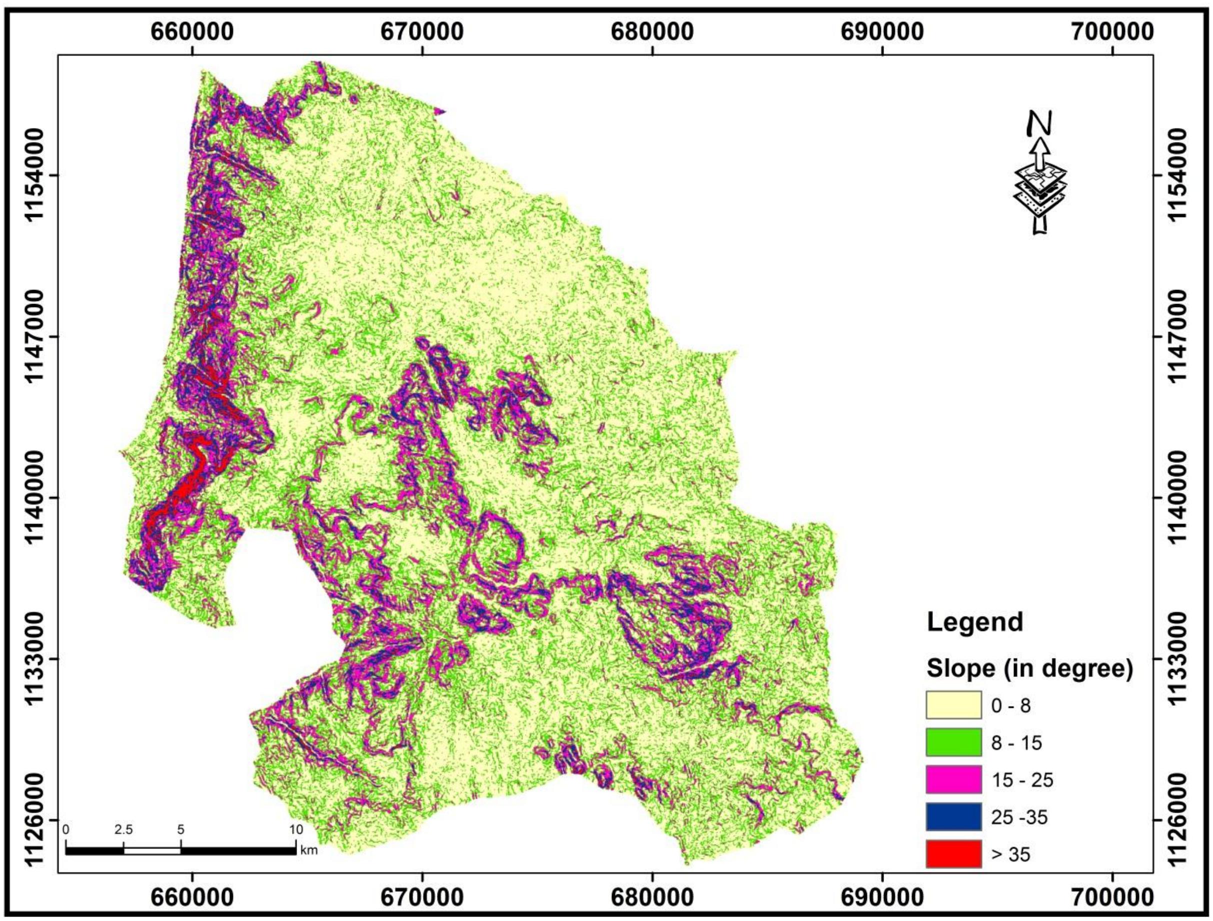

Figure 5: Slope Suitability Map of Homosha Woreda

3.3.1.1.1.2. Elevation

Elevation also called altitude is the height of place above or below a reference level such as mean sea level. To evaluate the nature and element of an area making the landscape what areas is suitable for human settlement, it is necessary to consider the position above mean sea level , because some species of flora and fauna have adapted themselves only in a limited elevation/altitude. For instance ,geographic distribution of Malaria disease for Ethiopia consists of four levels of elevation, those are, less than 1000m, 1000-1499m, 1500-1999m and greater than or equal to 2000m with the fact that Malaria transmission increase as elevation decrease below 2000m above the mean sea level (MoH, 2011). Homosha woreda is one of the areas' with high incidence of Malaria disease. Thus, villagization sites where Malaria occurrence expected are not suitable for human settlement.

Based on malaria distribution ecological zones of Ethiopia an attempt was made to categorize elevation of the study area. Homosha woreda has an elevation range from 758-1942 m above mean sea level, which lies in three ecological zones. Hence, the elevations of 758-1000 m are ranked as currently not suitable; 1000-1499m marginally suitable and 1500-1942 moderately suitable for human settlement (Figure 6 and Table 6).

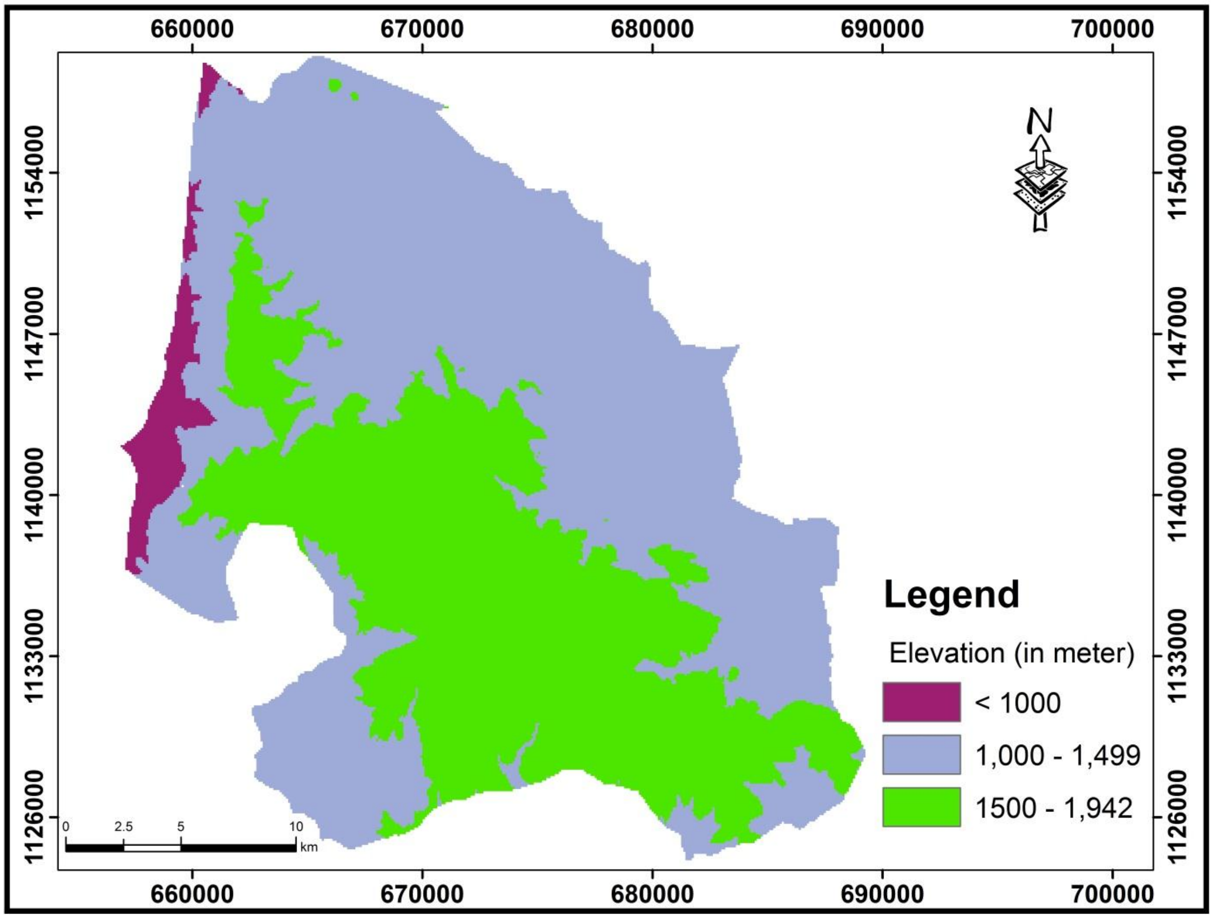

Figure 6: Elevation Suitability Map of Homosha Woreda

Table 6: Topographic Suitability classes and their area coverage

Factors	Classes	Suitability	Area (Km^2)	%
Slope	$0\text{-}8^0$	highly suitable	361.9	51.3
	$8^0 - 15^0$	moderately suitable	206.4	29.3
	$15^0 - 25^0$	marginally suitable	97.4	13.8
	$25^0 - 35^0$	currently not suitable	31.6	4.5
	$>35^0$	permanently not suitable	7.7	1.1
Elevation	>2000m	highly suitable	-	-
	1500-1999m	moderately suitable	275.6	39.1
	1000-1499m	marginally suitable	409.7	58.1
	<1000m	currently not suitable	19.7	2.8

3.3.1.1.2. Climatic Factors

Climate has greater influences on the suitability of environment for human settlement. The characteristics of diseases, animal distribution, hydrologic cycle, drainage conditions, distribution of vegetation, and crop adaptation are related to climate. Thus, climate affects the human settlement in certain area directly or indirectly through its complex relation with almost all environmental variables. In this research, temperature was considered as factors for analysis of environmental suitability sites for human settlement.

3.3.1.1.2.1. Temperature

Average temperature of certain area might determine the suitability of an environment for human settlement direct or indirectly. Patz et al. (2001) cited in Dagnachew Shibru. (2011) higher temperature is related with a couple of health related complications such as respiratory and cardiovascular problems. It is known that, heat stress may result in health complication including psychological depression .Temperature causes stress to human being in very hot and cool climates as a result work activities affected. Some vector –borne diseases have influenced by temperature of an area .Malaria is one of those; its occurrence is associated with temperature. The presence or absence of malaria epidemic could significantly affect human being in an area.

Ministry of health (2011), Malaria has a long history in Ethiopia of causing morbidity and mortality. It is prevalent in about three-quarters of the country's land mass, with minor seasonal and geographic variations. Malaria still is one of the top ten causes of health and socio-economic problems in the country. According to Tamiru Alemayehu (2006), Ethiopia has five climatic classification zones. Such as Mean annual temperatures range 10°C and less in the cool, 10°C - 15°C in the cool temperate, 15°C - 20°C in the temperate, 20°C - 25°C in the warm temperate and 25°C and above in the hot.

Ministry of health (2011), Malaria is a significant impediment to social and economic development in Ethiopia. In endemic areas, Malaria has affected the population during planting and harvesting seasons, cutting down productive capacity at a time when there is the greatest need for agriculture work. The disease has also been associated with loss of earning, low school attendance, and high treatment cost. According Ministry of health (2011), Malaria outpatient confirmed cases in Benishangul –Gumuz Region was 48,089 people. Thus, human settlement is affected by Malaria epidemic which in turn correlated with average temperature.

National Meteorological Agency (NMA) (2012) and *www.EthioDemographyAndHealth.Org* areas within mean annual temperatures of 10°-16°C is malaria free. Mean annual temperatures from approximately 16°-21°C and 21°-32°C is marginally and highly conducive for maintenance of transmission respectively. Where mean annual temperatures of above 32°C are moderately conducive (Dubit and Assaita in Afar Region) for malaria transmission in Ethiopia. According to Chikodzi (2013), areas with mean annual temperature below 22°C were considered unsuitable for Malaria disease transmission, while those from 22°C-32°C were deemed suitable for stable transmission. Temperatures above 32°C were deemed to be of moderate risk. However, in both cases thermal death for mosquitoes occurs around 40°-42°C and daily survival is zero at 40°C. The temperature suitability map of the study area from the reclassified and standardized temperature suitability classes is shown in figure 7.

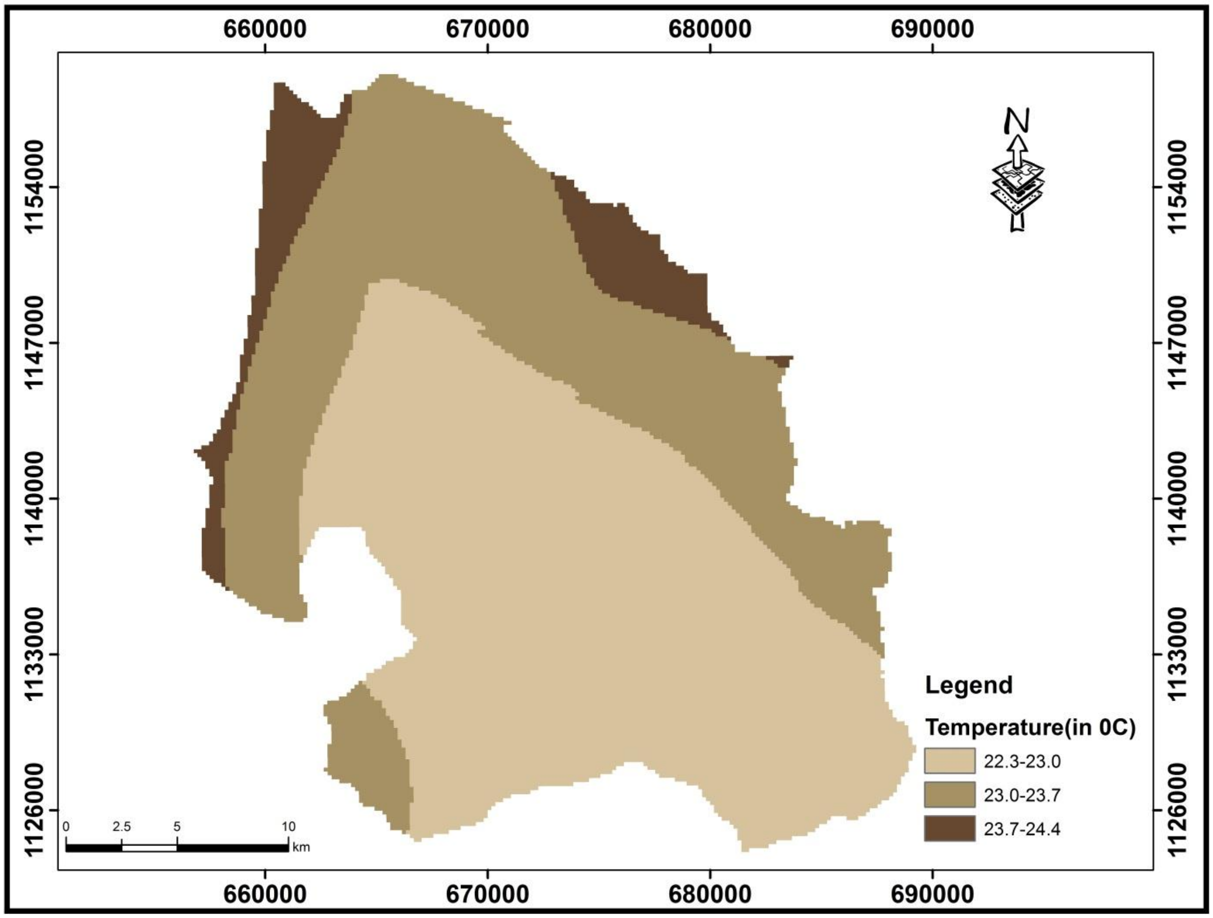

Figure 7: Temperature Suitability Map of Homosha Woreda.

3.3.1.1.3. Land Use / Land Cover

Land use/ land cover mapping is essential component wherein other parameters are integrated on the requirement basis to drive various index for land. Land use refers to human activities and the varied uses which are carried on land while land cover refers to natural vegetation, water bodies, rock/soil and artificial cover on the land (NRSA, 1989 cited in Prakasam, 2010).

Land Cover, defined as the assemblage of biotic and a biotic components on the earth's surface. Land cover is one of the most crucial properties of the earth system. Land cover includes: water, snow, grassland, forest, and bare Soil. Land Use includes agricultural land, built up land, recreation area and wildlife management area (Prakasam, 2010).

Land use and land cover is an important component in understanding the interactions of the human activities with the environment. Improper and intensive land use practices by human being mainly results in land degradation, flooding and eventually drought. Land use and land cover (LULC) change is dynamic and a major issue of global environmental change (Prakasam, 2010).

Thus, Land use and land cover are one of the essential factors in the analysis of environmental suitability for human settlement. It reflects day to day human activities on environment. Remotely sensed data of satellite image provides information on the spatial distribution of various land use / land cover analysis of land.

3.3.1.1.3.1. Land Use / Land Cover Classification

Remotely sensed image classification is the procedure of assigning similar pixels into groups that serves a specific goal that is, converting image data into thematic data for a particular purpose. The resulting classified image is comprised of a mosaic of pixels, each of which belong to a particular theme and is essentially a thematic map of the original image. In the application context, one is reasonably interested in thematic characteristics of an area rather than in the reflection values. Thematic characteristics such as land use / land cover can be used for further analysis and input into GIS based models. In addition, image classification can also be considered as data reduction: the n multispectral bands result in a single band raster file (Bakker et al., 2000).

There are two common image classification types: unsupervised and supervised classifications. In supervised classification, the partitioning of the feature space is realized by an operator who defines the spectral characteristics of the classes by identifying sample areas (training areas). The most common supervised classification techniques are the Maximum Likelihood classifier for parametric input data .The classification type requires the operator be familiar with the area of interest. Whereas in an unsupervised classification, clustering algorithms that compare the spectral signatures of a pixel with a computer determined cluster of signatures are used to partition the feature space into a number of clusters(Bakker et al., 2000).

This study used both types of image classification technique. These are unsupervised classification before field visit and the supervised classification after field survey to categorize the image into different land use / land cover classes using ERDAS IMAGIN 9.2 software. The scheme of land-use/land-cover classification utilized four classes that represent Built up, Agriculture, Shrub and Forest (Figure 8). The area coverage of classes are 23.3 km^2,241.5 km^2 ,434.1 km^2 and 6.1 km^2 for Agriculture land, Forest land, shrub land and built up areas respectively.

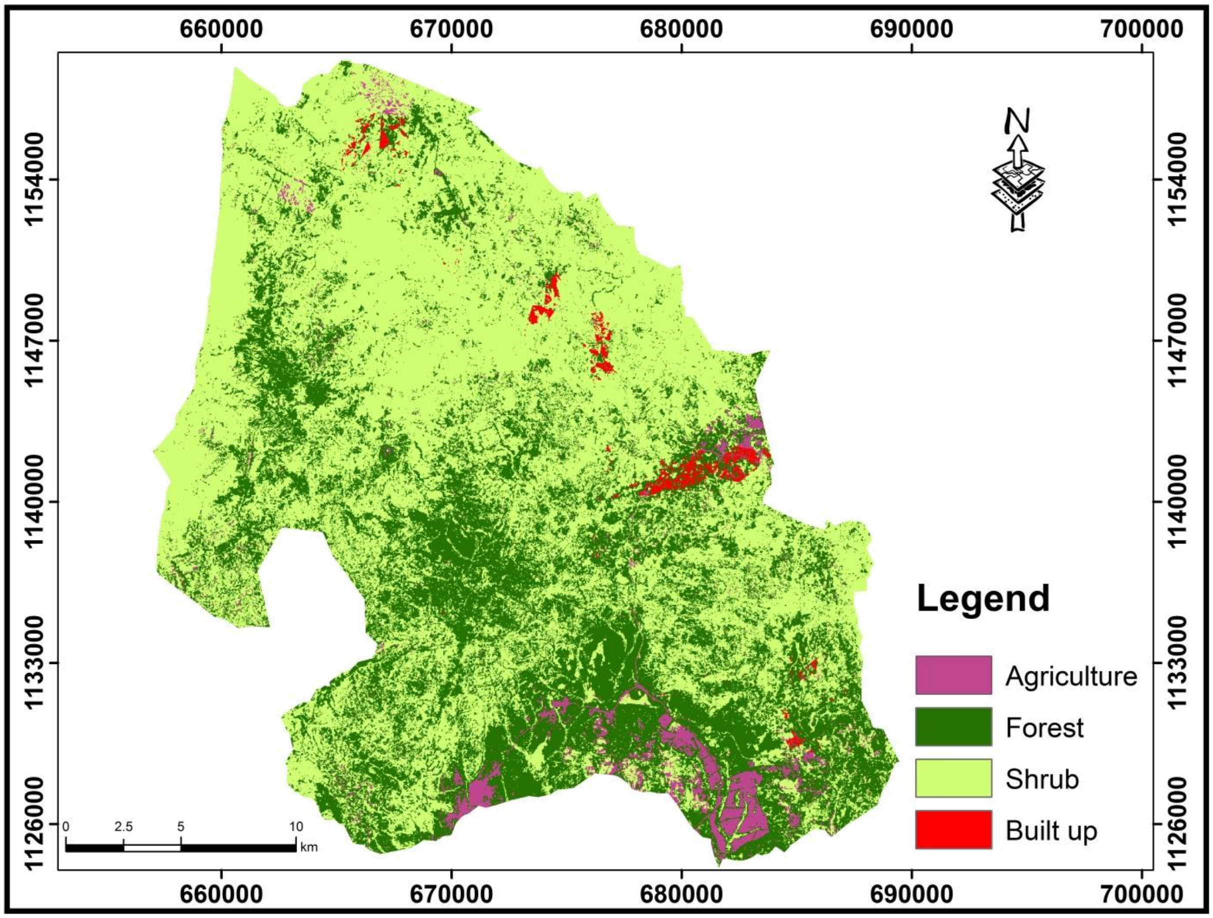

Figure 8: Land use / Land cover map of Homosha woreda

3.3.1.1.3.2. Accuracy Assessment

Land cover maps derived from remote sensing imagery always contain some sort of errors due to several factors which range from classification technique to method of satellite data capture. Therefore, owing to the complexity of digital classification, the reliability of the results needs robust and thorough assessments. One of the most common methods of expressing classification accuracy is the preparation of a classification error matrix or a confusion matrix (Congalton, 1991). It is a very effective way to represent accuracy because the accuracy of each category is evidently described.

Most assessments were conducted using the same data set as was used to train the classifier. The training and testing on the same data set result in overestimates of classification accuracy (Congalton, 1991). The accuracy of a classification is assessed by comparing the classification with some reference data that is believed to accurately reflect the true land-cover. Sources of reference data include ground truth and higher resolution satellite images. The present study, however, used a total of 998 randomly selected pixels for the 2013 Landsat ETM+ satellite imagery land use/land cover map, which were checked with 121 reference data (ground data) in the field to assess the accuracy of the classification.

The current study revealed an overall accuracy of 86.8% and a Kappa index, measure of agreement between the classification map and the reference data is 0.82 (Table 7).

It is stated that Kappa values of more than 0.80 indicate good classification performance. Kappa values between 0.40 and 0.80 indicate moderate classification performance and Kappa values of less than 0.40 indicate poor classification performance (Jensen, 2005 & Lillesand et al., 2004 cited in Abubaker et al., 2013). Based on this judgment, this study has proved high accuracy assessment for the image of 2013 Landsat ETM+ satellite imagery. The Kappa coefficient of 0.82 implies that the classification process is avoiding 82% of the errors that a completely random classification generates. Individual class accuracies ranged from 76.2% - 90.48% for producer's accuracy and 82.6% - 90.9% for user's accuracy. However, producer’s accuracy for agricultural land showed a value less than 80%. With regard to user’s accuracy all classes were over 80%.

It is to be noted that producer's accuracy is calculated as the total number of correct pixels in a category divided by the total number of pixels of that category as derived from the reference data (i.e. the column total). This accuracy measure indicates the probability of a reference pixel being correctly classified. If the total number of correct pixels in a category is divided by the total number of pixels that were classified in that category, it is said to be user's accuracy or reliability that represents reliability or probability a pixel class on the map represents the category on the ground.

Table 7: An error matrix for classification accuracy assessment of the 2013 image

	Classes	Reference Data(GCP)				RT	NC	PA (%)	UA (%)	OE (%)	CE (%)
		AL	FL	SL	BL						
Classified Data(PA)	AL	16	1	1	0	18	16	76.2	88.9	23.8	11.1
	FL	1	40	2	1	44	40	90.9	90.9	9.1	9.1
	SL	3	2	30	1	36	30	85.7	83.3	14.3	16.7
	BL	1	1	2	19	23	19	90.5	82.6	9.5	17.4
	CT	21	44	35	21	121	105	OA=86.8% , Kappa=0.82			

AL= Agriculture Land , FL= Forest Land , SL=Shrub Land , BL= Built up Land ,RT= Row Total , CT= Column Total , NC= Number Corrected , PA= Producer Accuracy , UA= User Accuracy , OE= Omission Error , CE=Commission Error , OA=Overall Accuracy

After the land use/land cover of the study area are evaluated for their accuracy they were reclassified and standardized. Finally they were assigned a suitability class based on their suitability for human resettlement. Accordingly the built up area were mapped as highly suitable, shrub lands were classified as moderately suitable, while agricultural lands were labeled as marginally suitable. Similarly, forest lands were mapped as currently not suitable.

3.3.1.2.Socio Economical factors: Infrastructure Proximity

3.3.1.2.1. Infrastructure Proximity Factors

The appropriateness of environment for human settlement is also determined by the presence or absence of sufficient infrastructure facilities .Consideration of all facilities: roads, schools, Health centers, Telecommunication, banks and others at a time could be more complicated. Large finance input requirement, data availability and time could be difficult for a private researcher to carry out the tasks in time .Therefore, it is important to consider the major factors that affects human settlement .In this work some of the most important and basic infrastructure factors are considered and analyzed, such as Schools, Water facilities, road networks and health centers.

3.3.1.2.1.1. Schools

Schools are a learning environment for human being. It is in schools that learners gain knowledge that influence and stimulate changes in their attitude and practice and develop life skills. Therefore, the environmental suitability site for human settlement should be at appropriate distance or within intended radius that the people get access to education. According to the BGRG (2011), the average distance of less than 3km is suitable, 3-7 km moderately suitable and more than 7km unsuitable coverage of schools (Figure 9).

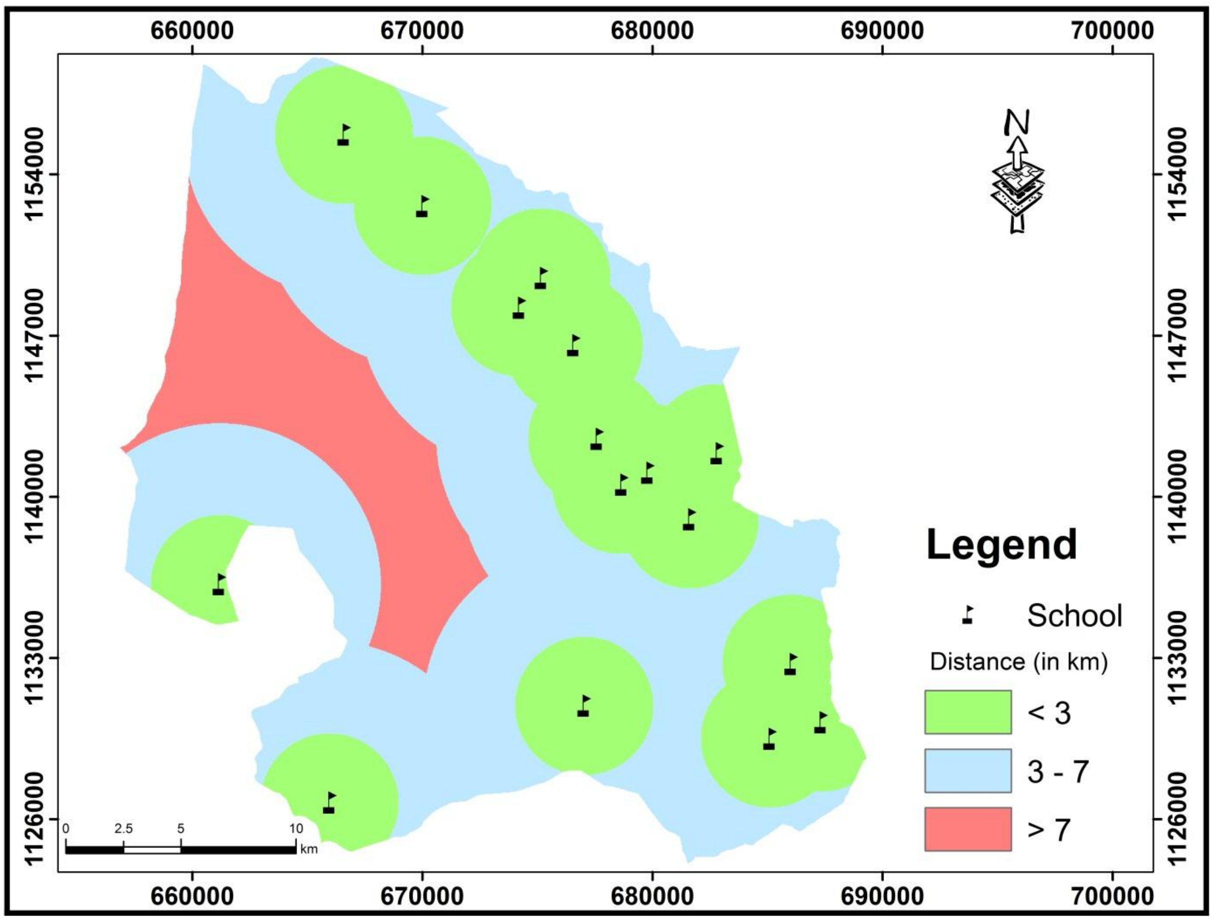

Figure 9: Schools accessibility Suitability Map of Homosha Woreda

3.3.1.2.1.2. Health Centers

Health centers and health posts refer to those institutions responsible for helping the community to improve their health status. They also offer education and consultation on hygiene practices (MoH and MWE, 2012).

According to the Ministry of health (2011), primary Health Care Unit (PHCU, includes health posts and health centers), general hospitals and specialized hospitals are expected to serve 5,000; 25,000 and 100,000 persons respectively. According to BGRG (2012), the distance of less than 10km for primary Health Care Unit is considered as suitable, 10-15 km moderately suitable and distance higher than 15 km is deemed as unsuitable access to health center. However, in Homosha Woreda the health center access distance varies among various administrative levels (Figure 10).

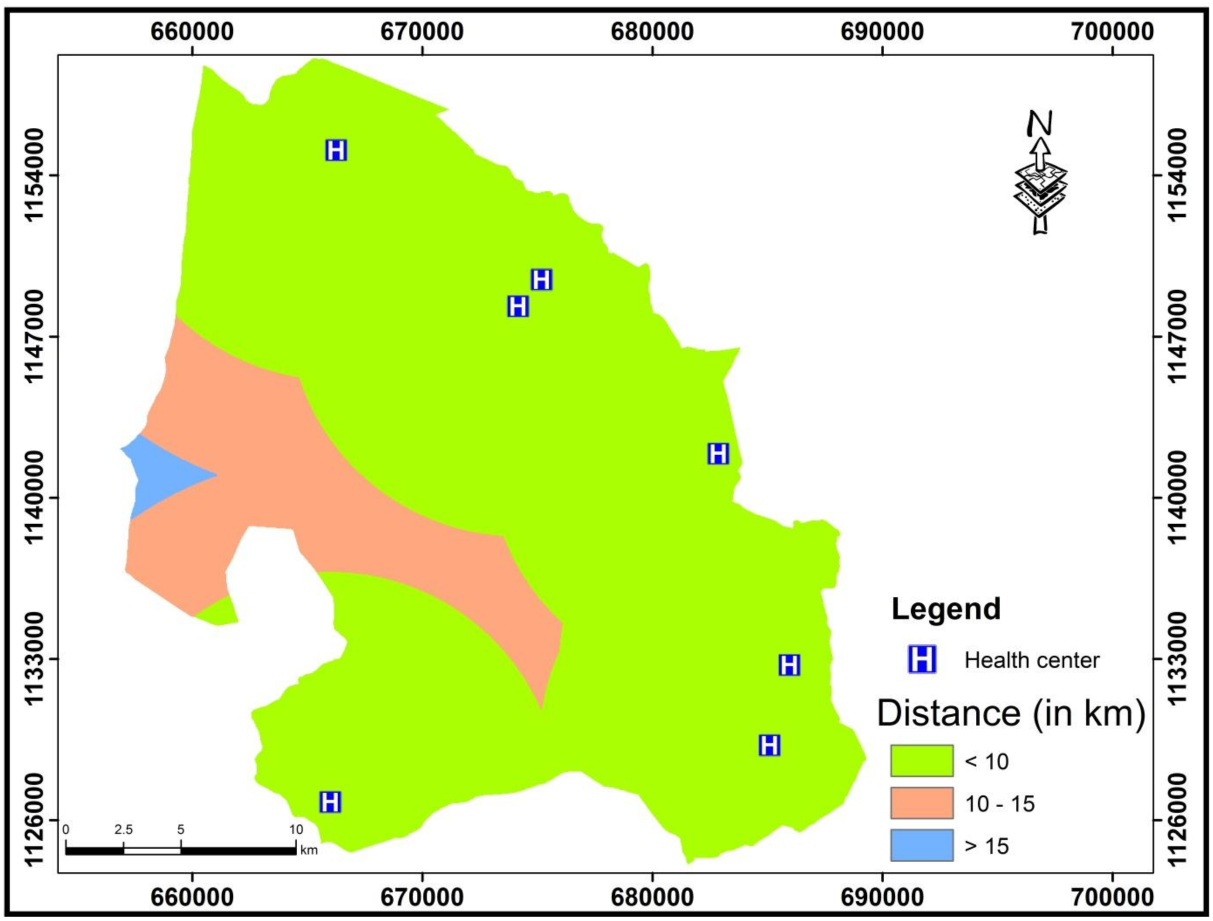

Figure 10: Health centers Suitability Map of Homosha Woreda.

3.3.1.2.1.3. Water points

Water is a universal solvent which is essential and compulsory for the growth and maintenance of human body and also for many biological activities. It plays a vital role for the survival of all forms of life on earth and works. Access to water source is one of the most important components to be considered in the analysis of environmental suitability for human resettlement. Water is a critically needed resource for both drinking and sanitary use , without adequate and reliable water supply, it is difficult to sustain human being in certain environment .Human needs water for different purposes including daily consumption at home for drinking, food processing, washing and sanitation. Therefore the existence and distribution of water have to be given due considerations in the analysis of environmental suitability for human resettlement as one component of environmental factor.

According to GoE (2010), the access to water supply points of distance less than 0.5km for water facilities is considered as highly suitable, 0.5-1.5 km moderately suitable and distance higher than 1.5 km is deemed as unsuitable access to water facilities (Figure 11).

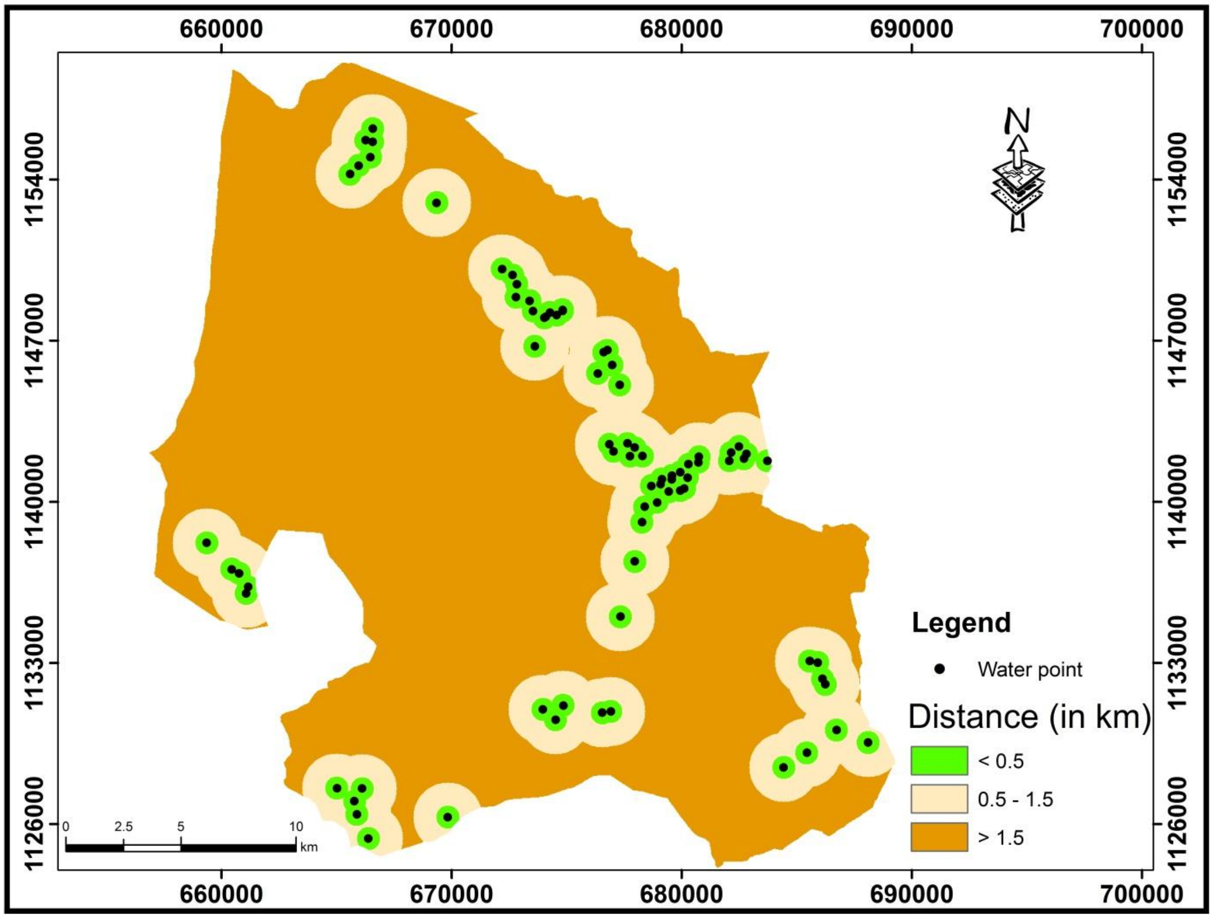

Figure 11: Water facility Suitability Map of Homosha Woreda.

3.3.1.2.1.4. Access to Road Network

Access to road network has significant impact on socio-economic growth of population. Human settlement sites should be at a very good distance from access to roads in order to acquire their daily likelihood. As a result, due consideration is given to road network as one component of infrastructure facility in mapping socio-economic environmental suitability factor of the area.

According to GoE (2013), the distance of less than 2 km for road network is considered as highly suitable, 2-3 km moderately suitable, 3-4 km marginally suitable, 4-5 km currently not suitable and distance higher than 5 km is deemed as permanently not suitable access to road network (Figure 12). Access of road network with distance less than 5 km is considered as suitable while distance more than 5 km is unsuitable access for human settlement GoE(2010),

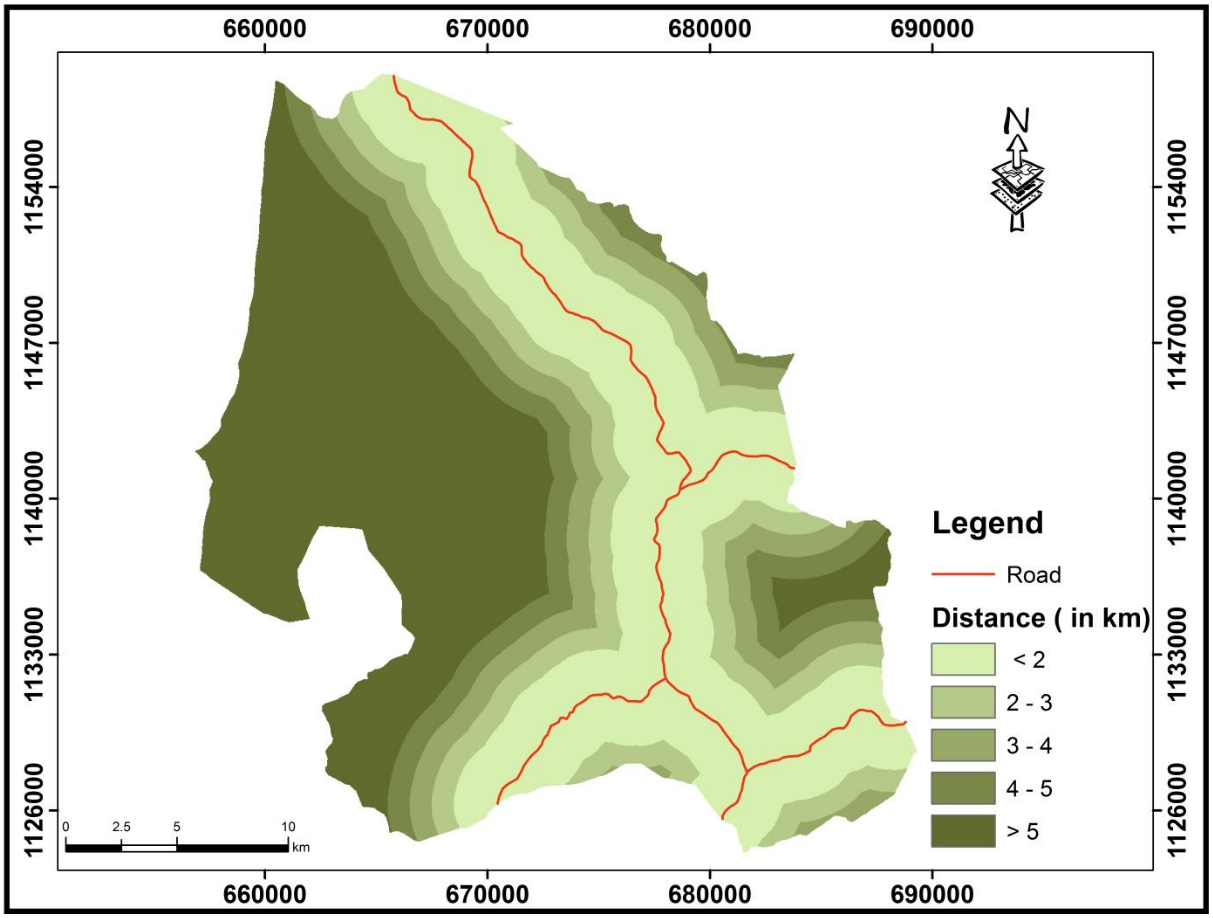

Figure 12: All Weather road network Suitability Map for Homosha Woreda

Table 8: Infrastructure Proximity Suitability classes and their area coverage

Factors	Classes	Suitability	Area (Km^2)	% share
School	< 3km	Highly suitable	275.6	39.1
	3-7 km	Moderately suitable	330.4	46.9
	>7 km	Marginally suitable	99.0	14.0
Health center	< 10km	Highly suitable	590.5	83.8
	10-15 km	Moderately suitable	108.0	15.3
	>15 km	Marginally suitable	6.5	0.9
Water point	< 0.5km	Highly suitable	41.1	5.8
	0.5-1.5 km	Moderately suitable	136.8	19.4
	>1.5km	Marginally suitable	527.1	74.8
Road network	<2 km	Highly suitable	234.2	33.2
	2-3km	Moderately suitable	91.3	13.0
	3-4km	Marginally suitable	74.4	10.6
	4-5 km	Currently not suitable	60.7	8.6
	>5 km	Permanently not suitable	244.4	34.7

3.3.2. Environmental Suitability Criteria Weight and Factors Weight

In order to produce the environmental suitability map for human settlement, the actual factors and class weights (or rating) of the parameters involved in the study are needed. These are determined systematically based on the AHP. Typically, the priority of each factor involved in the AHP analysis is determined based principally on the expert's opinions. The first step to achieve this goal was developing questionnaire where Benshangul-Gumuz Region Villagization steering committee having 12 members (Geographers, Health experts , Education experts ,Water experts, Environmental protection experts and agricultural experts)filled out through group discussion to determine the relative importance of each factor. The method evaluates the relative significance of all the parameters by assigning weight for each of them in the hierarchical order, and in the last level of the hierarchy, the suitability weight for each class of the used factors was given. Typically, the priority of each factor involved in the AHP analysis is determined based principally on the suggestions from experts (Saaty, 2008). Prioritization is the determination of the relative importance of the map elements which requires brainstorming among various experts to assign values on a

Saaty’s scale for a pair wise comparison of map elements (criteria). Experts were asked to rank the value of a criterion map for a pairwise matrix using Saaty‟s scale.

Analytic Hierarchy Process (AHP) is one of the most extended multi-criteria decision-making approache and was introduced by “Saaty” in 1980 (Triantaphyllou and Mann, 1995). It is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, sub-criteria, and alternatives. The pertinent data are derived by using a set of pairwise comparisons. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion. If the comparisons are not perfectly consistent, then it provides a mechanism for improving consistency.

Saaty(2008) , decision making, for which we gather most information, has become a mathematical science today. To make a decision we need to know the problem, the need and purpose of the decision, the criteria of the decision, their sub-criteria, stakeholders and groups affected and the alternative actions to take. We then try to determine the best alternative, or in the case of resource allocation, we need priorities for the alternatives to allocate their appropriate share of the resources. In addition, the AHP incorporates a useful technique for checking the consistency of the decision maker’s evaluations, thus reducing the bias in the decision making process.

AHP provides a structural basis for quantifying the comparison of decision elements and criteria in a pairwise technique (Al-Harbi, 2001). Once the pair wise matrix is made, relative weights are calculated by the following;

(1) For a matrix of pair wise elements (Normalization):

$$\begin{pmatrix} C11 & C12 & C13 \\ C21 & C22 & C23 \\ C31 & C32 & C33 \end{pmatrix} \quad \text{--Equation 2}$$

In step 1, sum the values in each column of the pairwise matrix,

$$C_K=\sum_{i}^{n} Cij \text{ , where k constant 1, 2, 3…}$$

--Equation 3

In step 2, divide each element in the matrix by its column total to generate a normalized pairwise matrix,

$$X_{ij} = \frac{1}{CK} * \begin{pmatrix} X11 & X12 & X13 \\ X21 & X22 & X23 \\ X31 & X32 & X33 \end{pmatrix}$$

-----------------------------------Equation 4

In step 3, divide the sum of the normalized row of matrix by the number of criteria used (n) to generate weighted matrix,

$$W_{ij} = \frac{1}{N} * \begin{pmatrix} W11 \\ W21 \\ W31 \end{pmatrix}$$

---Equation 5

(2) The consistency analysis:

Consistency vector is calculated by multiplying the pairwise matrix by the weights vector (priority vector),

$$\begin{pmatrix} C11 & C12 & C13 \\ C21 & C22 & C23 \\ C31 & C32 & C33 \end{pmatrix} * \begin{pmatrix} W11 \\ W21 \\ W31 \end{pmatrix} = \begin{pmatrix} Cv11 \\ Cv21 \\ Cv31 \end{pmatrix}$$

-----------------------Equation 6

Then it is accomplished by dividing the weighted sum vector with criterion weight,

$$Cv11 = [C11W11 + C12W21 + C13W31]$$

$$Cv21 = [C21W11 + C22W21 + C23W31]$$

$$Cv31 = [C31W11 + C32W21 + C33W31]$$

Consistency Measurement (CM) is calculated by dividing the Consistency vector by the weights vector (priority vector)

$$CM = \begin{pmatrix} Cv11 \\ Cv21 \\ Cv31 \end{pmatrix} \div \begin{pmatrix} W11 \\ W21 \\ W31 \end{pmatrix} = \begin{pmatrix} X1 \\ X2 \\ X3 \end{pmatrix}$$ -------------------------------- Equation 7

λ (eigenvalue) is calculated by averaging the value of the Consistency Measurement,

$$\lambda = \frac{\sum_i^n X\,ij}{N}$$ --Equation 8

Consistency index, CI measures the deviation, is calculated as follow:

$CI = \frac{\lambda - \mathrm{N}}{N-1}$, where, N is number of criteria used ---------------------------------------Equation 9

Consistency Ratio, CR is calculated as follow:

$CR = \frac{CI}{RI}$, where, RI is Random Consistancy Ratio. -----------------------------------Equation 10

Table 9: The average consistencies of random matrices (The Random Index—RI-values)

Size	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
RI	0		0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source: adapted from Al-Harbi, 2001.

However, to ensure the credibility of the output weights, the consistency ratio index (CR) was also calculated. Based on the properties of reciprocal matrices, the CR can be calculated. Dalalah et al., (2010) suggests that if the value of Consistency Ratio is smaller or equal to

10%, the consistency is acceptable. But if it is larger than 0.10(10 %,), then there are inconsistencies in the evaluation process, and the subjective judgment should be revised.

3.3.2.1.Calculation of the Details of the Criteria, factors and Class Weights

The method is usually implemented using the pair wise comparison technique that simplifies preference ratings among decision factors. In this study, Villagization steering committee opinions were used to calculate the relative importance of the involved criteria and factors. In this regard, the Benshangul-Gumuz Region Villagization steering committee having 12 members filled the questionnaire through group discussion. They were selected based on their experience on villagization scheme site selection. The questionnaire used contained the comparison matrices of the 4 major important criterion and the 8 factors selected for this study. The final weights of the criteria and factors were computed based on the AHP method. The calculations of pairwise comparison matrix and computation of consistency ratio for criterion are given in Tables 10 and 11, respectively.

Table 10: Development of the pair wise comparison matrix

Criteria	C1	C2	C3	C4
Land-use/Land- cover(C1)	1.000	2.000	4.000	7.000
Socio-Economic(C2)	0.500	1.000	3.000	6.000
Topography (C3)	0.250	0.333	1.000	4.000
Climate(C4)	0.140	0.167	0.250	1.000
Total(Sum)	1.893	3.500	8.250	18.000

The AHP also provides measures to determine inconsistency of judgments mathematically. The CR, which is a comparison between Consistency Index (CI) and Random Consistency Index (RI), can be calculated using the following formula:

$$CR = \frac{CI}{RI} \text{ , where, RI is Random Consistancy Ratio.}$$

Table 11: Computation of the criteria weights and estimate of the consistency ratio

Criteria	C1	C2	C3	C4	Sum	Weight	Consistency Measurement
Land-use/Land- cover(C1)	0.528	0.571	0.485	0.389	1.973	0.493	4.161595
Socio-Economic(C2)	0.264	0.286	0.364	0.333	1.247	0.317	4.170166
Topography (C3)	0.132	0.095	0.121	0.222	0.571	0.143	4.056999
Climate(C4)	0.075	0.048	0.030	0.056	0.209	0.052	4.026651
Total(Sum)	1	1	1	1		CI = 0.034618	
						RI = 0.9	
						CR =0.038464	

The consistency ratio presents values below 0.1. CR was also calculated and found to be 0.04 for environmental suitability for villagization,of human being which is acceptable to be used in the suitability analysis.

3.3.2.2.Calculation Detail of Factor Rate

This part shows the relative weights and rates of the attributes associated with the criteria. The calculations of pairwise comparison matrix and computation of consistency ratio for factors and classes are given in appendixes part. The calculations of factor rate performed in this work are as follows.

1. Land-use/land- cover

Step I: Development of the pair wise comparison matrix

Factors	Built up	Shrub	Agriculture	Forest
Built up	1.000	3.000	5.000	9.000
Shrub	0.330	1.000	3.000	7.000
Agriculture	0.200	0.330	1.000	5.000
Forest	0.110	0.140	0.200	1.000
Total(Sum)	1.644	4.476	9.200	22.000

Step II: Computation of the factor rate

Factors	Built up	Shrub	Agriculture	Forest	Sum	Weight	Consistency Measurement
Built up	0.608	0.670	0.543	0.409	2.231	0.558	4.304288
Shrub	0.203	0.223	0.326	0.318	1.070	0.268	4.275987
Agriculture	0.122	0.074	0.109	0.227	0.532	0.133	4.075511
Forest	0.068	0.032	0.022	0.045	0.167	0.042	4.043022
Total(Sum)	1	1	1	1		CI =0.058234	
						RI =0.9	
						CR =0.064704	

2. Socio-economic factors

Step I: Development of the pair wise comparison matrix

Factors	School	Water	Health	Road
School	1.000	0.330	0.250	3.000
Water	3.000	1.000	3.000	4.000
Health	3.000	0.330	1.000	3.000
Road	0.330	0.250	0.330	1.000
Total(Sum)	7.333	1.917	4.583	11.000

Step II: Computation of the factor rate

Factors	School	Water	Health	Road	Sum	Weight	Consistency Measurement
School	0.136	0.174	0.055	0.273	0.637549	0.159	4.037766
Water	0.409	0.522	0.655	0.364	1.949012	0.487	4.33117
Health	0.409	0.174	0.218	0.273	1.073913	0.268	4.334437
Road	0.045	0.130	0.073	0.091	0.339526	0.085	4.115347
Total(Sum)	1	1	1	1		CI =0.068227	
						RI =0.9	
						CR =0.075808	

3.3.3. Combining Criterion Weight and Standardized Criterion Maps

The aim of weighting criterion and factors in suitability analysis for villagization sites are to express the importance of each suitability factor relative to the other variables. It is also important to notice that the weights sum is 1. In this study Expert Choice software(developed in excel environment) tool applied for the pairwise comparison technique so as to calculate the values for the weights from an analytic hierarchy process (AHP) matrix and weighting the evaluation criteria.

All the physical and socio-economic suitability factors used in this study were exported into the environment of Expert Choice software tool for comparison purpose and eventually obtain their relative weight. Once the relative weights are evaluated, the values are used as input for multi-criteria evaluation in GIS environment. Figure 13: reveals the Expert Choice software weight derivation interface to derive the weights for the criterion and factors used in the analysis of environmental suitability for villagization sites.

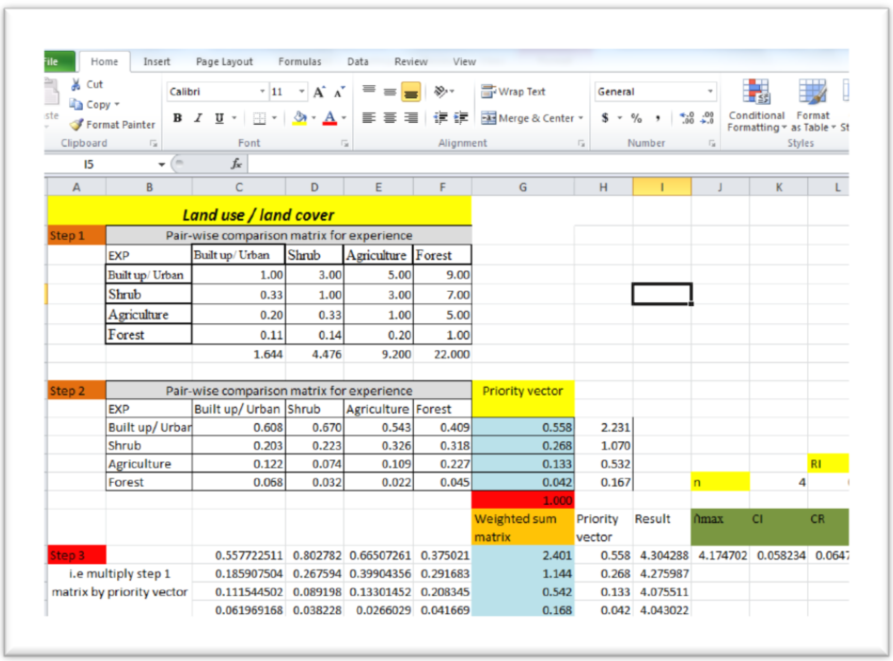

Figure 13: Expert Choice software weight derivation method for factors considered for Villagization site suitability analysis.

Geographic information system (GIS) can be used not only for storing, manipulating, analyzing, visualizing spatial data and producing maps for decision-making, but it is unique in its capacity for integration and analysis of multisource spatial datasets (Boroushaki and Malczewski , 2010). These data are manipulated and analyzed to obtain information useful for a particular application such as environmental suitability analysis for human settlement. Once the factors maps are developed and weighing of criteria performed, an evaluation step is carried out to aggregate the information from various sources. All criteria maps were overlaid using fundamental classes of multicriteria evaluation methods in GIS environment.

A combination rule can be defined as a procedure that enables the decision-maker to rank and select one or more alternatives from a set of available alternatives (Starr and Zeleny, 1977; Malczewski, 1999 cited in Boroushaki and Malczewski , 2010).There are many ways in which decision criteria can be combined in multi criteria decision analysis . Boolean overlay operators and weighted linear combination procedures of map combination(overlay) operations are two commonly used classes of GIS-based multi criteria decision analysis applications (Malczewski, 2006a cited in Boroushaki and Malczewski , 2010 and Malczewski , 2004).The simplest type of aggregation is the Boolean intersection or logical AND. This method is used only when factor maps have been strictly classified into Boolean suitable/unsuitable images with values 1and 0. The evaluation is simply the multiplication of all the images.

According to Drobne and Lisec(2009) , Weighted linear combination is based on the concept of a weighted average in which continuous criteria are standardized to a common numeric range, and then combined by means of a weighted average. The decision maker assigns the weights of relative importance directly to each attribute map layer. The total score for each alternative is obtained by multiplying the importance weight assigned to each attribute by the scaled value given for that attribute to the alternative and then summing the products over all attributes. The scores are calculated for all of the alternatives and that with the highest overall score is chosen. The method can be executed using any GIS system with overlay capabilities, and allows the evaluation criterion map layers to be combined in order to determine the composite map layer which is output. The methods can be implemented in both raster and vector GIS environments.

This study adopts only the weighted overlay technique for deriving composite suitability maps of villagization sites selection. The factors and their resulting weights were used as input for the multi criteria evaluation (MCE) module for weighted linear combination of overlay analysis.

The weighted overlay is used to drive composite suitability map for two or more input rasters data reclassified to a common measurement scale of 1 to N. The algorithm executed during weighted overlay process is presented as follow

(*http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=weighted_overlay*).

2	2	3
2	1	1
1	2	2

Input raster_1,
Influence (75%)

+

3	3	2
1	3	1
2	3	1

Input raster_2,
Influence (25%)

=

2	2	3
2	2	1
1	2	2

output raster

Each raster is assigned a percentage influence. The cell values are multiplied by their percentage influence, and the results are added together to create the output raster. For instance, consider the top left cell. The values for the two inputs become (2 * 0.75) = 1.5 and (3 * 0.25) = 0.75. The sum of 1.5 and 0.75 is 2.25. Because the output raster from Weighted Overlay is integer, the final value is rounded to 2.

CHAPTER FOUR

4. Results and Discussion

4.1. Environmental Suitability Analysis for Villagization sites in Homosha Woreda

It is mentioned in chapter 3, that environmental suitability analysis for Homosha Woreda was done by weighted overlay of the criterion that governs human settlement. The criterions are climate, topography, socio-economic and land use / land cover. Weight is made for all criterions deemed essential in this study with respect to each other using Analytical Hierarchy process (AHP). The suitability analysis result shows four classes of environmental suitability. These are, highly suitable, moderately suitable, marginally suitable and currently not suitable. Moreover, the area coverage of each environmental suitability classes were calculated after converting the raster output of the weighted overlay analysis to a polygon feature in a GIS platform. Each suitability classes are discussed as follow.

4.1.1. Topographic Suitability

The slope and elevation of the Homosha Woreda were independent analyzed. The area is characterized by five suitability classes of slope. This study considered the lower slope highly suitable than the land with higher slope, different research shows that areas with high slopes will have high risk of natural hazards: flooding and landslide, and high cost for construction of infrastructure. The majority of the study area falls under the slope class of 0-8^0, which covers 51.3% of the total study area. According to Wei et al. (2013), the land with a slope less than 8^0 is highly suitable for human settlement. Based on this, most of the land in Homosha Woreda is suitable for villagization site. Whereas 29.3%, 13.8%, 4.5% and1.1% of the study area was covered by slope classes 8-15^0, 15-25^0, 25-35^0 and greater than 35^0 respectively. However, 5.6 % of the area is found to have unsuitable slope either currently or permanently.

The elevation of the study area is between 758 to 1942m a.s.l , and has large varations in elevation , which is 1184 m. However, 58.1% of the study area lies between 1000 and 1499m a.m.s.l. The remaining 39.1% and 2.8% of the area falls within 1500 and 1999m a.m.s.l , and less than 1000m a.m.s.l respectively. Based on Malaria disease distribution ecological zones of Ethiopia areas with an elevation of 1000-1499m are considered as marginally suitable and areas with an elevation 1500-1942 are considered as moderately suitable for human settlement (MoH, 2011).

Finally, to produce combined topographic suitability of human settlement, slope and elevation variables were aggregated together. The result indicates 51.2%, 29.0%,13.8%,4.9% and 1.1% of the study area has highly, moderately, marginally, currently not and permanently not suitable for human settlement respectively in terms of topographic factors (Figure 14:1).

4.1.2. Climatic Suitability

The average annual temperature of the area falls between 22.3^0C – 24.4^0C.According to Tamiru Alemayehu (2006), Ethiopia has five climatic classification zones. The Mean annual temperatures range 10°C and less in the cool, 10°C - 15°C in the cool temperate, 15°C - 20°C in the temperate, 20°C - 25°C in the warm temperate and 25°C and above in the hot. Malaria prevalence is directly associated with the increase of temperature of the area. Thus, average temperature of certain area might determine the suitability of an environment for human settlement direct or indirectly. Homosha Woreda falls under single temperature class warm temperate, which covers 100% of the total study area (Figure14:3). . This shows that temperature is not a significant criterion for villagization site selection in Homosha Woreda.

4.1.3. Land Use / Land Cover Suitability

The land use/land cover of the study area was analyzed from the Landsat ETM+ of 22 December 2013 imagery. Questionnaire filled out through intensive group discussions by the Benishangul-Gumuz region villagization scheme steering committee having 12 members (Geographers, Health experts, Education experts, Water experts Environmental protection experts and agricultural experts) to prioritize land for human settlement/vilagization sites selection. In Homosha Woreda, major land cover and use classes were built up areas (0.9%), Shrubs (61.6%), agricultural fields, which is reserved for mechanized farm (3.3%) and forest lands (34.2%). Hence, the highest value is given for built up areas and shrub land class types to villagization site selection. The land which is covered by Agriculture and forest lands that account for about 37.5% from the total area.

4.1.4. Socio-economic Suitability: Infrastructure

4.1.4.1. Suitable distance from schools to villagization sites

The safeness of distances from schools to villagization sites might determine the quality, efficiency, equity and coverage / access of education system. Therefore schools must be available within appropriate distance so as to get maximum benefit from education and consequently to reduce time wastage due travel from school to house .According to BGRG (2011), the average distance of less than 3km is highly suitable, 3-7 km moderately suitable and more than 7km marginally suitable coverage of schools. In Homosha Woreda, the moderately suitable area covered the highest share as compared to other level of suitability. It covers 46.9% of the total area. The highly suitable and marginally suitable areas accounts 39.1 % and 14.0% respectively.

4.1.4.2.Suitable distance from Health centers to villagization sites

Health center refers to those institutions responsible for helping the community on health and sanitation issues to improve the health status. The Health centers should be found near to the villagization sites for human settlement. The suitability of access to health centers decrease as distance from sites increases. According to BGRG (2012), the distance of less than 10km for health center is considered as highly suitable, 10-15 km moderately suitable and more than 15 km is deemed as marginally suitable access to health center. In Homosha Woreda about 83.8% from the total area were located within a distance of 10km form environmentally sensitive area. The remaining 15.3 % and 0.9% belongs at distance of 10-15km and greater than 15 km respectively.

4.1.4.3.Suitable distance from water points to Villagization sites

The existing source of water supply for the study area is ground water. The villagization sites for human settlement must be located at appropriate distance from water sources. According to GoE (2010), the access to water supply points of distance less than 0.5km for water facilities is considered as highly suitable, 0.5-1.5 km moderately suitable and distance higher than 1.5 km is deemed as marginally suitable access to water facilities. Based on this, in Homosha Woreda 74.8% of total area is marginally suitable for villagization site. Whereas 5.8% and 19.4% of the study area was covered by water facilities classes of highly suitable and moderately suitable respectively.

4.1.4.4. Suitable distance from main roads to villagization sites

Villagization sites for human settlement must be located at suitable distance from roads network in order to facilitate transportation and consequently to reduce relative costs. According to GTP (2010), access to road network with distance more than 5 km is considered as unsuitable coverage for human settlement. In addition to this, GoE (2013), the land with a road network less than 2km is highly suitable for human settlement. Based on this, in Homosha Woreda 34.7% of total area is unsuitable (coverage of road network is more than 5km) for villagization site. Whereas 33.2%, 13.0%, 10.6% and 8.4% of the study area was covered by road network classes less than 2km, 2-3km, 3-4km, and 4-5km respectively. However, the 43.3% area is found to have unsuitable road network either currently or permanently. This shows that the study area's all weather road network coverage was poor. This means that there is no road network that joins kebeles within the boundary.

The aggregated infrastructure weighted overlay analysis for Homosha Woreda indicates that 22.4% of the area is highly suitable and large part (65.5%) of the area is moderately suitable for human settlement under various degrees. However, under the currently existing infrastructural facilities the remaining 12.1 % of the study area is marginally suitable (Figure 14:2). This is because they lack either one or more of the basic elements of infrastructural facilities that determine the suitability of the site for human resettlement.

The overall suitability level of the entire physical and socio-economic environmental suitability factors used in this study are summarized in Table 12 in terms of their area coverage(in square km) and percentage share. As it can be observed from the table almost all physical environmental factors and socio-economic variables, except topography aspect, are moderately suitable for human settlement.

Table 12: The area coverage and percentage share of environmental suitability factors

Factors	Suitability classes									
	Highly		Moderately		Marginally		Currently not		Permanently not	
	Area (in km^2)	% of share	Area (in km^2)	% of share	Area (in km^2)	% of share	Area (in km^2)	% of share	Area (in km^2)	% of share
Topography	361.0	51.2	204.4	29.0	97.6	13.8	34.4	4.9	7.5	1.1
Climate	-	-	705	100	-	-	-	-	-	-
LU/LC	6.1	0.9	434.1	61.6	23.3	3.3	241.5	34.2	-	-
Infrastructure	158.2	22.4	461.8	65.5	85.0	12.1	-	-	-	-

The environmental suitable sites selection for villagization involves comparison of different options based on physical and social- economic criterion and factors. Hence, based on experience and likely impact on human settlement, different weights were assigned to all the parameters. The larger the weight, the more important is the criterion in the overall utility. The weights were developed by providing a series of pairwise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated. The procedure by which the weights were produced follows the logic developed by Saaty in 1980 under the Analytical Hierarchy Process (AHP). Weight rates were given based on pairwise comparison 9 point continuous scale in Table 4 .These pairwise comparison were then analyzed to produce of weights that sum to 1(100%). The criteria and their resulting weights were used as input for the spatial analysis of weight overlay analysis. Accordingly, as shown in Table 11 land use/land cover suitability criteria takes the first and climate the least ranks. The calculated weights were lands use/land cover (49%), socio-economic (32%), topographic (14%) and climate (5%) for Homosha Woreda.

In order to combine all the layers to process overlay analysis, standardization of each data set to a common scale of 1, 2, 3,4 and 5 (value 1 = permanently not suitable, value 2= currently not suitable, value 3= marginally suitable, value 4 = moderately suitable, value 5 = highly suitable) was performed. Finally, all the parameters were weighted with their respective percent of influence and overlay to produce the suitability map of the study area (Figure 14).

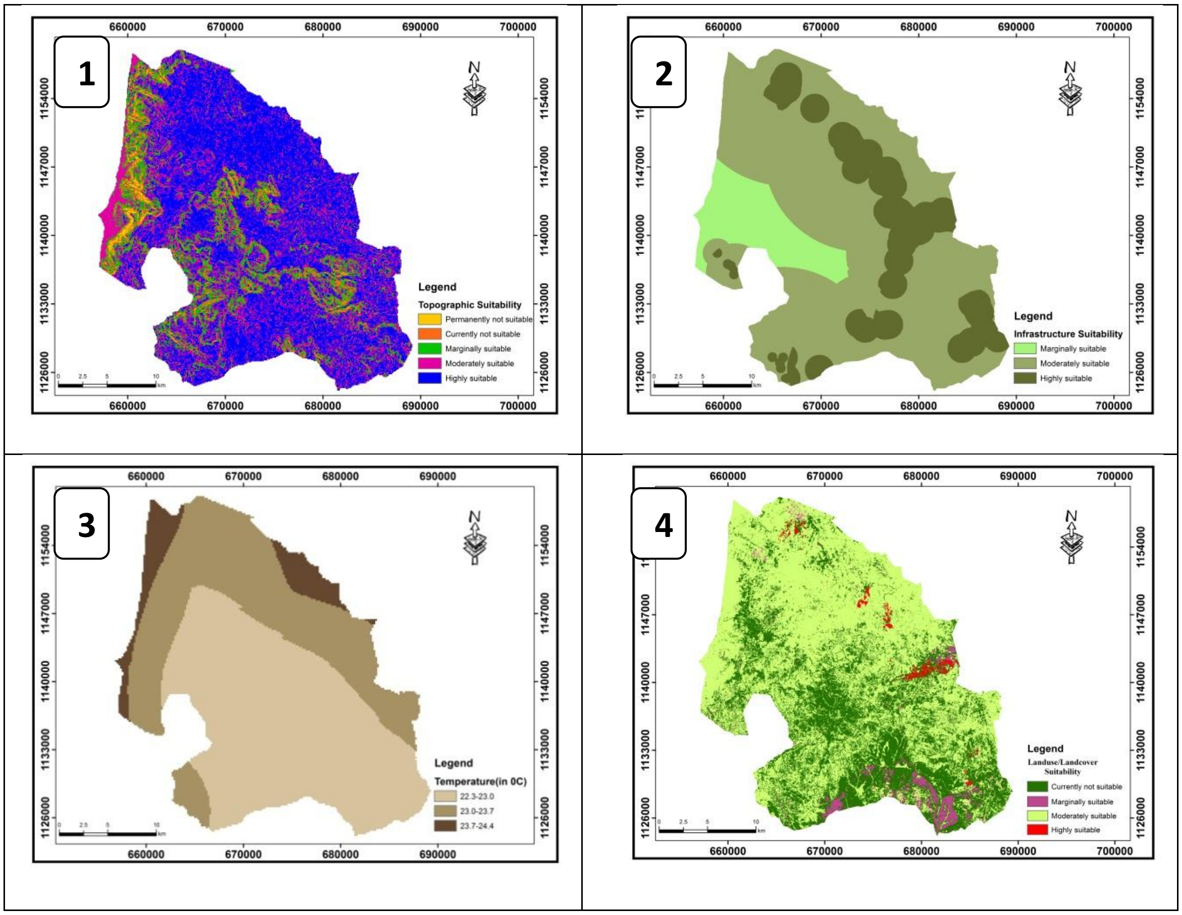

Figure 14: Standardized Environmental Suitability map of criterion

The final map (Figure 15 has four colors (classes)): red, green, jade and blue. The most suitable area for villagization site is marked by red color shaded. Out of the total area of the study site, about 1.2% (8.8Km^2) falls under this category. The green color represents moderate suitable area and it covers an area of 63.4% (447 Km^2). The areas which are shaded by jade and blue colors cover 34.6% (243.9 Km^2) and 0.8% (5.3 Km^2), representing marginally and currently not suitable for human settlement respectively (Table 13).

Table 13: The overall environmental Suitability in area coverage and percentage share

Suitability Classes	Area (in km^2)	Percentage (%)
Highly suitable	8.8	1.2
Moderately suitable	447	63.4
Marginally suitable	243.9	34.6
currently not suitable	5.3	0.8
Total	705	100

By using the stated criteria, environmental highly suitable areas for villagization sites where the physical and socio-economic conditions meet all the highest suitability requirements for human settlement fall on the north-east, east and south-east part of the study area following the main road that connects Assosa to kurmuk boarder of Ethiopia (Figure 15). Hence, the capacity to use integrated approach of GIS with AHP and remote sensing techniques for the effective identification of suitable villagization sites will minimize environmental risk, wastage of resource and human health problems.

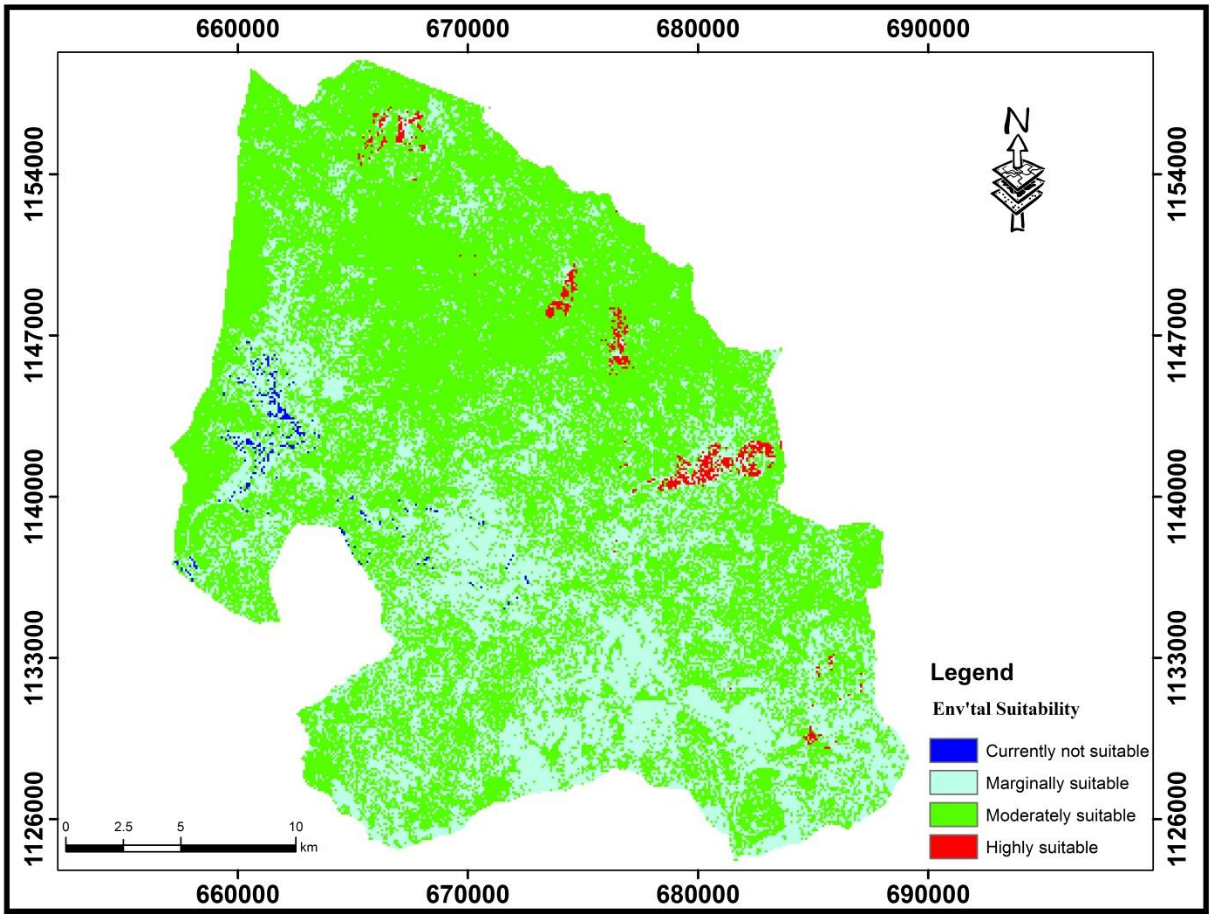

Figure 15: Environmental Suitability map of Homosha Woreda.

CHAPTER FIVE

5. Conclusion and Recommendations

5.1. Conclusion

The purpose of this study was to develop a new approach and to identify the environmental suitability of sites for villagization of human being in Homosha Woreda. This study presents an integrated approach of GIS with AHP to assess the environmental suitability sites for human settlement. This integrated approach is capable to resolve complex parameters for human settlement.

The main contribution of this study was the identification criteria and factors of villagization sites by applying the hierarchical structure of AHP in geospatial environment. The study started by the calculation of weighting and rating from the AHP analysis where the Benishangul-Gumuz region villagization scheme steering committee having 12 members were asked to determine the relative importance of each criterion and factor. The determination of criteria and classification of factors for the identification of villagization sites for human settlement were divided into 2 main categories: physical and socio-economic sections. There were four criteria and eight factors. These are topography (elevation, slope), climate (temperature), land use/ land cover and socio-economic (distance from road, distance from school, distance from health center and distance from water points).

The results of the analysis revealed that, some of the physical factors have crucial role in determining the environmental suitability sites for human settlement. The individual analysis of these criteria indicated that 705 km^2 (100%) of the study area has warm temperate climatic condition. This indicated that the area is more or less similar in its climatic condition, and 360.0km^2 (51.2%) of the study area has highly suitable topographic condition, which is more than half of the total area. The remaining proportion (29.0%) has moderately suitable topographic condition. Thus, Homosha Woreda is of large portion (80.2%) that belongs to highly and moderately suitable for human settlement. In relation to land use/land cover, 37.5% of the study area is marginally and currently not suitable for human settlement. This is due to the fact that the area is covered with forest and agriculture (agricultural area protected for Bal-zaf alcohol factory) which are not currently recommended for human settlement.

In the case of the socio-economic: such as infrastructure factor, the study area has relatively good number of school and water points compared to health centers. However, it is important to note that still large proportion of the area has low coverage of access to road and health centers. Largest portion (65.5%) of aggregated socio-economic factors of the study area has moderately suitable infrastructural facility. This implies that it is necessary for all stakeholders to work together to expand the basic infrastructural facilities.

It is therefore, Homosha Woreda, falls within four categories of environmental suitability classes. More than half 63.4% of the area is moderately suitable for human settlement having 447km^2 out of the total 705km^2, 34.6% marginally,0.8% currently not suitable and the remaining small proportion (1.2%) of the area has high environmental suitability condition that adequately satisfies all the major and most important suitability requirements of human settlement.

In conclusion, the result of this study could be used for generating alternative scenarios of environmental suitable sites for villagization of human being. In the same way, human settlement is a complex phenomenon involving besides its spatial dimension, social and environmental implications. Thus, a further study should be carried out with the implementation of other related factors for human settlement. This study should provide the stimulus for the continuation of research and future investigation on environmental suitable site for villagization of human being, utilizing this integrated approach which is capable to handle such complex parameter for environmental suitability.

5.2. Recommendations

Based on the findings of the study the writer of this research would like to recommend the drawn out the following points:

- It is necessary to use AHP analysis since it provides reflection of real situation of study area. This analysis was effectively used to calculate the details of the factors and class weights for environmental suitable sites for villagization of human being. Therefore, the integration of the GIS with AHP combines decision support methodology which in turn facilitates the creation of suitability map for villagization of human being.
- Priority should be given in moving people who were settled in marginally and currently not suitable areas into highly and moderately suitable areas so as to achieve the intended goals.
- Since human settlement is largely depend upon quality and access to basic services, the study recommends to harmony local and national stakeholder to construct schools, water points, roads and health centers in areas of moderately suitable for human settlement.
- Priority should be given to road network development. Thus, it makes easier the expansion and construction of school, health center and water points in the study area.
- Prepare guidelines for capacity building to specifically address issues related to villagization scheme (educate people on the concept of human settlement in nucleated sites).
- Since a small number of physical and socio-economic factors have been considered for the analysis of environmental suitability for human settlement, it is recommended to incorporate more factors to represent a holistic view of the actual process of environmental suitable sites for human settlement.

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Appendices

Appendix I: Ground Control Points

No	Longitude	Latitude	LU/LC type	No	Longitude	Latitude	LU/LC type
1.	676710	1146480	Built Up	2.	680055	1139940	Forest
3.	681270	1141530	Built Up	4.	686715	1129350	Forest
5.	682890	1142175	Built Up	6.	682380	1125840	Forest
7.	680055	1141080	Built Up	8.	682275	1145565	Agriculture
9.	683145	1141665	Built Up	10.	660720	1141740	Forest
11.	680700	1141290	Agriculture	12.	664665	1138110	Forest
13.	667395	1155315	Built Up	14.	680670	1138125	Forest
15.	674655	1149690	Built Up	16.	681660	1126635	Forest
17.	680775	1142175	Built Up	18.	675150	1142040	Shrub
19.	680340	1141260	Shrub	20.	672945	1136085	Forest
21.	679650	1141410	Built Up	22.	661530	1137480	Forest
23.	679110	1141740	Built Up	24.	665970	1125555	Forest
25.	683310	1141815	Built Up	26.	673485	1127550	Forest
27.	680925	1141395	Built Up	28.	682260	1128330	Shrub
29.	681960	1141890	Shrub	30.	671790	1134495	Forest
31.	673410	1147875	Built Up	32.	670275	1138110	Forest
33.	682815	1141110	Built Up	34.	681465	1127160	Forest
35.	680580	1141005	Built Up	36.	671580	1142295	Forest
37.	679350	1141185	Built Up	38.	682500	1136520	Forest
39.	679845	1141050	Built Up	40.	688605	1127715	Built Up
41.	679230	1141515	Built Up	42.	671055	1130490	Forest
43.	667425	1156275	Built Up	44.	671445	1137480	Forest
45.	684600	1129635	Forest	46.	668550	1125870	Forest
47.	668625	1141185	Shrub	48.	674190	1128735	Forest
49.	673080	1143435	Shrub	50.	685260	1133490	Forest
51.	659475	1145055	Shrub	52.	671475	1155900	Forest
53.	669585	1152345	Shrub	54.	665025	1129860	Forest
55.	665235	1152960	Shrub	56.	665190	1143570	Forest
57.	673935	1148085	Agriculture	58.	675645	1142295	Forest
59.	658590	1143510	Shrub	60.	671445	1134600	Forest
61.	668775	1134915	Shrub	62.	671880	1135710	Forest
63.	664125	1151625	Shrub	64.	670170	1152585	Forest
65.	658635	1136235	Shrub	66.	660990	1153230	Forest
67.	666825	1140405	Agriculture	68.	676140	1143435	Forest
69.	666825	1140135	Shrub	70.	674805	1132410	Forest
71.	663075	1141455	Shrub	72.	661395	1139145	Forest
73.	683655	1131015	Agriculture	74.	664890	1126785	Forest
75.	665175	1155255	Shrub	76.	677400	1132560	Forest

No	Longitude	Latitude	LU/LC type	No	Longitude	Latitude	LU/LC type
77.	666900	1139550	Shrub	78.	675120	1137285	Forest
79.	672825	1151685	Shrub	80.	686220	1137225	Forest
81.	683730	1140585	Shrub	82.	675435	1131600	Forest
83.	686100	1132590	Forest	84.	674535	1131900	Forest
85.	660525	1151130	Shrub	86.	680310	1130250	Agriculture
87.	669555	1153245	Shrub	88.	679275	1128870	Agriculture
89.	687030	1134630	Shrub	90.	683220	1127520	Agriculture
91.	668730	1151160	Shrub	92.	670005	1126140	Agriculture
93.	667995	1158285	Shrub	94.	681840	1126455	Agriculture
95.	669195	1148610	Forest	96.	687435	1129545	Agriculture
97.	662445	1154655	Shrub	98.	674490	1130835	Agriculture
99.	665460	1143615	Shrub	100.	673710	1131315	Shrub
101.	666240	1145655	Shrub	102.	680640	1129650	Agriculture
103.	681120	1132350	Shrub	104.	685170	1126335	Agriculture
105.	666120	1127700	Shrub	106.	671070	1126875	Agriculture
107.	658740	1144560	Built Up	108.	685080	1127970	Agriculture
109.	667110	1132050	Shrub	110.	682230	1125645	Agriculture
111.	668850	1127580	Shrub	112.	682005	1127160	Agriculture
113.	681495	1131165	Shrub	114.	661710	1136265	Agriculture
115.	662970	1130400	Shrub	116.	672945	1150170	Forest
117.	668325	1126470	Shrub	118.	688470	1129080	Agriculture
119.	683775	1127790	Forest	120.	663030	1148565	Agriculture
121.	687315	1130985	Forest				

Appendix II: Gridded temperature data

No	Longitude (Decimal Degrees)	Latitude (Decimal Degrees)	Hybrid mean annual temperature (^{0}C)
1.	34.404107	10.497541	26.1
2.	34.504107	10.497541	23.6
3.	34.604107	10.497541	24.2
4.	34.704107	10.497541	25.7
5.	34.804107	10.497541	25.7
6.	34.404107	10.397541	25
7.	34.504107	10.397541	23
8.	34.604107	10.397541	23.8
9.	34.704107	10.397541	24.1
10.	34.804107	10.397541	24.8
11.	34.404107	10.297541	24.6
12.	34.504107	10.297541	22.3
13.	34.604107	10.297541	22.4
14.	34.704107	10.297541	23.5
15.	34.804107	10.297541	24.2
16.	34.404107	10.197541	24.8
17.	34.504107	10.197541	23.3
18.	34.604107	10.197541	22.3
19.	34.704107	10.197541	22.5
20.	34.804107	10.197541	23.4
21.	34.404107	10.097541	26.3
22.	34.504107	10.097541	22.9
23.	34.604107	10.097541	21.8
24.	34.704107	10.097541	23.2
25.	34.804107	10.097541	24

Appendix III

3.1 .Land Slope

Development of the pair wise comparison matrix

Factors	$0-8^0$	$8-15^0$	$15-25^0$	$25-35^0$	$>35^0$
$0-8^0$	1.000	3.000	5.000	7.000	9.000
$8-15^0$	0.330	1.000	3.000	5.000	7.000
$15-25^0$	0.200	0.330	1.000	3.000	5.000
$25-35^0$	0.140	0.200	0.330	1.000	3.000
$>35^0$	0.101	0.140	0.200	0.330	1.000
Total(Sum)	1.787	4.676	9.533	16.333	25.000

Computation of the factor rate

Factors	$0-8^0$	$8-15^0$	$15-25^0$	$25-35^0$	$>35^0$	Sum	Weight	Consistency Measurement
$0-8^0$	0.560	0.642	0.524	0.429	0.360	2.514	0.503	5.455432
$8-15^0$	0.187	0.214	0.315	0.306	0.280	1.301	0.260	5.43179
$15-25^0$	0.112	0.071	0.105	0.184	0.200	0.672	0.134	5.20352
$25-35^0$	0.080	0.043	0.035	0.061	0.120	0.339	0.068	5.029699
$>35^0$	0.062	0.031	0.021	0.020	0.040	0.174	0.035	5.092594
Total(Sum)	1	1	1	1	1		CI =0.060652	
							RI = 1.12	
							CR = 0.054153	

3.2 Elevation

Development of the pair wise comparison matrix

Factors	>2000m	1500-1999m	1000-1499m	<1000m
>2000m	1.000	3.000	5.000	7.000
1500-1999m	0.330	1.000	3.000	5.000
1000-1499m	0.200	0.330	1.000	3.000
<1000m	0.140	0.200	0.330	1.000
Total(Sum)	1.676	4.533	9.333	16.000

Computation of the factor rate

Factors	>2000m	1500-1999m	1000-1499m	<1000m	Sum	Weight	Consistency Measurement
>2000m	0.597	0.662	0.536	0.438	2.232	0.558	4.222175
1500-1999m	0.199	0.221	0.321	0.313	1.053	0.263	4.174659
1000-1499m	0.119	0.074	0.107	0.188	0.487	0.122	4.0362
<1000m	0.085	0.044	0.036	0.063	0.228	0.057	4.040829
Total(Sum)	1	1	1	1	CI = 0.039489		
					RI=0.9		
					CR=0.043876		

3.3 Temperature

Development of the pair wise comparison matrix

Factors	<22^0C	22-32^0C	>32^0C
<22^0C	1.000	3.000	9.000
22-32^0C	0.330	1.000	5.000
>32^0C	0.110	0.200	1.000
Total(Sum)	1.444	4.200	15.000

Computation of the factor rate

Factors	<22^0C	22-32^0C	>32^0C	Sum	Weight	Consistency Measurement
<22^0C	0.692	0.714	0.600	2.006593	0.669	3.056955
22-32^0C	0.231	0.238	0.333	0.802198	0.267	3.025571
>32^0C	0.077	0.048	0.067	0.191209	0.064	3.005109
Total(Sum)	1	1	1		CI =0.014606	
					RI=0.58	
					CR=0.025182	

3.4 Schools

Development of the pair wise comparison matrix

Factors	<3 km	3-7km	>7km
<3km	1.000	5.000	9.000
3-7km	0.200	1.000	4.000
>7km	0.110	0.250	1.000
Total(Sum)	1.311	6.250	14.000

Computation of the factor rate

Factors	<3 km	3-7km	>7km	Sum	Weight	Consistency Measurement
<3km	0.763	0.800	0.643	2.205569	0.735	3.156746
3-7km	0.153	0.160	0.286	0.598257	0.199	3.048972
>7km	0.085	0.040	0.071	0.196174	0.065	3.011616
Total(Sum)	1	1	1		CI =0.036222	
					RI =0.58	
					CR =0.062452	

3.5 Water points

Development of the pair wise comparison matrix

Factors	<0.5 km	0.5-1.5km	>1.5km
<0.5km	1.000	3.000	7.000
0.5-1.5 km	0.330	1.000	5.000
>1.5km	0.140	0.200	1.000
Total(Sum)	1.476	4.200	13.000

Computation of the factor rate

Factors	<0.5 km	0.5-1.5km	>1.5km	Sum	Weight	Consistency Measurement
<0.5km	0.677	0.714	0.538	1.930167	0.643	3.121457
0.5-1.5 km	0.226	0.238	0.385	0.848517	0.283	3.062387
>1.5km	0.097	0.048	0.077	0.221316	0.074	3.012692
Total(Sum)	1	1	1	CI =0.032756		
				RI=0.58		
				CR=0.056476		

3.6 Health centers

Development of the pair wise comparison matrix

Factors	<10 km	10-15km	>15km
<10km	1.000	4.000	9.000
10-15 km	0.250	1.000	5.000
>15km	0.110	0.200	1.000
Total(Sum)	1.361	5.200	15.000

Computation of the factor rate

Factors	<10 km	10-15km	>15km	Sum	Weight	Consistency Measurement
<10km	0.735	0.769	0.600	2.103925	0.701	3.147466
10-15 km	0.184	0.192	0.333	0.709314	0.236	3.058023
>15km	0.082	0.038	0.067	0.186761	0.062	3.011301
Total(Sum)	1	1	1		CI =0.036132	
					RI=0.58	
					CR=0.062296	

3.7 Distance to roads

Development of the pair wise comparison matrix

Factors	<2km	2-3km	3-4km	4-5km	>5km
<2km	1.000	3.000	5.000	7.000	9.000
2-3km	0.330	1.000	3.000	5.000	7.000
3-4km	0.200	0.330	1.000	3.000	5.000
4-5km	0.140	0.200	0.330	1.000	3.000
>5km	0.110	0.140	0.200	0.330	1.000
Total(Sum)	1.787	4.676	9.533	16.333	25.000

Computation of the factor rate

Factors	<2km	2-3km	3-4km	4-5km	>5km	Sum	Weight	CM
<2km	0.560	0.642	0.524	0.429	0.360	2.514	0.503	5.455432
2-3km	0.187	0.214	0.315	0.306	0.280	1.301	0.260	5.43179
3-4km	0.112	0.071	0.105	0.184	0.200	0.672	0.134	5.20352
4-5km	0.080	0.043	0.035	0.061	0.120	0.339	0.068	5.029699
>5km	0.062	0.031	0.021	0.020	0.040	0.174	0.035	5.092594
Total(Sum)	1	1	1	1	1		CI =0.060652	
							RI =1.12	
							CR =0.054153	

Appendix IV: Partial view of the study area (Photographs taken during field work)

Villages

Agricultural land

Shrub land

Forest land

D E C L A R A T I O N

I hereby declare that the dissertation entitled "Environmental Suitability Analysis for Villagization Sites Using Analytical Hierarchy Process, Remote Sensing Techniques and GIS, The Case of Homosha Woreda, Benishangul-Gumuz Regional State, Western Ethiopia" has been carried out by me under the supervision of Dr. Getachew Berhan, School of Earth Sciences, Addis Ababa University, Addis Ababa during the year 2013-2014 as a part of Master of Science programme in Remote Sensing and GIS. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

Place: Addis Ababa

Date: May 2014

Signature ______________

(MELKAMU DESSALEGN)

C E R T I F I C A T E

This is certified that the dissertation entitled ***"Environmental Suitability Analysis for Villagization Sites Using Analytical Hierarchy Process, Remote Sensing Techniques and GIS, The Case of Homosha Woreda, Benishangul-Gumuz Regional State, Western Ethiopia"*** is a bonafied work carried out by Melkamu Dessalegn under my guidance and supervision. This is the actual work done by Melkamu Dessalegn for the partial fulfillment of the award of the Degree of Master of Science in Remote Sensing and GIS from Addis Ababa University. Addis Ababa.

Signature _______________

Dr. Getachew Berhan

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