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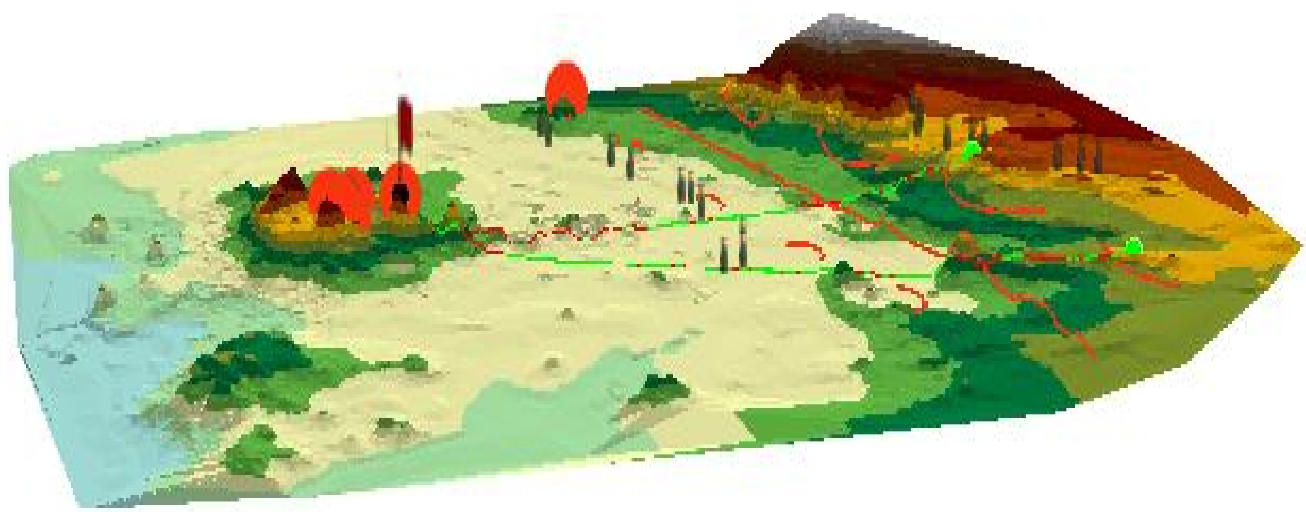
ANALYSIS ON TERRAIN AND RELATED CHALLENGES IN DEFENCE COMMAND POST SITE SELECTION USING WEB-BASED GIS, A CASE OF ADA'A DISTRICT, EASTERN SHOWA ETHIOPIA



A Thesis Submitted to the School of Graduate Studies of Addis Ababa University for Partial Fulfillment of the Requirements for the Degree of Master of Science in Remote Sensing and Geographic Information Systems

BY: MENBERE AKELE KIBRET

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Addis Ababa

ANALYSIS ON TERRAIN AND RELATED CHALLENGES IN DEFENSE COMMAND POST SITE SELECTION USING WEB-BASED GIS: A CASE OF ADA'A DISTRICT, EASTERN SHOWA ETHIOPIA

By

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A Thesis Submitted To
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Presented for Partial Fulfillment of the Requirements for the Degree of Master of Science in Remote Sensing and Geographic Information Systems

Under the guidance of

Mr. Degelo Sendabo

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School of Graduate Studies

This is to certify that the thesis prepared by Menbere Akele Kibret, entitled: "***Analysis on Terrain and Related Challenges in Defense Command Post Site Selection Using Web-Based GIS: A Case Of Ada'a District, Ethiopia***" and submitted for partial fulfillment of the requirements of Degree of Master of science in Remote Sensing and GIS compiles with the regulations of the university and meet the accepted standards with respect to originality and quality.

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CERTIFICATE

This is to certify that the thesis entitled *"Analysis on Terrain Related Challenges on Defense Command Post Site Selection Using Web-Based GIS: A Case Of Ada'a District, Ethiopia"* is a bonafied work carried out by Menbere Akele under our guidance and supervision. This is the actual work done by Menbere Akele for the partial fulfillment of the award of the Degree of Master of Science in Remote Sensing and Geographic Information Systems from Addis Ababa University, Addis Ababa.

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DECLARATION

I, the undersigned, declare that this thesis is my original work, has not been presented for a degree in any other university and that all sources of materials used for the thesis have been duly acknowledged.

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ABSTRACT

Analysis on Terrain and Related Challenges in Defense Command Post Site Selection Using Web-Based GIS, a case of Ada'a District, Ethiopia

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Addis Ababa University, 2015

The defense force keeps the sovereignty of the nation and responsibility to the operation of mission success at right time and place to control key terrain areas, to deliver logistics and to combat troops with accurate terrain information. But manually combining terrain information is tiresome, time taking, costy and results vary from expert to expert, therefore the analysis of terrain features for command post best site selection is one of the basic tasks from different military operations and the study provides decision makers and commanders to analyze the terrain visually using automated systems to obtain correct information about the terrain and evaluate the terrain in terms of military aspects. To understand the ground and achieve military goals, the basic sources of information for studying the terrain are topographic maps, aerial photographs, military sketches and sand model. This research paper identifies terrain features for defense command post site selection using RS and GIS techniques and customize and publish maps in web-GIS C4I system for decision makers or commanders. The command post suitable site selection is based on input data layers of elevation, slope, roads, land use land cover, soil types, geological and geomorphological features. The multi-attribute and multi-criteria evaluation methods (GIS with AHP) are used for factor analysis and aggregation. Multi factor analysis or weighted overlay analysis assigns more importance of some criteria over the others. The AHP principle can be used to aggregate the priority for all level of hierarchy structure and the method can be done using any GIS system having overlay capabilities, combine input layers and generate the output command post suitable map. The result showed that optimal sites clearly identified as a higher elevation weight equal to 39% influence is the most important criteria from others. The resulting maps of GIS – AHP indicates best result and suitable location for military command post in Ada'a district.

Keywords: Ada'a, AHP, C4I, Command Post, Terrain, Web-GIS

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ACRNOMYS

- AAs - Avenue of Approaches
- AAU - Addis Ababa University
- AHP - Analytical Hierarchical Process
- AI - Artificial Intelligence
- API - Application Programming Interface
- ASP - Active Server Pages
- C2 - Command and Control
- C4I - Command, Control, Communication, Coordination and Intelligence
- CCM - Cross-Country Movement
- CV - Consistency Vector
- DEM - Digital Elevation Model
- DSS - Decision Support System
- ERDAS - Earth Resources Data Analysis System
- FAO - Food and Agriculture Organization
- FM - Field Manual
- GIS - Geographic Information System
- HTML - HyperText Markup Language
- HTTP - HyperText Transfer Protocol
- ILRI - International Livestock Research Institute
- INSA - Information Network Security Agency
- IPB - Intelligence Preparation of the Battlefield
- ISO - International Organization for Standardization
- IT - Information Technology
- ITCZ - Inter Continental Convergence Zone
- JSON - JavaScript Object Notation
- JSP - Java Server Pages
- LOS - Line of Site
- LULC - Land Use Land Cover
- MCDA - Multi- Criteria Decision Analysis

- MIL - STD - Military Standards of Symbology
- MoND - Ministry of National Defence
- OCOKA - Observation and Field of Fire, Cover and Concealment, Obstacles, Key Terrain and Avenue of Approach
- OGC - Open Geospatial Consortium
- PCM - Pair wise Comparison Matrix
- PHP - Hypertext Preprocessor
- RS - Remote Sensing
- SMCE - Spatial Multi-Criteria Evaluation
- SDSS - Spatial Decision Support Systems
- TIFF - Tagged Image File Format
- TIN - Triangulated Irregular Network
- URL - Universal Resource Locator
- USAID - United States Agency for International Development
- UTM - Universal Transverse Mercator
- UNESCO - United Nations Education, Scientific and Cultural Organization
- WCS - Web Coverage Service
- WFS - Web Feature Service
- WGS - World Geodetic System
- WLC - Weighted Linear Combination
- WMS - Web Map Service
- WOA - Weighted Overlay Analysis
- XML - Extensible Markup Language

CHAPTER ONE

INTRODUCTION

1.1. Background

The need to understand terrain has always been an essential requirement for military commanders. This understanding has been supported by paper maps enabling military operations for hundreds of years. The imperative to evolve the paper map to the digital environment has included military advances and applications such as motorized vehicles, aircraft, resource assessment and now digitization (Northrop, 2002, Bedenbough, 2006).

The effectiveness of Command, Control, Communication and Coordination in military operations is largely dependent on the availability of accurate information. In the digital era, GIS is an excellent tool for military commanders in the operations (Chandan, 2014). There are several instances in military history wherein a smaller army having a good knowledge of the terrain has defeated a much larger, well-equipped and organized army. Planning of military operations is a complex process and is guided by the experience and capability of the commander and the staff. This decision making process can be made intelligent by developing geospatial web-based systems. A GIS-based approach is capable of taking inputs in the form of data layers that may be generated from satellite images, aerial-photographs, topographical maps or any other ancillary data (Baijal *et al.* 2000).

From its early beginnings, GIS has been an integrating technology both from the point of view of its development as well as its use. This is because, once geographic information of any kind is translated into the digital form in a GIS, it becomes easy to copy, edit, analyze, manipulate and transmit it. This allows vital linkages to be made between apparently unrelated activities based on a common geographic location. This has led to fundamental changes in the way resource management decisions are made in a variety of situations. The modern battlefield is highly mechanized with heavy arms and ammunitions to shift around (Chandan, 2014). The mobility of any armored column depends upon the terrain conditions over which it has to move. Parameters like topography, soil type, land use and land cover have a direct bearing on the mobility, methods of crossing obstacles, selection of tactically important areas, etc. In Ethiopia any site selection for defense battlefield operations is totally manual it depends on paper topographic maps and expertise on identifying terrain features helps with binoculars and compasses. There are several ways to study and understand the ground to achieve military goals the, basic systems of studying terrain are by topographic map, aerial photograph, military sketches and by sand model(Maj. Hadish, 2015). The ground truth is that the military officers manually combine terrain-based information and the tactical significance of various terrain features. Manually combining terrain information is cumbersome for experts and time taking and results vary from expert to expert. Such terrain based tasks can effectively be automated using GIS based decision making tools (Gebreslasie, 2009).

There is no well organized and documented finding in this regard. Currently dissemination of information has virtually become computerized and application of technologies and softwares make it easy. The modern approach, RS, GIS and artificial intelligence technologies are sitting on top of IT tools that can together be effectively utilized to develop intelligent systems for war planning. Command, Control, Communication, Coordination and Information (C4I) is one such system where these technologies can be effectively used. For example, satellite RS data can be used to generate a wide range of products such as land use, land cover maps, obstacle maps, slope maps, road mobility maps, line of sight plots etc. A GIS can receive process, create, store, retrieve, update, manipulate and compress digital terrain data to generate a number of products (Maj. Baijal *et al.*, 2000).

There are different techniques by which spatial information is analyzed to solve a particular spatial problem in GIS. Many of these techniques are integrated with GIS. Among these, Multi- Criteria Decision analysis (MCDA) is used to identify a single most preferred option, to rank options, to list a limited number of options for subsequent detailed evaluation, or to distinguish acceptable from unacceptable possibilities (Dodgson, 2000). Among the techniques of Spatial Multi-criteria Evaluation (SMCE), the Weighted Overlay Analysis (WOA) is commonly used in modeling many spatially indexed problems and selection of suitable sites for several purposes.

1.2. Problem Statement

All military activities are terrain sensitive and need careful planning and reconnaissance to ensure success (Satyanarayana *et al.*, 2006). This makes operations planning more complex process in military than it is in other sectors. It is evident that the complexity of the planning process results in difficulty and uncertainty in decision making. Geographic Information System play a pivotal role in Military operations as they are essentially spatial in nature. It speeds up terrain based decisions thereby improving the quality and management of terrain based information for military operations. Besides to the availability of information on the terrain of the battle field, the way it is manipulated and delivered to decision makers in a very accurate and scientific manner is of more importance.

Therefore, manually combining terrain information is cumbersome, time taking, costy and results vary from expert to expert. This research analyze the challenges of current manual defense command post site selection, identification of terrain features for military battlefield operation processes. The study applies analyzing, modeling and customizing web-GIS using spatial information for the enhancement of Command, Control, Communication and Coordination (C^4I) system.

1.3 Objectives

1.3.1 General Objective

The main objective of this research is to analyze the major terrain related challenges in defense command post site selection and to develop web-based GIS C4I system for decision makers.

1.3.2 Specific objectives

- To investigate and analyze the existing site selection system for command posts with respect to terrain using LULC, geologic and geomorphologic factors;
- To select suitable sites of command posts for division, regiments and combats;
- To identify major operational site and common war fighting symbologies for mission planning;
- To develop web-based GIS C4I system for decision makers.

1.4 Significance of the Research

In the National Defense of the country site selection for military task is carried out using manual conventional approaches. Hence, compilation and combination of terrain information from different layers is tedious and time consuming and therefore, inaccurate terrain information can be obtained which leads to difficult decision made by commanders. GIS application has becoming a powerful tool to address the need of decision makers and to cope with problems of uncertainties. This research output will indicate application and reliability of RS and GIS approaches in reduction of the labor, time, cost and inaccuracy. Commanders or decision makers will use accurate and efficient information than the conventional one.

1.5 Scope of the Study

The thematic scope of this study is limited for command post suitable site selection from many tasks of military operations. Mainly focused on military terrain analysis, weighted factor analysis and visibility analysis technique related with military aspects of terrain select the best suitable site model and customize web-GIS approaches for defense commanders or decision makers in all types of weather condition around Ada'a Woreda, Showa Ethiopia.

CHAPTER 2

REVIEW OF RELATED LITERATURES

2.1. Ethiopian Military Operation Experience

The topographic maps have been advancing in Ethiopia, but it is difficult to describe the specific date of map construction of Ethiopia, however, after 15thcentury the map of Abyssinia was printed by England, Italy and Dutch (German) geographers and then European colonizers. During emperor Menelik II the Americans printed 1:50,000 map scale along roads Messewa to Asmera and then to Addis Ababa and finally to Nekemet. The development of topographic maps enables the user to utilize the terrain depends on the content and scale of maps. The awareness and the importance of accurate topographic maps for military purpose increased after five years of invasion. After invasion by aid of American different map scales have been printed like 1:50,000; which covered 60% of the country, 1:250,000 and 1:1,000,000; its coverage was the whole country, however, the maps basically concerned about the resource of the country rather than military purpose. Therefore to fulfill military interests the country begun relationship with USSR and in form of aid and sell had obtained 1:100,000,1:200,000,1:500,000, and 1:1,000,000 scale maps; their coverage were the whole country (Defense Topography Manual, 1998).

2.2. GIS for Military

It is a known opinion that reading and assessing the paper maps for military operations is not easy. A commander should visualize the terrain in his mind before making a decision for an appropriate behavior. Settlement of the troops, finding the optimum directions, and so many military operations can be easily decided by visualizing the terrain. Terrain visualization is a basic and fundamental leadership skill (Satyanarayana *et al*., 2006).

It portrays and allows a detailed understanding of the background upon which enemy and allied forces and the actions are displayed. A battle commander must understand how terrain influences every aspect of military operations. The commanders and the decision makers even use the sand box of operation terrain. GIS can be used to visualize the battlefield and to make appropriate decisions. GIS would help commanders and decision makers as a decision support mechanism using up-to-date digital data stored in a database.

GIS also plays an important role in military logistics because with the use of GIS, it becomes efficient to move supplies, equipment and troops to a selected location where they are needed at the right time (Smith, 1999). In military, the GIS is an extremely useful tool for determining target locations, troop movement, avenues of approach, and management of the battlefield (Clayton *et al*.,1999).

2.2.1 Terrain Analysis

US field manual (FM 5-33, 1990) terrain analysis, an integral part of the intelligence preparation of the battlefield (IPB), plays a key role in any military operation. During peacetime, terrain analysts build extensive data bases for each potential area of operations. They provide a base for all intelligence operations, tactical decisions, and tactical operations. They also support the planning and execution of most other battlefield functions.

Terrain intelligence and military concepts dealing with the effects of the ground on military construction and maneuver be made available to forward units that may have to act quickly on their own initiative (Whitmore, 1960). Terrain intelligence or terrain analysis is the process of interpreting a geographical area to determine the effect of the natural and man-made features on military operations. The knowledge of the terrain derived from analysis by specialists of many sorts is combined in the intelligence report, a document, usually with a number of specially designed maps, which predicts terrain conditions of an area of military interest. The area of study is usually inaccessible, although terrain studies may also be made of maneuver areas or test sites for training or experimental purposes (Whitmore, 1960).

2.2.2 Military aspects of Terrain Analysis

Commanders take their decisions fitting the military aspects of terrain. Terrain analysts and decision makers should pay attention to these military aspects. Military terrain aspect is formulized as OCOKA and contains the information of Observation and Field of Fire, Cover and Concealment, Obstacles, Key Terrain and Avenue of Approach (FM 5-33, 1990).

Observation and Field of Fire is an important factor for military decisions. Field of Fire supplies horizontal line-of-sight for direct-fire weapons and radars. Observation areas are important for ground surveillance. Vegetation with qualified density or a hill point might be observation and field of fire, cover protection from enemy fire is a vital part of military operations. Examples of concealments which protect observation are the rocks, river banks, vegetation, quarries, walls, and buildings.

This information is important for judging where the enemy might be located. It is especially important in areas where rebel forces might be operating because it helps the commander predict the attacks. Concealment may be provided by woods, underbrush, snow drifts, tall grass, cultivated vegetation, roof coverage, or any other feature that denies observation. An obstacle is any natural or man-made feature that slows, diverts or stops the movement of personnel, armored or wheeled vehicles. The obstacles are classified as natural obstacles such as embankment and man-made obstacles, such as built up areas and cemetery.

Key terrain is a part of operation zone which effects the operation for both enemy and friendly forces sides. The side which captures the key terrain claims an advantage in respect of other side. Therefore, the key terrains are important during the planning of operation and for the operations going on. Examples are bridges, urban areas, and key military installations. The cross-country movement (CCM) information sometimes referred to as an avenue-of-approach because it tells the best routes through which various vehicles can get to an objective when they cannot use the prepared roads. It also shows the parts of the terrain that the military vehicles cannot cross.

In military concept, there are five terrain analysis factors which are formulized as OCOKA (Gurbuz and Mustafa, 2002). These factors are important during reconnaissance, planning, and execution of the operations. The decision makers can select each of OCOKA for each military unit at all weather conditions. Seeing without being seen and shooting without being shot is important for a soldier. Therefore, the observation and field of fire should be selected exactly. Cover and concealment areas are important to preserve the troops from enemies' eyes and fires. Obstacles divert or stop the troops. Therefore, the obstacles provide advantages for defender and disadvantages for attacker. Key terrain affects the operation directly and the side which captures the key terrain has important advantages. Avenue of approach is important because of vehicle route.

According to Gurbuz and Mustafa (2002), terrain analysis application developed using ArcView 3.2 GIS software which is older, has not fully facilities or tools than ArcGIS, and they also used paper maps, using software (Digital Map Supported Military Applications Software Project), and OCOKA to conduct their research. But they are not mentioned which database software is used for database development. But, in this research ArcGIS 10.1 is used for better analysis.

In addition here web-GIS is customized with open source programming software which is free and anyone can edit, customize, add layers and maps in their own way of approach and military commanders or decision makers can effectively utilized this automated web-GIS system to develop intelligent systems for war planning and for the enhancement of C4I.

Generally terrain analysis is evaluated like in country Ethiopia the topographic structure is mountain highlands, rifts and valleys due to this reason terrain analysis is more sensible even for civil tasks. This difficult terrain is more challenging for military operational planning for military commanders solved their mission manually with paper maps. Therefore in this research the specific terrain will be analyzed and evaluated by selecting military suitable site for command post and verified by military aspects of terrain factors.

2.3. GIS Based Approach

The GIS-based approaches to site suitability analysis have their roots in the applications of hand drawn overlay techniques used by American landscape architects in the late nineteenth and early twentieth century. McHarg (1969) advanced the overlay techniques by proposing a manual overlay cartographic procedure.

The method is widely recognized as a precursor to the classical overlay procedures in GIS. One can distinguish three major groups of approaches to GIS-based site suitability analysis: (i) computer-assisted overlay mapping, (ii) Multicriteria evaluation methods, and (iii) AI (soft computing or geo - computation) methods (Collins *et al*., 2001).

2.4. Multi factor Analysis and Aggregation Method

Multi factor analysis or Weighted Overlay Analysis is one the components of the methods of spatial modeling using spatial Multi-criteria evaluation. Weighted Overlay Analysis assigns more importance to some criteria over the others. It has been used by several authors (Seid *et al*., 2007 and Alemayehu, 2006). They have adopted the Weighted Overlay Analysis method in undertaking spatial modeling for several purposes. IDRISI software is commonly used to generate the weight factors for each criterion in the context of analytical hierarchy process. These authors have adopted the Weighted Overlay Analysis method for site selection of new housing sites in urban areas; mapping vegetation vulnerability analysis; live stock production; crop suitability.

Hopkins (1977) compared the advantage and disadvantages of methods of generating suitability maps using GIS, and remarked that the best approach is to use the Weighted Overlay Analysis. Most of the spatial modeling tasks involved in suitability of modeling usually using the WOA analysis. Another comparative research undertaken between Multi-criteria evaluations in GIS environment is conducted of Barredo *et al.* (1998), who is compared the Weighted Overlay Analysis, and the ranking method to allocate urban areas. In their finding, the two approaches have brought about similar result except in a slight difference in the classes that are out of the highly suitable range. Barredo *et al.* (1998) argued that the fact that the accord is not good for intermediate groups is not very important because these places are not of much interest for territorial planning.

Although factor weights using analytical hierarchy process are used for decision making in military operations planning (Jaiswal, 1997), the Weighted Overlay Analysis of spatial data layers is rarely used if not at all in terrain based decision making and suitability modeling for various military tasks. Despite the fact that weighted overlay analysis method is a more convenient method and easy to be used (Barredo *et al.* 1998). This method has not been exhaustively used in the military sector, while it is the most prominent method in the civilian sector in handling various decision making processes that are of multiple criteria in nature and spatial in context.

2.5. Computer-Assisted Overlay Approach

One of the overlay mapping techniques the computer-assisted overlay technique were developed as a response to the manual method's limitations of mapping and combining large datasets (MacDougall, 2005 and Steinitz *et al.*,2006). Rather than manually mapping the values of a series of suitability factors in gray or color scales, the models are stored in numerical form as matrices in the computer. The individual suitability maps can then be analyzed and combined to obtain an overall suitability map. The major criticism of the conventional map overlay approach is related to the inappropriate methods for standardizing suitability maps and untested or unverified assumptions of independence among suitability criteria (Hopkins, 1977 and Pereira and Duckstein, 1993).

The WLC method is often applied without any insight into the meanings of two critical elements of (i) the weights assigned to attribute maps and (ii) the procedures for deriving commensurate attribute maps. In many case studies the overlay site suitability models have been applied incorrectly and with uncertain results because analysts (decision makers) have ignored or been unaware of these the underlying assumptions. But this limitation can be removed by integrating GIS and multi – criteria decision making (MCDM) methods.

The other approach is multi – criteria decision making method it is an integration of MCDM techniques with GIS has considerably advanced the conventional map overlay approaches to the land suitability analysis (Carver, 1991, Banai, 1993, Eastman, 1997 and Malczewski and Thill1999). GIS-based MCDA can be thought of as a process that combines and transforms spatial and aspatial data (input) into a resultant decision (output). The MCDM procedures or decision rules define a relationship between the input maps and the output map. A number of multicriteria decision rules have been customized in the GIS environment for tackle site suitability problems. The decision rules can be classified into multiobjective and multiattribute decision making methods (Malczewski, 1999). The multi objective approaches are mathematical programming model oriented methods, while multiattribute decision making methods are data oriented. Multiattribute techniques are also referred to as the discrete methods because they assume that the number of alternatives or plans is given explicitly, while in the multi objective methods the alternatives must be generated (they are identified by solving a multiobjective mathematical programming problem).

2.6. Multi - Objective and Multi - Attribute Methods

The model implicitly defines the alternatives in terms of decision variables. The computation complexity is one of the reasons that multi - objective optimization methods are difficult to implement in the GIS environment. The Multiattribute approaches are much easier to implement in GIS (especially, for the raster data model). Consequently, there are a substantial number of GIS multiattribute applications to site suitability analysis. A number of multiattribute (or Multicriteria) evaluation methods have been customized in the GIS environment including WLC and its variants (Carver, 1991 and Eastman, 1997), (Carver, 1991 and Joerin *et al.*, 2001), and analytic hierarchy process (Banai, 1993).

WLC (or simple additive weighting) is based on the concept of a weighted average. The decision maker directly assigns the weights of 'relative importance' to each attribute map layer. A total score is then obtained for each alternative by multiplying the importance weight assigned for each attribute by the scaled value given to the alternative on that attribute, and summing the products over all attributes. When the overall scores are calculated for all of the alternatives, the alternative with the highest overall score is chosen. The method can be manipulated by using any GIS system having overlay capabilities. The overlay techniques allow the evaluation criterion map layers (input maps) to be combined in order to determine the composite map layer (output map).

The methods can be customized in both raster and vector GIS environments. Another Multiattribute technique, which has been incorporated into the GIS-based site suitability procedures, is the Analytical Hierarchy Analysis (AHP) method (Saaty, 1980). It can be used in two distinctive ways within the GIS environment. First, it can be employed to derive the weights associated with suitability (attribute) map layers. Then, the weights can be combined with the attribute map layers in way similar to the linear additive combination methods.

This approach is of particular importance for problems involving large number of alternatives represented by means of the raster data model, when it is impossible to perform a pairwise comparison of the alternatives (Eastman *et al.*, 1993). Second, the AHP principle can be used to aggregate the priority for all level of the hierarchy structure including the level representing alternatives. In this case, a relatively small number of alternatives can be evaluated (Banai, 1993 and Jankowski and Richard, 1994). This approach is also more appropriate for implementation in the vector-based GIS (Jankowski, 1995). It should be noted that AHP can be used as a consensus building tool in situations involving a committee or group of decision makers (Saaty, 1980).

The wide variety of MCDM rule there is a question which of the methods is the best one to be used in particular situation. Several studies demonstrate that the different Multicriteria evaluation rules generate and used the procedures available in IDRISI and SPANS (Heywood *et al.*, 1995). Another solution to this problem is to integrate MCDA and AI techniques to develop the knowledge - based or 'intelligent' multicriteria decision support (Carver, 1991). AI includes the modern computational techniques that can help in modeling and describing complex systems for inference and decision making. Prominent research areas in developing hybrid systems include the integration of GIS and AI approaches such as fuzzy logic techniques (Wang *et al.*, 1990 and Burrough and McDonnell, 1998).

In conclusion the development of GIS-based methods for suitability analysis has evolved over the last 30 years or so from the map overlay modeling through MCDM techniques to a wide range of AI approaches. It is important to point out that many case studies use a combination of these methods; e.g. Multicriteria evaluation methods can be used in conjunction with AI techniques. In addition, the classical overlay modeling is present, in one way or another, in most, if not all, of the methods. The classical overlay mapping and modeling approaches are the most commonly used methods for terrain suitability analysis in the GIS environment. The major limitation of these approaches is the lack of well defined mechanize for incorporating value judgments (e.g. the decision-makers preferences) into the GIS-based procedures. This limitation can be removed by integrating GIS and MCDM methods.

2.7. Web-GIS Decision Support System

Web GIS is a type of distributed decision support system, comprising at least a server and a client, where the server is a GIS server and the client is a web browser, desktop application, or mobile application. In its simplest form, web GIS can be defined as any GIS that uses web technology to communicate between a server and a client (Esri.com). The main key elements essential to web-GIS are first the server has a URL so that clients can find it on the web, next the client or decision makers relies on HTTP specifications to send requests to the server, then the server performs the requested GIS operations and sends responses to the client via HTTP. The format of the response sent to the client can be in many formats, such as HTML, binary image, XML (Extensible Markup Language), or JSON (JavaScript Object Notation).

In a server-side web GIS application, a web browser is used to generate server requests and display the results on client-side browser. A web GIS server usually combines a standard web (HTTP) server, GIS application server, and the GIS databases and functionalities that reside completely on the server. But in client-side web-GIS application require software of some kind (other than browser) or the client system should be enhanced to support GIS operations. That is, to implement client-side solutions, software must be transferred to the client (Dang, 2000).

2.7.1 Web-GIS for Military Application

Military web-GIS application provides the military geospatial data via web interface includes web mapping which is process of cartography, spatial visualization, and map production. It allows browser-based access to GIS, utilizing geospatial information from multiple defense nodes, deliver advanced GIS Web services throughout the global defense network, develop custom applications using .NET or Java to meet specific defense and intelligence needs. It also integrate GIS and other IT technologies to provide centrally managed multiuser editing capabilities. Web-GIS support the geospatial standards that are critical to exchange information between defense capability areas. This support is for Open Geospatial Consortium (OGC) Inc., International Organization for Standardization (ISO) and Web-GIS application for military branches such as army, navy, Guard, Marine Corps and Air force.

2.7.2 Web Technology for Web-Based GIS

There are open source, commercial and public softwares for web-based GIS and those softwares used different technologies like application programming interface (API) for controlling the communication between protocols or operating systems and DBMS. It facilitates the interaction between the user and the computers. Application Programming Interface (API) which constitutes a language and message format is set of data structures, routines or protocols used by an application to communicate with other control program, communication protocol or operating system. Almost every application depends on the APIs of the underlying operating system to perform such basic functions as accessing the file system (Orenstein, 2000). The scripting languages PHP, ASP and JSP are the popular server side scripts runs on the application servers and HTML and JavaScript are client side scripting languages allows controlling one or more software applications. Web servers also another web technology that accepts HTTP requests such as HTML documents and linked objects (images) from the clients sends HTTP responses with the requested data .

The main aim of the implementation and development of web-based GIS is for decision support system. There are many open source software available to develop the web-based GIS. In this research the most popular open source software web server which is Geo-Server is used and it supports java programming language which is easy to installation, implementation and development.

GeoServer is an open source server for sharing geospatial data and designed for interoperability; it publishes data from any major spatial data source using open standards. GeoServer is an OGC compliant implementation of a number of open standards such as Web Feature Service (WFS), Web Map Service (WMS), and Web Coverage Service (WCS). GeoServer requires neither programming skills nor basic knowledge of HTML, JavaScript, php or similar. It is managed via the web administration interface.

PostgreSQL is an advanced SQL database server, available on a wide range of platforms. One of the clearest benefits of PostgreSQL is that it is open source, meaning that you have a very permissive license to install, use, and distribute PostgreSQL without paying anyone fees or royalties. On top of that, PostgreSQL is well-known as a database that stays up for long periods, and requires little or no maintenance in many cases. Overall, PostgreSQL provides a very low total cost of ownership.

PostgreSQL is also noted for its huge range of advanced features, developed over the course of more than 20 years continuous development and enhancement. Originally developed by the Database Research group at the University of California, Berkeley, PostgreSQL is now developed and maintained by a huge army of developers and contributors. Many of those contributors have full-time jobs related to PostgreSQL, working as designers, developers, database administrators, and trainers. PostgreSQL has the following main features:

- Excellent SQL Standards compliance,
- Client-server architecture, highly concurrent design where readers and writers don't block each other,
- Highly configurable and extensible for many types of application, and
- Excellent scalability and performance with extensive tuning features

2.7.3 General Architecture of Web-Based GIS Applications

Different architectures can be used to develop web-based GIS applications. 2-tier architectures retain the user interface and functional part of the web application on the first tier and deploy the database and data storage functions on the second tier. However, a more efficient architecture is a 3-tier architecture in which the user interface and functional parts are separated on different tiers. In such circumstances, if any part of the application needs to be changed, other parts do not get affected by that change, and the web application remains scalable to changes in different development environments. When developing web-based GIS applications it is better to use three-tier architecture.

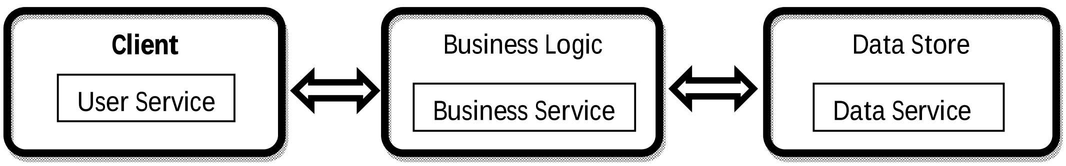


Figure. 2.1 Three-tier of web-based GIS applications architecture

Clients are any web-browsers used when users try to access the maps through the web-server, Business logics are GIS functionalities that implements on the Geo-server and data store is repository of maps data created in PostgreSQL database.

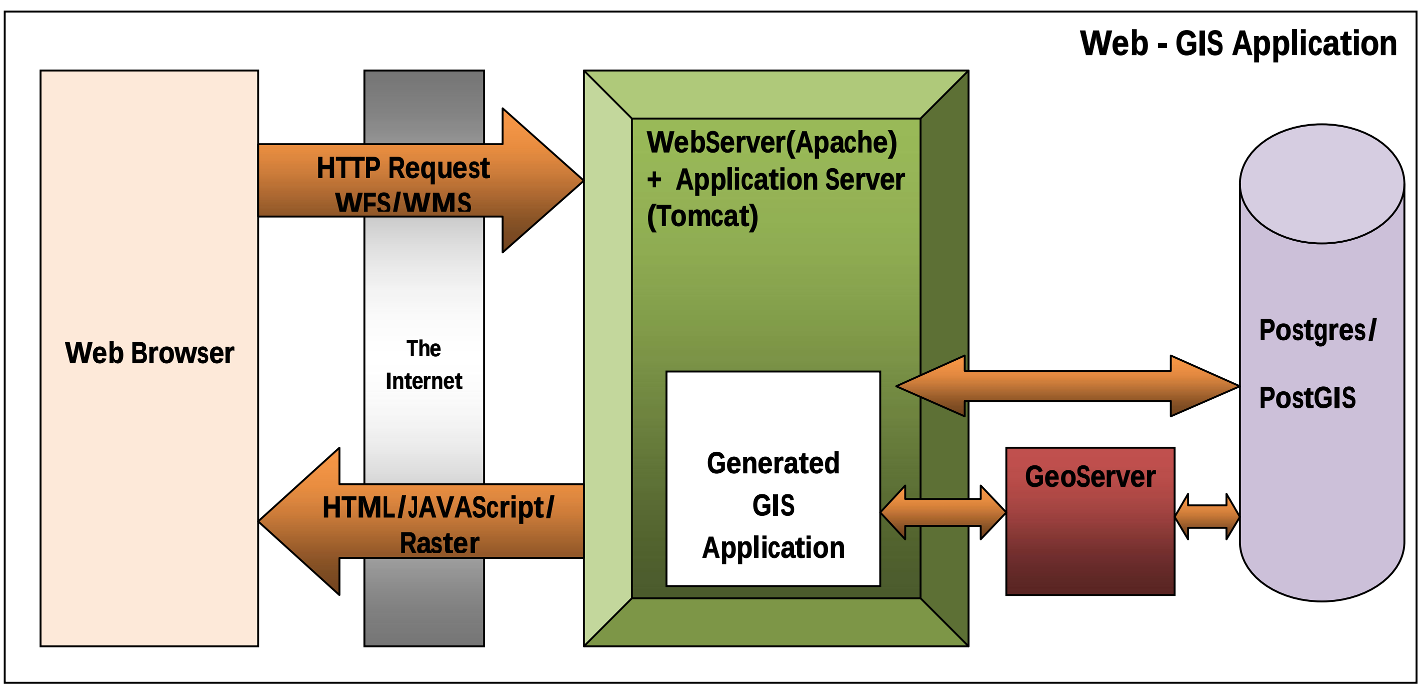


Figure 2.2 Conceptual Model for Web-GIS

CHAPTER 3

MATERIALS AND METHODS

3.1. Description of Study Area

3.1.1. Location

Ada'a Woreda is located 45km South-East of the capital city Addis Ababa in Oromia national regional state, East Showa central main Ethiopian rift. Its geographical location is 8º 42' 0" - 8º 45' 0" N and 38º 55' 0" - 39º 2' 0" E. The Ada'a Woreda comprised about 0.16 million ha in size and consists of various topographical features dominated by flat terrain. Elevation ranges from 1580 to 3024 meter above sea level. Ada'a area is also comprised with different soil types dominated by Cambisol and Vertisols. Agro-climatically the Woreda is dominated by 'Woinadaga' (warm moist) (Source:- International Livestock Research Institute, ILRI).

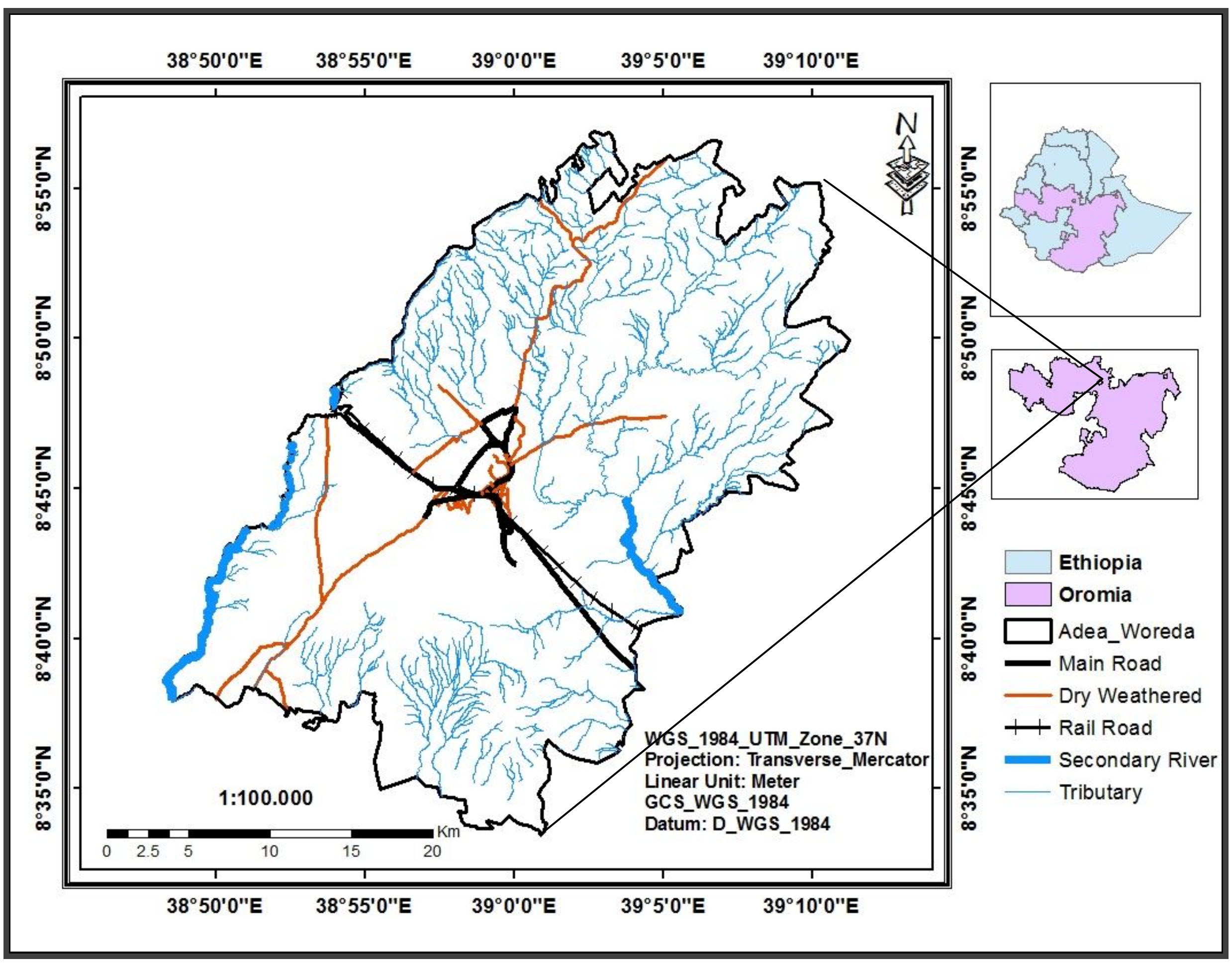


Figure. 3.1 Location Map of the study area

3.1.2. Topography and Geomorphology

Ethiopia is a country of great geographical diversity with high and rugged mountains, flat topped plateaus, deep gorges, incised river valleys and rolling plains. Over the ages, erosion, volcanic eruptions, tectonic movements and subsidence have occurred and continued through millennia to accentuate the unevenness of the surface. The study area is generally characterized by flat topography mostly underlain by diverse volcanic products of the Quaternary rift volcanics and sediments (Tamiru and Antonio, 1995).

The study area placed under zone of Ethiopian main rift and the area mainly covered by in the rift axis complex, large areas covered by intra rift complex, a western part of the study area covered by the western rift margin complex, deep gorges, fractures and inferred fractures formed by the rift. Central part of the area are covered by alluvial deposits. It consists of silt, sand, clay, and gravel, as well as much organic matter and lacustrine deposits. Although there is mostly alkaline basaltic lava flows in the area which forms and looks flat topography. The area uniquely identified by volcano lakes created by volcanic eruption which are craters (spatter cones with basaltic lava flows) and maars lakes formed by volcanism namely, Bishoftu, Hora, Babogaya, Kuriftu, Cheleleka and Green lake. There is Yerer volcano highland, Bede Gebabe highland volcanic unit which contain intercalated rhoyalitic to minor trachytic lavas and pumices, mountain Ziquala peralkaline trachytes has volcanic lake on the top of the mountain.

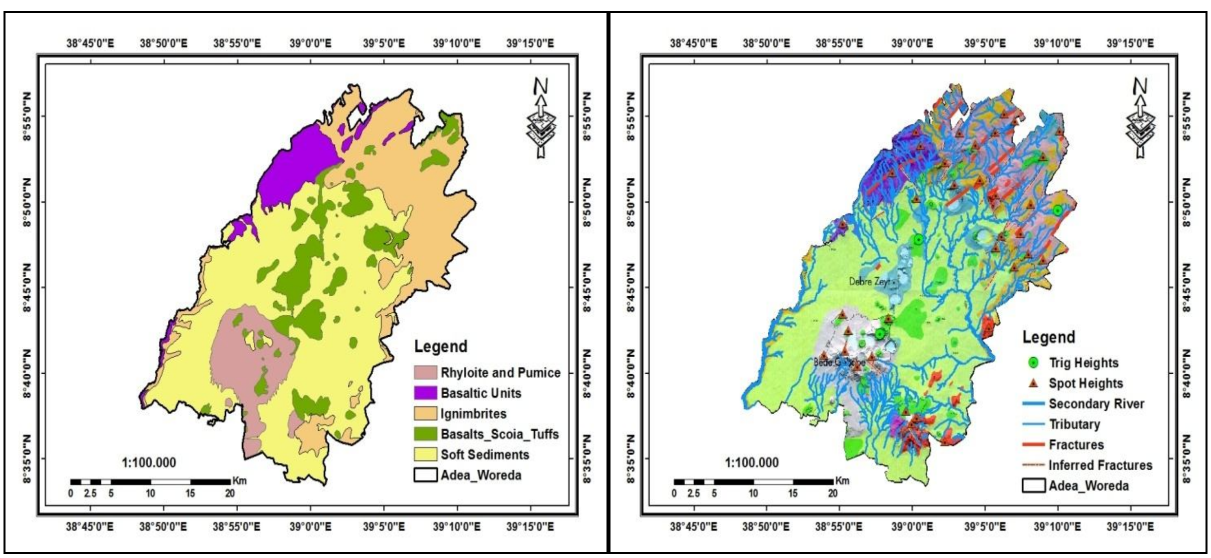


Figure 3.2 Generated geological map(left), geology, geomorphology and structural map of the study area(right) Source :- (Abebe *et al.*, 1999)

3.1.3. Land Use Land Cover of the Study Area

The Woreda has about 161056 hectares of total area. Most of the rural populations are practicing on agricultural farming, livestock raring and mostly they depend on communal pastoral lands to graze livestocks but those lands are heavily stocked and overgrazed.

Table 3.1 The land use pattern of the Ada'a Woreda

Land use Type	Area in hectare
Cultivated	106,607.5
Forest land	2,489.00
Grazing land	5,395.38
Bush land	13,834.06
Others	32,730.59
Total	161,056.53

Source:- International Livestock Research Institute (ILRI,2005)

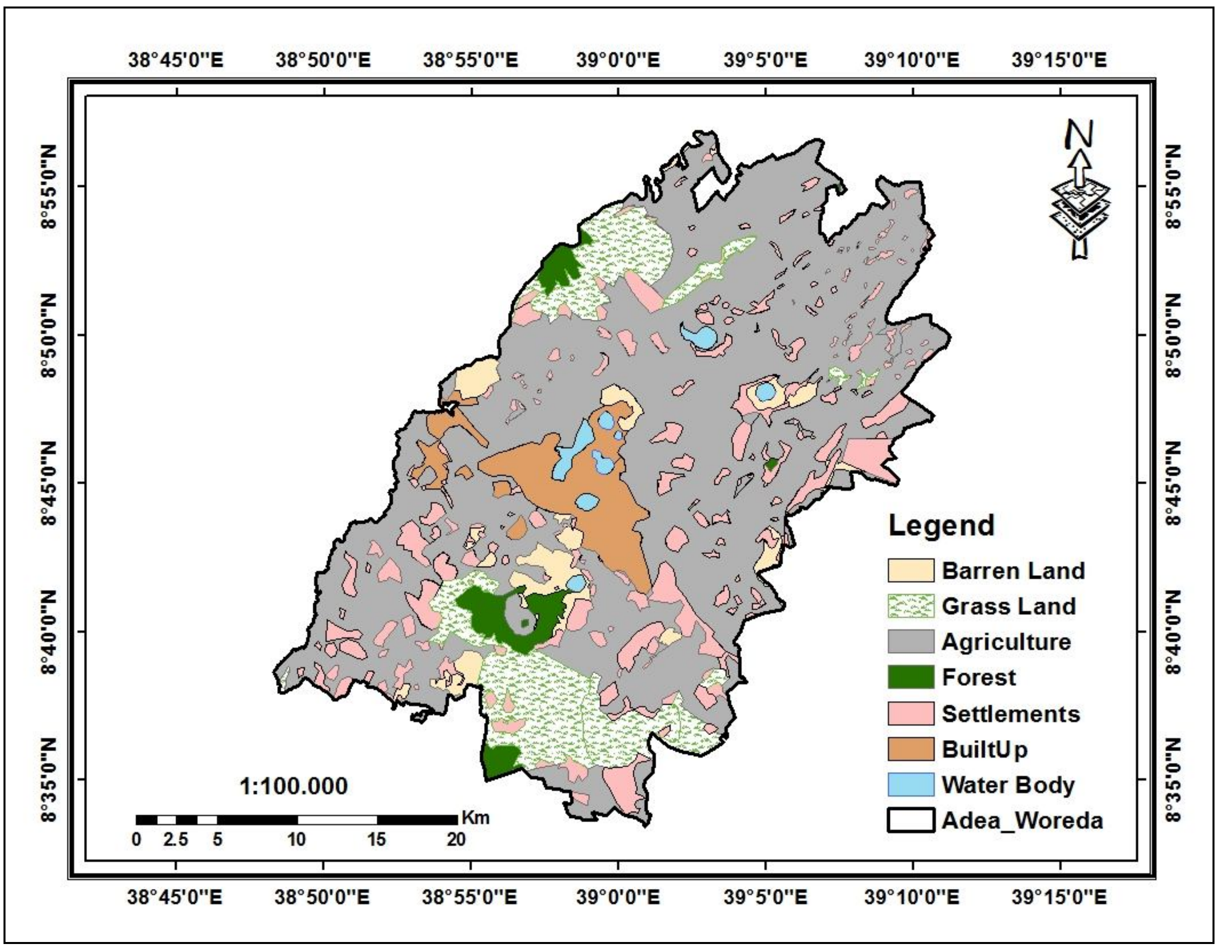


Figure 3.3 Land use land cover map

3.1.4. Soil Type and Properties

Soil of the study area is dominantly clay (black cotton soil) and brown in color. The type of clay mineral will have greater importance to determine the soil water storage property. The physical assessment of soils of the study area shows dominantly vertisols or black cotton soil. The average soil depth is about 0.65 to 1.05m with medium infiltration rate and medium water storage capacity (OIDA, 2002).

Table 3.2 Dominant Soil type in the study area

S. No	Soil type	Woreda Coverage) in %
1	Sand and silt	3.0
2	Clay (Black cotton)	88.0
3	Clay Loam	9.0

Source: - Ada'a Woreda Bureau of Agriculture (2005)

Black clay and red light soils are the dominant types. Specifically, they are called black clay soil, locally called Koticha, Light sand soil, hillside soil-locally called Gombore, a mixture of black and red light soil, locally called Abolse and Stony soils, locally called Cheri. Lithosols in Ada'a Woreda are highly degraded infertile soils while vertisols are generally fertile with good moisture holding capacity. The soil is hard and crack during dry season, and sticky when wet (FAO, 2006).

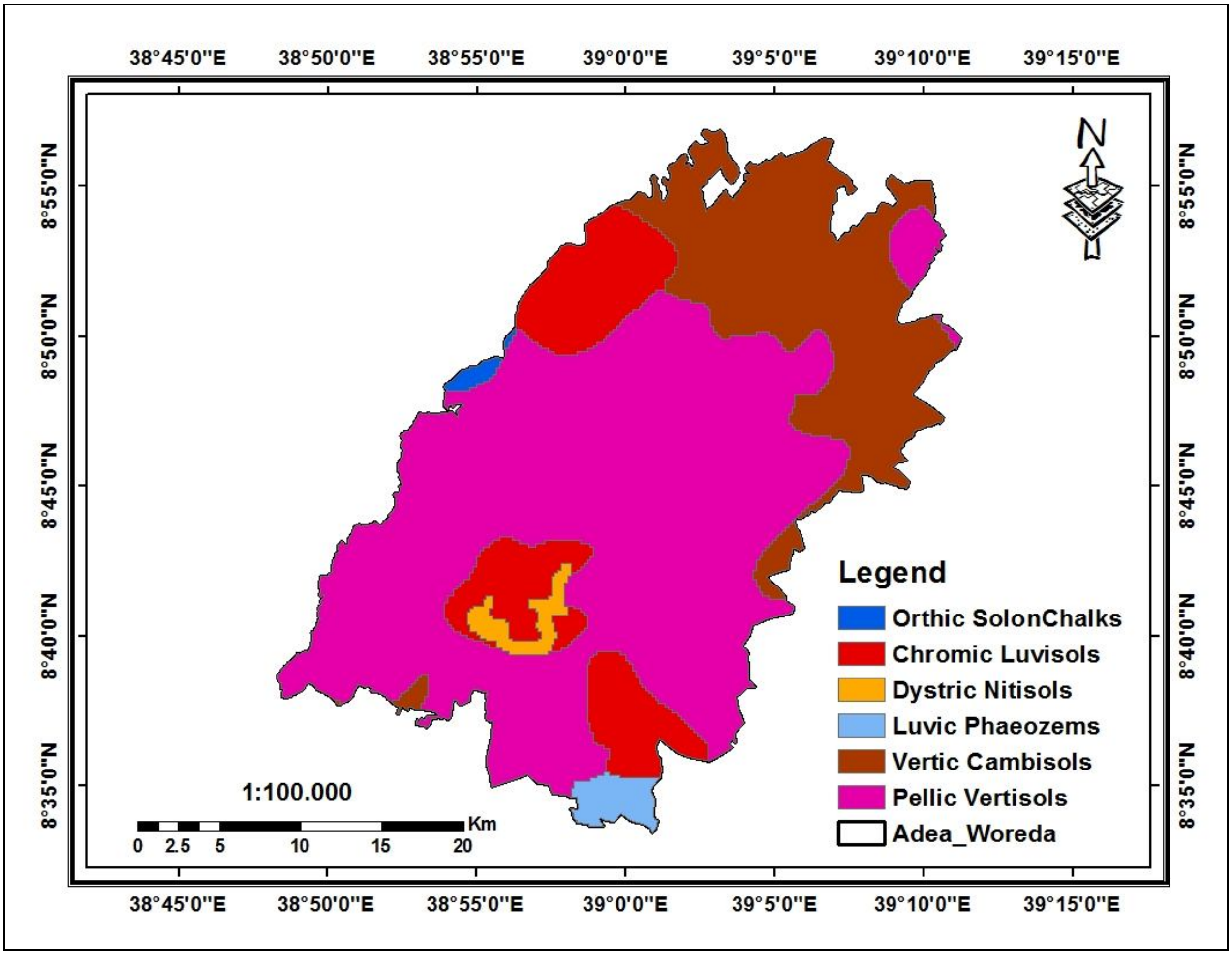


Figure 3.4 Soil type of the study area

3.1.5. Slope of the Study Area

Slope or Gradient is the angular difference the inclined surface makes with the horizontal plane. The tangent of the slope angle is determinedly dividing the vertical distance by the horizontal distance between the highest and lowest elevations of the inclined surface. The percent of slope is the number of meters of elevation per 100 meters of horizontal distance. Slope information that is available to the analyst in degrees or in ratio values may be converted to percent of slope by using a monogram. Slope of relief is the difference in elevation between the points in a given area, the elevation or irregularities of a land surface are represented on map by contours. The study area slope is from 0 to 67 degrees, therefore for the research input the slope layers reclassified with related to vehicle mobility.

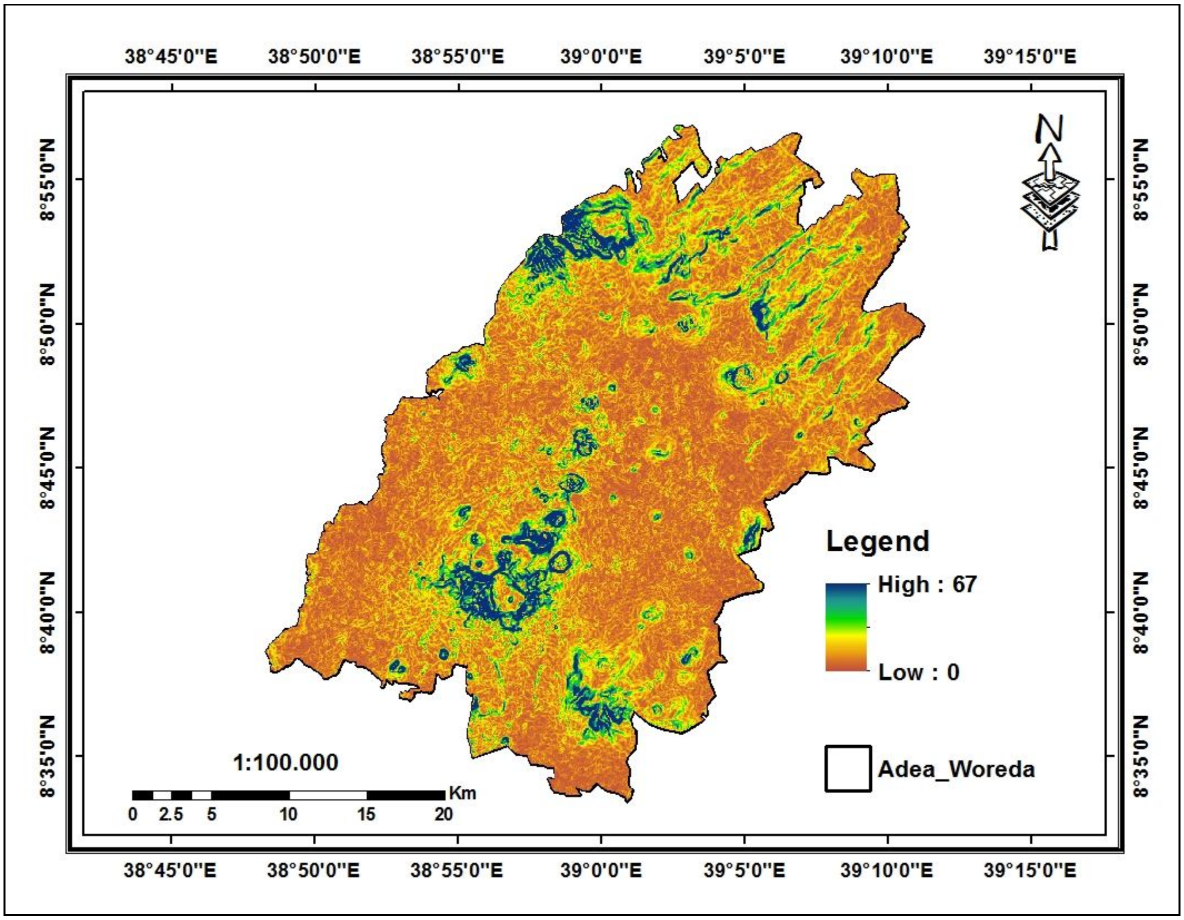


Figure 3.5 Slope of the study area

3.1.6 Climate and Rainfall

Ada'a Woreda is characterized by a semiarid to sub humid climate with mean annual precipitation varying from (851-1130)mm and mean annual temperature 28^0 C. The region is characterized by three main seasons. The long rainy season in the summer (June–September; summer monsoon rainfall, locally known as 'kiremt') is primarily controlled by the seasonal migration of the Inter Tropical Convergence Zone (ITCZ) which lies to the north of Ethiopia at that time.

The dry period extends between October and February (known as 'bega') when the ITCZ lies south of Ethiopia. The 'small rain' season 'belg' occurs during March to May when the ITCZ moves from south to north over the country.

Table 3.3. Monthly weather data for the year 2005 cropping season

Max Temp ℃	-	-	-	21.1	27.3	26.8	23.5	24.8	26.5	25.8	25.8	27.9	229.5
Min Temp ℃	8.2	8.3	11.6	11.9	12.9	11.8	13.1	13.5	13.5	8.6	7.4	4.6	125.4
Humidity %	54.0	44.7	51.2	49.1	59.7	62.4	71.4	67.3	69.7	49.7	49.1	49.4	677.7
Rainfall (mm)	34.7	0.0	95.5	83.4	57.4	103.3	179.9	138.2	129.3	0.0	6.7	0.0	828.4
Number of rainy days	6	0	8	9	17	17	26	15	22	0	1	0	121
Sunshine hours	7.7	8.5	6.7	5.6	3.4	4.2	2.7	5.6	6.1	8.2	-	-	58.7
Wind speed	1.81	2.41	2.68	2.69	1.84	1.55	1.35	1.38	1.54	2.49	3.02	3.02	25.78
Wind direction	SE	NE	SE	NE	E	NE	E	SE	NE	SE	E	SE	SE
Soil temperature													
At 10 cm	-	-	-	-	--	-	-	-	--	-	-	-	-
At 20cm	17.6	19.1	21.8	21.8	21.9	21.3	20.5	21.4	21.6	21.6	17.4	15.5	241.5
At 50cm	16.9	16.7	21.2	21.6	21.5	21.9	21.1	21.5	21.8	21.4	19.6	17.2	242.4
At 100cm	17.6	18.6	21.0	21.3	21.4	20.8	20.7	21.3	21.4	21.4	20.7	18.4	244.6

Source:-Debrezeit Agricultural Research Center

3.2. Data Sources and Materials Used

3.2.1 Data Sources and Data Collection Methods

Table 3.4 Materials used in this study

S. N.	Data/Input layers	Source
1	Satellite Image SPOT 5m Resolution	Ministry of Defense
2	Topographic Map (1:100.000)	"
3	DEM 30m resolution	INSA, MoND
4	Study Area Shape file	Ethio-GIS
5	Road	Ethio-GIS
6	River	"
7	Land Use/Cover	Spot Image
8	Slope	Generated from DEM
9	Military Symbology	From MoND, ArcGIS
10	Geological Data	AAU(School of Earth Sciences)
12	Geomorphologic and Structural Data	AAU(School of Earth Sciences)
13	Soil	FAO (East Africa)

3.2.2 Softwares Used

Table 3.5 Softwares used in the study

S. N.	Software	Purpose
1	ArcGIS 10.1	For all GIS tasks or analysis
2	ERDAS IMAGINE 10	For Preprocessing and Classification
3	3DEM/Global Mapper, Arcscene	For Visualization (TIN)
4	IDRISI Andes	PCM for aggregation of factor weights
5	Symbol	For military Symbology
6	Military Analyst extension in ArcGIS	For line of site, viewshed
7	PostgreSQL	For creating database application
8	GeoServer	For Web Mapping services

3.3 Methodology

3.3.1 RS Image preparation and Interpretation

Based on the investigation of the existing approach in defense, conventional approach is conducted by using topographic maps with the help of expertise judgment for identifying suitable terrain features. In this research study SPOT image 5m resolution found from MoND is used. Image enhancement and transformation is carried out for better visual analysis and interpretation.

Spot image 5m resolution, which was found from MoND and processed on March 10, 2015 (with a map projection of UTM zone 37, spheroid and datum WGS 84) has been used for LULC processing and mapping activities. These images were imported to ERDAS IMAGINE 10 software and the study area was subset from the full scene. From Digital elevation model (DEM) where slope, viewshed and TIN data layer were produced.

According to Lilles and Kiefer (2000), any spatial data under consideration should be geo-referenced specifically its position must be fixed with respect to latitude and longitude correctly before processing further activities. In image preparation the first step is georeferencing and in this research the geological map 1:100.000 of the study area is used. This scanned image is geometrically corrected and given the same coordinate system as the SPOT image, that is world geodetic system (WGS_1984_UTM_Zone_37N) and also the topographic map 1:100.000 scale image is mosaiking in order to create a continuous surface of the study area. Generally, different images are georeferenced to get exact latitude and longitude location of the research area.

Image enhancement is applied to image data in order to more effectively display or record the data for subsequent visual interpretation. These techniques are most useful because many satellite images, when examined on a color display give inadequate information for image interpretation. Contrast stretching, density slicing, edge enhancement, and spatial filtering are the more commonly used techniques.

Image transformation is also done in order to differentiate between the various brightness values, which are obtained from identical surfaces due to topographic slope and aspect, shadows, or seasonal changes in sunlight illumination angle, and intensity. This condition may hinder the ability of an interpreter to identify correctly surface materials or land use in remotely sensed image. Ratio transformation of the image can reduce the effect of such environmental conditions and may also additionally provide unique information not available in any single band that is useful for discriminating between soils and vegetation. For vegetation discrimination in land use/cover mapping band ratio of 4 to 3 band and false color combinations in RGB order of bands 432 was done.

Image classification involves the analysis of multispectral image data and the application of statistically based decision rules for determining the land cover identification of each pixel in an image. Decision based on spectral radiance classification process is spectral pattern recognition whereas decision based on geometric shapes, size, and patterns the procedure falls into spatial pattern recognition (Lilles and Kiefer, 2000). Image classification depends on the brightness value of each pixel and it categorizes pixels of nearly the same values. Unsupervised classification was performed in order to have a general idea of the area. Supervised classification was performed for final land use/cover mapping.

Therefore supervised classification is done by ERDAS Imagine 10 for pure RS satellite image analysis. Supervised classification helps to identify training areas for the representation of the ground features selected for the study on the basis of research objectives and questions. This enhanced RS data helps to generate LULC, surface configuration (Slope maps), road maps, surface materials (soil maps) and the geological map helps to generate geologic, geomorphologic and structural maps of the study area.

3.3.2 Image Interpretation

Image interpretation is done for particular thematic information either manually or using software, annotation tool and vector layers should be used (Liu, 2009). Identifying features from the image is carried out by observing change in color, tone, shape, texture and size. In this step, visual interpretation is done and land use land cover data collected, water body appears as light and dark blue on the image, forest appear dark green or black, barren land and agricultural areas were identified by their rectangular and square pattern and shapes. Geological and structural features interpretation is done by, lithologic type either by explosive volcanic lava flows for identifying basalts, rhyolite and pumice domes or pyroclastic(fall or flow or surge) for identifying ignimbrites and tuffs mostly flat bed of rocks, type of color and rock formation. Faults and fractures by their shapes and extents. Field and post field activities are used to cross check the image interpretation for accurate information. Therefore, the accuracy in correspondence between observation and reality is looking good by comparing the result from remote sensing derived classification map and the reference datas. Using error matrix or contingency matrix the overall classification accuracy 90.91% and the overall kappa

0.8804 is obtained. So it is acceptable accuracy assessment result between the observed field data and the remote sensing classification.

3.3.3. GIS Image Analysis and Processing

Data input and data management processes are the most expensive and time-consuming, approximately 80% of the duration of large GIS project spend on these activities (Aronoff, 1993). The process of site suitable selection depends on the input layers which are preprocessed and classified according to the study area LULC, geologic, geomorphologic and structural features. To create geodatabase, all feature classes such as set of points, polygons or linear features related to the area of interest in ArcGIS must be identified. Some of the analysis was done in geodatabase are the following:-

- Study area extracted from the satellite image,
- Georeferenced geologic map converted into image or TIFF format,
- DEM, slope, viewshed and TIN generated on ArcGIS,
- Proximity analysis of road input layer done by Euclidean distance to measure distance of the roads, reclassed road raster as an output layer,
- Buffer analysis (creates buffer polygons around input features to a specified distance, to delineate protected zones around features or to show areas of influence) to faults and fractures as well as big river channels,
- Selected by attributes and locations of a specific layer from the overall data,
- Digitalizing all geological, geomorphologic and structural features from the study area geologic map and so on.

Generally, conversion of all vector data to raster data (and/or vice versa) used for reclassification purposes. Changing the vector to raster made certain values together to a common scale and elimination of the detail from an input data set carried out respectively. Equal interval technique results important pattern of spatial distribution of the data for further GIS analysis.

3.3.4. Terrain Suitability Overlay Analysis Using Pairwise Comparison Matrix

The GIS data layers are generated and prepared by ArcGIS 10.1 to process, create, store and retrieve digital terrain data. Further processing is done for military operation planning. In this research to generate suitable command post site selection using weighted overlay analysis (WOA), the factor weights of each parameters used for analytical hierarchical process (AHP) on IDRIS software.

The pairwise comparisons method was developed by Saaty (1980) in the context of the AHP. This method involves pairwise comparisons to create a ratio matrix as input, it takes the Pairwise comparisons of the parameters and produces their relative weights as an output. Therefore, all the reclassified data inputs being weighted and using weighted overlay table calculation the multiple criteria analysis between those input layers scale values are determined.

3.3.5. Applying Military Symbol Specification in ArcGIS

ArcGIS 10.1 supports two military symbol specification documents, the first is MIL-STD-2525C and its related publication, FM 1-02 operational terms and symbols; and secondly APP-6B. These documents provide details on how military symbols should behave and display on maps and how symbols can be transmitted from one system to another (Esri.com). It enhances the effectiveness of command and control (C2) and mission planning applications by combining the spatial analysis capabilities of ArcGIS with common war fighting symbology of the Ministry of Defense (MoND) based on MIL-STD-2525C specification. Therefore, such an approach helps to customize and add own military symbols to mission planning.

3.3.6 Terrain Visibility

In this research using Military Analyst tool installed into ArcGIS 10.1 as an extension for terrain visibility analysis purpose. Military Analyst and 3D analyst tool is used to create Linear Line Of Sight (LOS). The ArcGIS Spatial Analyst extension viewshed tool takes one or more observer points or observer polylines and returns a raster showing areas that are visible and are not visible to the observers. The LOS tool in Military Analyst adds the ability to interactively add observer points before running viewshed (ArcGIS.com). Determination of the visible and hidden areas of locations is helps to the commanders or decision makers to execute their mission and to increase the intelligence of the battlefield.

3.3.7 Web-Decision Support System Customization and Publishing

The last step is web-interface design and database development which operate web-GIS application for military command post suitable site selection. All prepared maps in ArcGIS are customized and loaded on Geoserver web interface design and corresponding attributes of maps are created on geodatabase PostGreSQL database software. After the creation of the database followed by, create tables, add spatial fields and import shape files using PostGIS import export manager onto the Postgres database. On the GeoServer data store directory, creates the new datasets by logically groups of the datasets using name spaces, then queried, manipulated, and exported the data, and indexed the data for performance and visualized it using a desktop viewer. Finally, how this data can share the information over the web is an issue to be resolved. Then has become possible to both visualize the data in a web browser (using WMS) and share the data as a standards-compliant OGC web service (using WFS). The OGC services are used as a set up for data discovery across the servers and implementations.

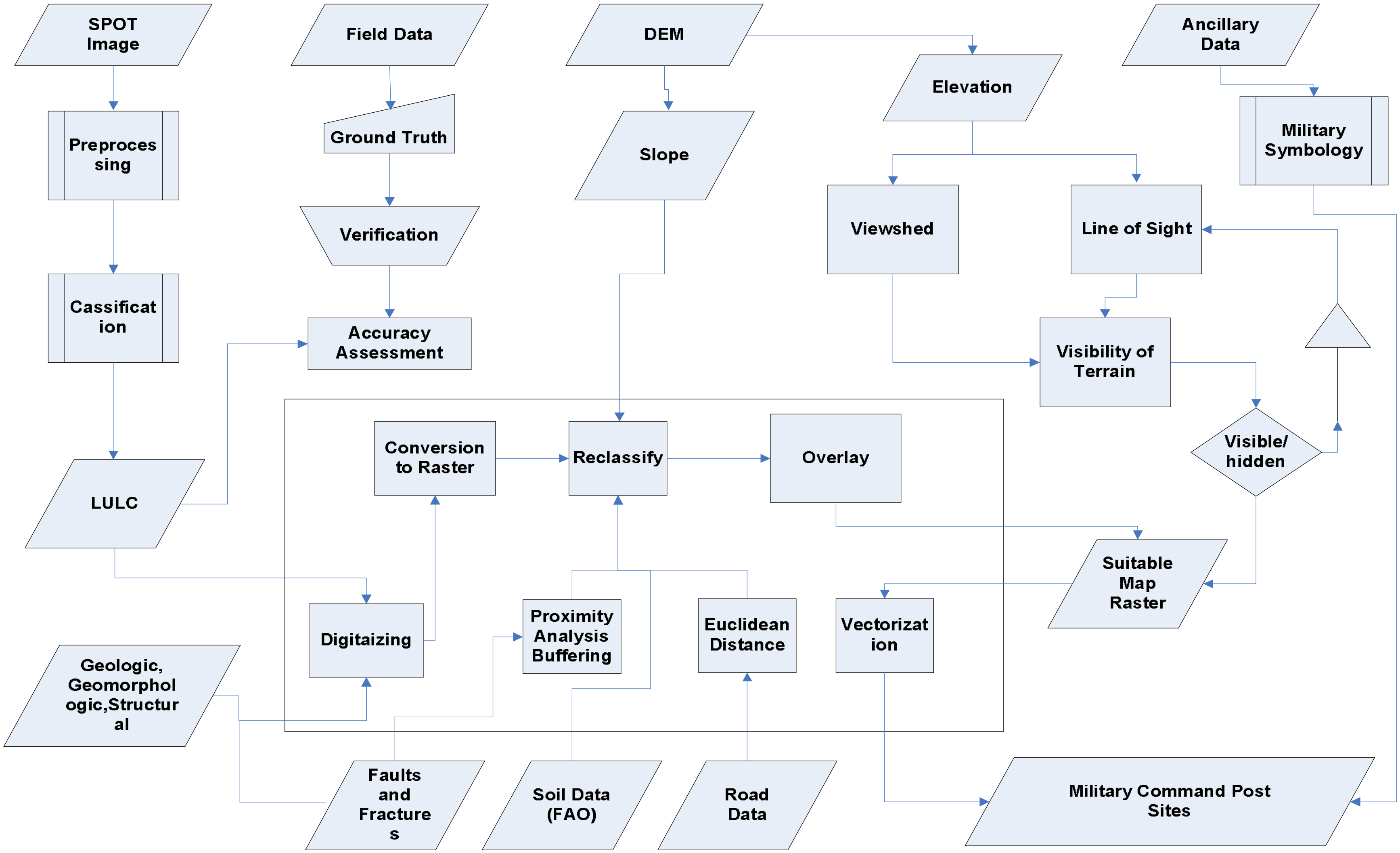


Figure.3.6 Conceptual Model (Flow Chart)

3.4. Factor Description and Preparation method

3.4.1. General Description

3.4.1.1. Factor Analysis and Process

Integration of GIS with IT improves the capability of information collection, information processing and information utilization. Detailed data analysis and processes are discussed in the this section, the LULC, geologic, geomorphologic and structural factors on the specific terrain. Landcover is essential parameter for military operations which helps to identify whether the specific battlefield area has vegetation cover or not, or it is a bare land or agricultural/forest and so on. Geomorphology is a logical discipline used to investigate military ground operations. Geomorphologic parameters like landforms, relief, drainage, water bodies (ground or surface water) and geologic parameters like rock types and soil types are key factors to understand the terrain suitability. Here terrain refers to surface features, or topography, of a region. Military geomorphology is better discipline to examine the linkages between the physical environment and military ground operations.

The study of landforms encompasses formation, denudation, and the complex interrelationships and dynamic processes at work in all aspects of landform evolution. The analysis of the physical geography is a key variable in military operations, it is critical to provide and then assess a coherent, understandable model useful for applied military science. Clearly, military operations affect the physical landscape in a multitude of ways and they may create unique opportunities for research. Wheeled and tracked vehicle maneuvers, obstacle and fortification building and live fire exercises all have differing effects on terrain (Daniel, 2003).

Therefore, understanding terrain which explained by geomorphic processes is fundamentally and inextricably linked to the successful execution of ground warfare (Winter *et al.*, 1998). Finally, this landform based analysis integrates to web-GIS application and shows how GIS and IT perform easier for manipulation of geospatial data to the world.

3.4.1.2. Criteria Selection based on Terrain Challenges and Solving Approach

It is clear that difficult terrain has made challenges for any type of battlefield challenges such as, the difficulty to cover or defend from direct and indirect light and heavy weapons, explosives, air bombardment, the difficulty to camouflage and view/observe; to move with out to be seen by the enemy; to make reconnaissance and observation activates and the suitability of fire for direct and arc fire. In relation to the execution of mission, it is difficult to pass or move for infantry, tank and other armored vehicles and animals. Those challenges have more complexity in the manual system only reading by topographic maps.

Therefore, from the point of view of military profession study of the terrain information has an impact on the execution of all types of operations i.e. battles and other types of field activities such as, damage and capabilities assessment, damage control including environmental cleanup and programs such as fire fighting and it supports to win the battles. To solve the above terrain challenges, first one has to identify the type of terrain (such as flat/plain ground, hill, mountains with their respective elevation and slope) whether the terrain is natural (like vegetations, growing crops, forests), artificial (like buildings, villages and cities). Every little bush or tree, undulation or fold and faults, cutting or embankment determined and they have their own approach for solving their related challenges.

Based on the characteristics of the terrain the following approaches are identified:-

- The degree of the terrain to give cover and which can be determined by the shape and formation of the ground such as coverage of vegetation or forest, hedges, logs, natural fortification, dry beds of streams, undulations.
- The ability of terrain to camouflage and observation /view/ which influenced by suitability of the terrain for observation by posts in order to gain full intelligence on such as enemy manpower, weapons, degree of conceal;
- The ability to pass or to move which controlled by degree of difficulty or simplicity of the ground to pass or to move through it army units and can be classified as easily passable, difficult to pass and impassable;
- Its use of orientation which is determined by ability and skill of every soldier to know their own position on the ground and to familiarize themselves with the ground makes, the accomplishment of the mission and indication of target easy ;
- Its capability of fire decided by the feature of the terrain and the availability of vegetation; and
- The importance of terrain for engineering decided by the type of soil, geology, and availability of aids /materials/ for construction, natural cover and concealment.

Therefore according to the type of terrain on the study area and the objective of this research the criteria's are selected, analyzed and processed to resolve the challenges.

3.4.2 Factors and Parameters of Site Suitability Analysis Related with military Aspects of Terrain

3.4.2.1. Landforms

Land forms are the physical expression of the land surface such as plains or plateaus, hills and mountains. The underlying geological, geomorphologic and structural properties and processes generally determine volcanic landforms. The rock types determine the primary landform such as basaltic lava flows, rhyolite and pumice domes, ignimbrite sheets, and scoria cones, crates and maars. Geomorphological processes such as erosion or deposition can determine secondary landforms such as slope cuts, gorges, alluvial plains and fans, etc. Structural processes such as normal faulting can also lead to the formation of secondary structural landforms such as cliffs (vertical faults planes) or structurally controlled fractures leading to narrow but deep trenches. Moreover, human activities such as quarrying, road cutting and construction activities can modify primary landforms leading to the formation of modified landform. A complete study of a landform includes determination of its size, shape, arrangement, surface configuration, and relationship to the surrounding area.

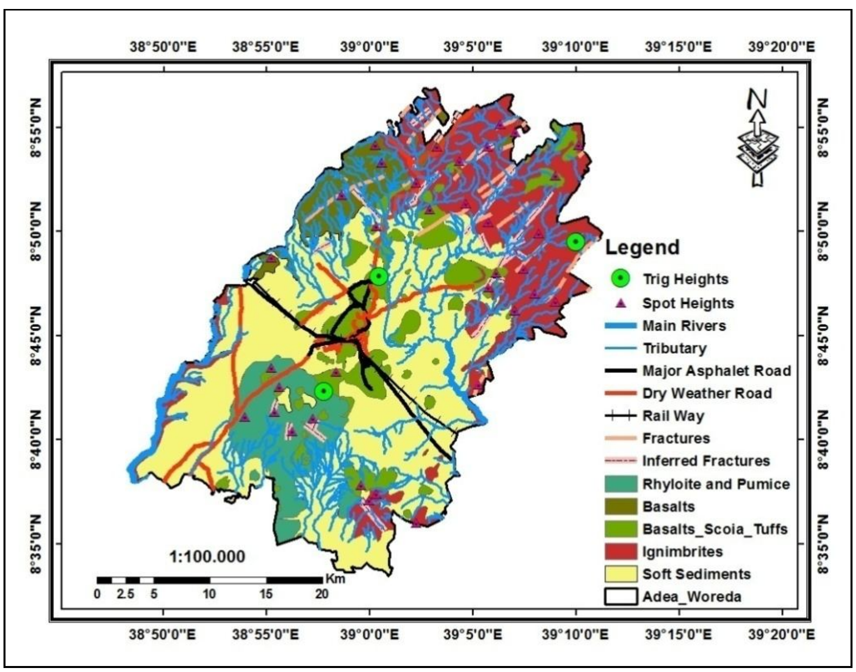


Figure. 3.7 Landform factor map

3.4.2.2 Geological Features

Geological map of the area should be taken as a parameter. Rock types are important in determining all the above features in soil type and classification. The rock types are categorized into rift axis complex, intra rift complex and western margin complex. Geology of the Ada'a Woreda comprises volcanic units (craters and maars), alluvial cover, lacustrine deposits. geological structures like fractures and faults are observed. Identifying the geological features helps to study the suitability and stability of rock type for command post best site selection. From the geologic type more than thirteen types of geologic features identified, extracted and reclassified into five categories and ranked based on their rock type formation and stability for the movement of armored vehicles. The first one is intercalated rhyolite and pumices domes, pure basalts, basalts_scoriacones_tuffs, ignimbrites and soft sediments(alluvial fans and lacustrine deposits) respectively. Based on the classification intercalated rhyolite and pumice domes are more suitable and optimal for the research purpose but soft sediments are less suitable.

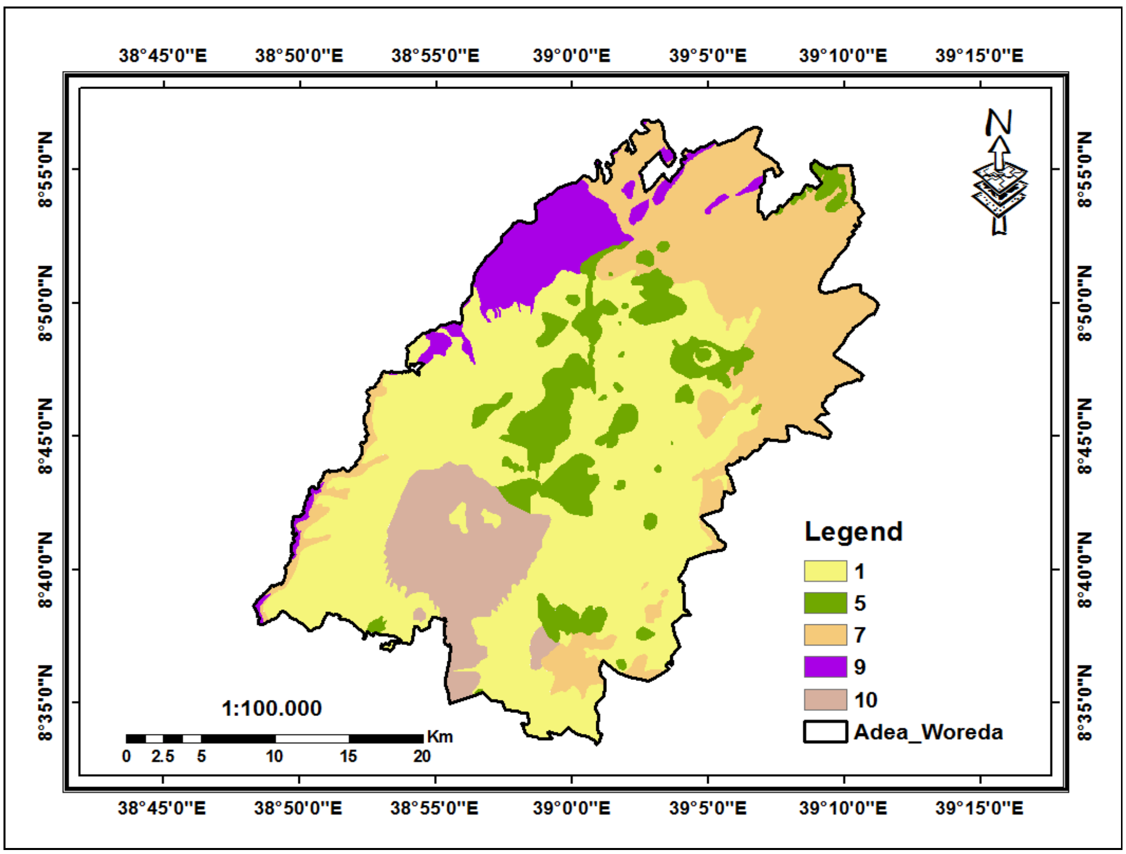


Figure. 3.8 Geology type factor map

Based on the classification intercalated rhyolite and pumice rock types are more suitable and optima (ranked as value 10), basalts are ranked as value 9, ignimbrites and basalts_scoia_tuffs are ranked as 7 and 5 respectively for the selected site in the study area and soft sediments are less suitable than others and ranked as value of 1.

a. ***Rhyloites and Pumices:-*** extremely optimal for the objective of the research and they are extrusive igneous rocks that are the volcanic equivalent of granite. Most rhyolites are porphyritic, indicating that crystallization began prior to extrusion. Crystallization may sometimes have begun while the magma was deeply buried; in such cases, the rock may consist principally of well-developed, large, single crystals (phenocrysts) at the time of extrusion. Most pumice is acidic/felsic in composition associated with rhyolite since those lavas tend to have more volatiles, but intermediate and basic varieties are known to occur. In the study area rhyolite and pumice occurred as an interbeded unit and formed dome shape topography with higher elevation.

b. ***Basalts (basaltic lava flow):-*** which are very optimal, extrusive igneous (volcanic) rock that is low in silica content, dark in color, and comparatively rich in iron and magnesium. Some basalts are quite glassy (tachylytes), and many are very fine-grained and compact. It is more usual, however, for them to exhibit porphyritic structure, with larger crystals (phenocrysts) of olivine, augite, or feldspar in a finely crystalline matrix (groundmass). Basalts are the hardest type of igneous rocks than rhyolite and pumice dome but the majority of basalts in the study area occupied flat topography.

c. ***Ignimbrites:-*** an ignimbrite is ranked as optimal, and the deposit of a pyroclastic density current, or pyroclastic flow, which is a hot suspension of particles and gases flowing rapidly from a volcano driven by having a greater density than the surrounding atmosphere.

d. ***Basalts_Scoria and Tuffs:-*** moderately optimal and Scoria is a highly vesicular, dark colored volcanic rock that may or may not contain crystals (phenocrysts). It is typically dark in color (generally dark brown, black or purplish red), and basaltic or andesitic in composition. Scoria is relatively low in mass as a result of its numerous macroscopic ellipsoidal vesicles, but in contrast to pumice, all scoria has a specific gravity greater than 1, and sinks in water.

e. ***Soft Sediments (alluvial cover and lacustrine deposits):-*** are less optimal, alluvial deposits are material deposited by rivers. It consists of silt, sand, clay, and gravel, as well as much organic matter in lacustrine deposits. They form a perfectly flat, terrace like feature surrounding the lake area.

3.4.2.3. Slope or Gradient

Military topographers traditionally calculate the slope information from paper maps but in ArcGIS generates faster with better accuracy from DEM. The slope of the terrain is an effect on mobility in the study area therefore according to FDRE military topography standards reclassified into the following classes. The slope value less than 5 is easily passable for mobility, the classes value of 5-10 and 10-20 are passable and easily passable for mobility and the classes from 20-25 and greater than 25 are classified their suitability as difficult to pass and impassable.

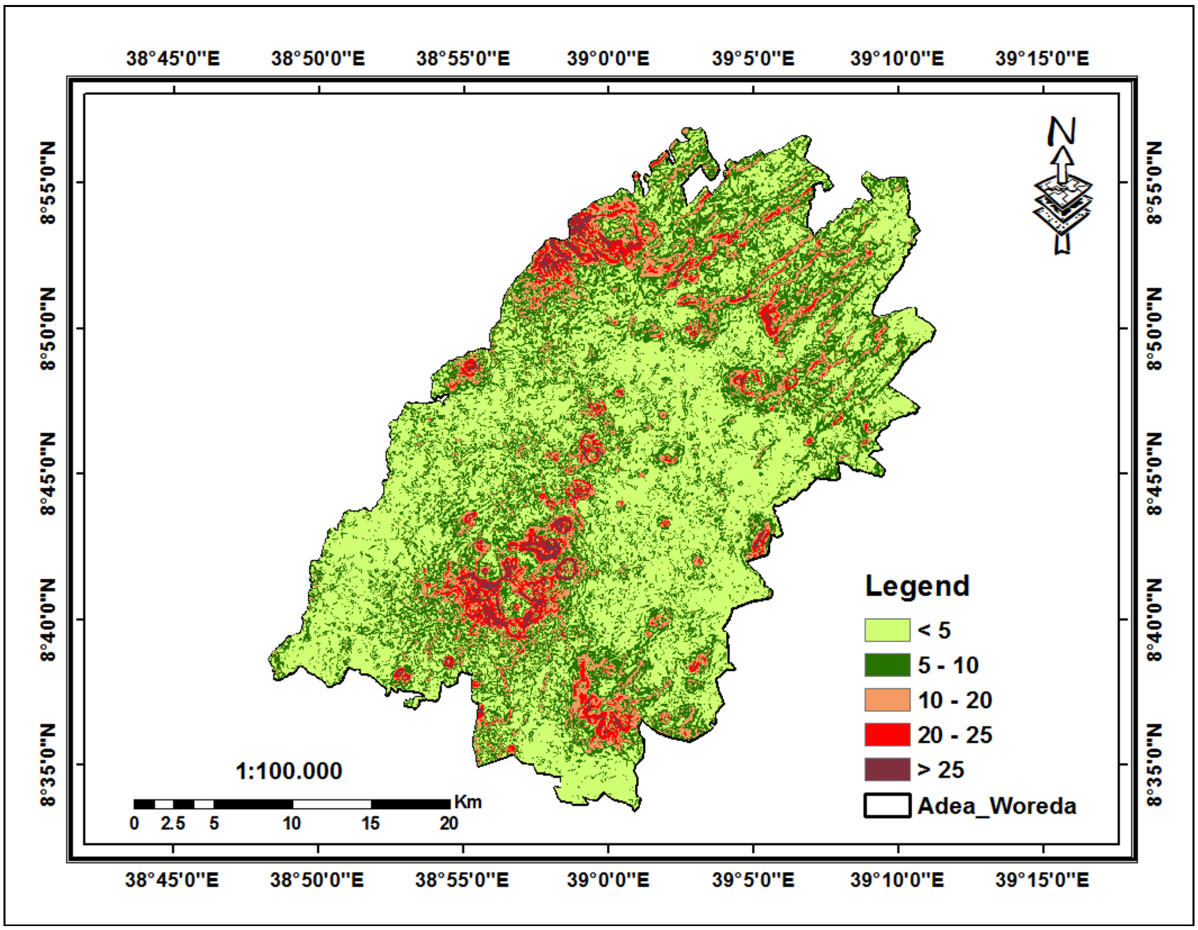


Figure. 3.9 Slope or Gradient Factor Map

3.4.2.4. Land Cover

Particularly vegetation features, Plant cover can affect military tactics, decisions, and operations. Perhaps the most important is concealment. On military maps, any perennial vegetation high enough to conceal troops or thick enough to be a serious obstacle to free passage is classified as woods or brushwood. Although trees provide good cover and concealment, they can present problems to movement of armor and wheeled vehicles. Woods also slow down the movement of dismounted troops. Terrain analysts should identify either a specific area is forest Land, Agricultural/Crop Land, Bare Land or Settlements. According to the study area land cover and the experts judgment for the landcover suitability for the command post, the bareland is ranked as higher value of 10, then the grass land, agriculture and forest are ranked as 9,7,5 respectively, settlements and buildups are ranked as low value of 3 and 1 and the water bodies as ranked as restricted for the selected command post.

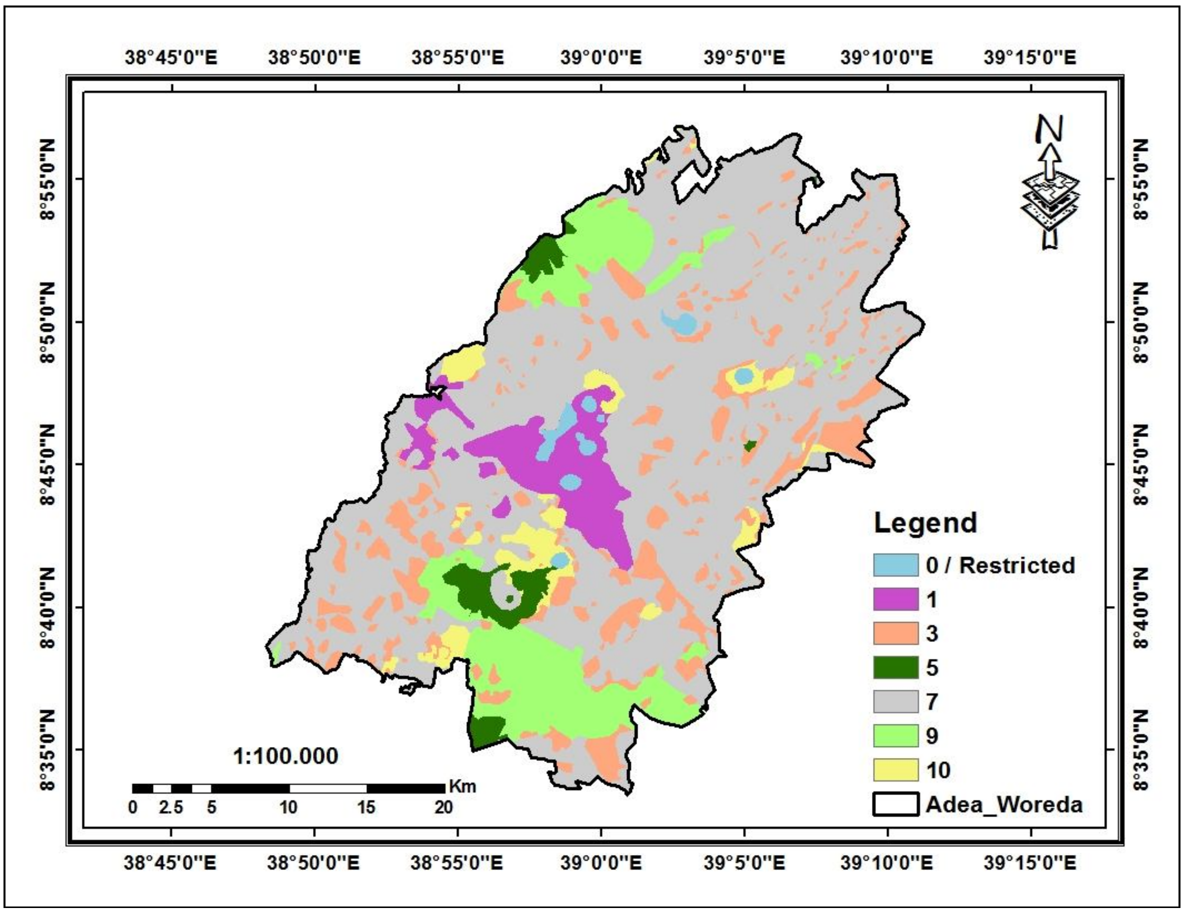


Figure. 3.10 Land cover factor map

3.4.2.5. Soil Features and Surface Materials

Since soils vary in their ability to slipperiness, their ability to withstand vehicle passes, and their ease of digging, military planners rely heavily on soil analyses. Soil type, drainage characteristics, and moisture content affect road construction, material location, and traffic ability determination. For field identification and classification, soils may be grouped into five principal types: gravel, sand, silt, clay, and organic matter.

As it is explained in its attribute the soil classification is based on FAO (1993). Accordingly six soil mapping units were identified and soil map has been produced in Arc GIS environment. Some of the soil types described in the map as Orthic Solonchaks, Chromic Luvisols, and Dystric Nitisols are ranked as higher value of 10, 9, 7 respectively and Luvic Phaeozems and VerticCambisols are ranked as 5 and 3. But Pellic Vertisols are muddy black soils and ranked as minimum value of 1.

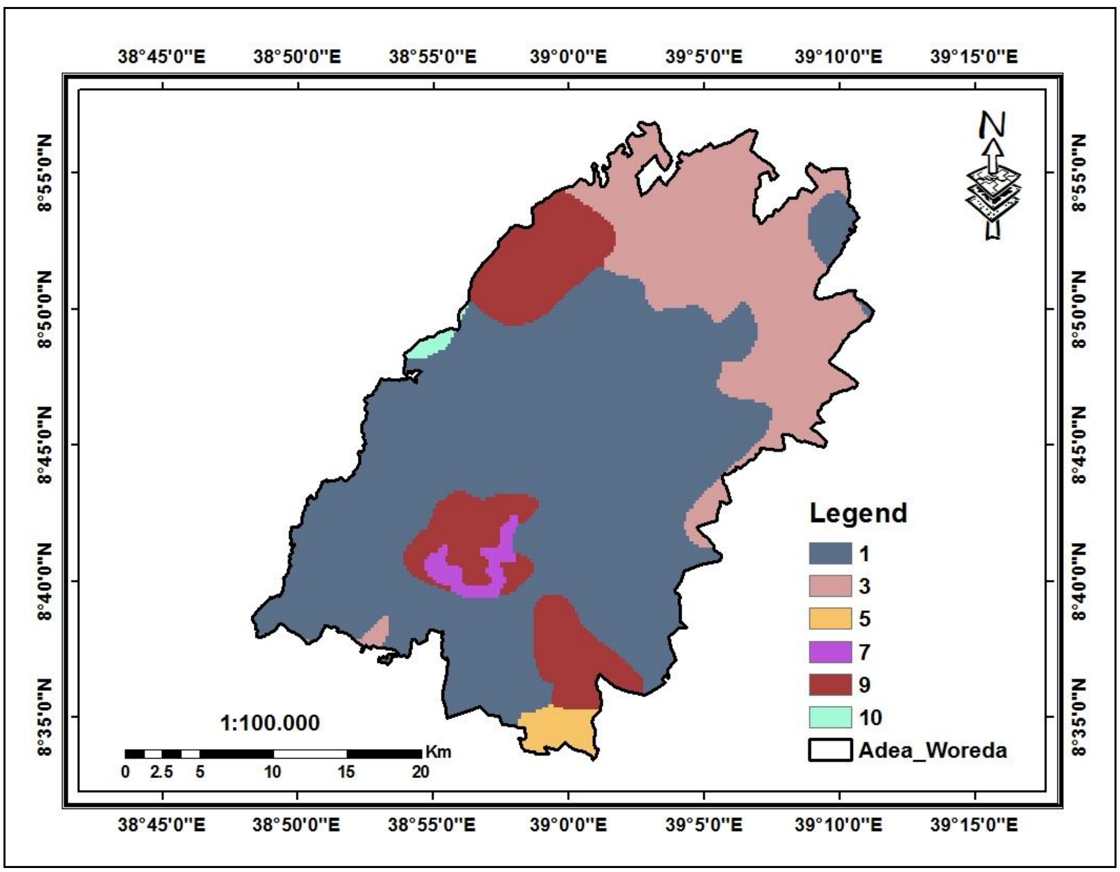


Figure. 3.11 Soil factor map

1. ***Orthic Solonchaks*:-** very optimal type of soil formed usually by the salinization of soils in steppe, desert, and semi-desert regions Solonchaks are defined by high soluble salt accumulation within 30 cm (1 foot) of the land surface and by the absence of distinct subsurface horizonation (layering), except possibly for accumulations of gypsum, sodium, or calcium carbonate or layers showing the effects of water logging.

2. ***Chromic Luvisols:-*** are also very optimal soils that have higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Luvisols have high-activity clays throughout the argic horizon and a high base saturation at certain depths.

3. ***Dystric Nitisols:*** are optimal soils which are deep, well drained, red tropical soils with diffuse horizon boundaries and a subsurface horizon with more than 30 percent clay and moderate to strong angular blocky structure elements that easily fall apart into characteristics shiny, polyhydric(nutty) elements.

4. ***Luvic Phaeozems:*** less optimal soil types Phaeozems are characterized by a humus-rich surface layer covered in the natural state with abundant grass or deciduous forest vegetation. They may exhibit a layer of clay accumulation, however. Their surface layers are usually higher in humus than those of Chernozems.

5. ***Vertic Cambisol:*** are least optimal medium and fine-textured materials derived from a wide range of rocks characterized by slight or moderate weathering of parent material and by absence of appreciable quantities of illuminated clay.

6. ***Pellic Vertisols:*** are not optimal for mobility, churning, heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks from the surface downward when they dry out, which happens in most years.

3.4.2.6 Geomorphological Features

The way of approach is man-made roads or any route that approaches to the target. The way of approach in this study depends on the main roads within the study area. The distance of the road is determined by using Euclidean distance calculation. Therefore, distance less than 4km is closer and suitable for command post sites but greater than 18km is not recommended. Obstacles are any natural or man-made features that slow, divert, or stop the movement of personnel or vehicles. Obstacles that will be delineated should be in areas where they are of primary concern for the diversion of cross country movement. The main obstacles in the study area are faults and main river channels for the movement of vehicles as well as troops and created a buffered zone for 100m distance from them.

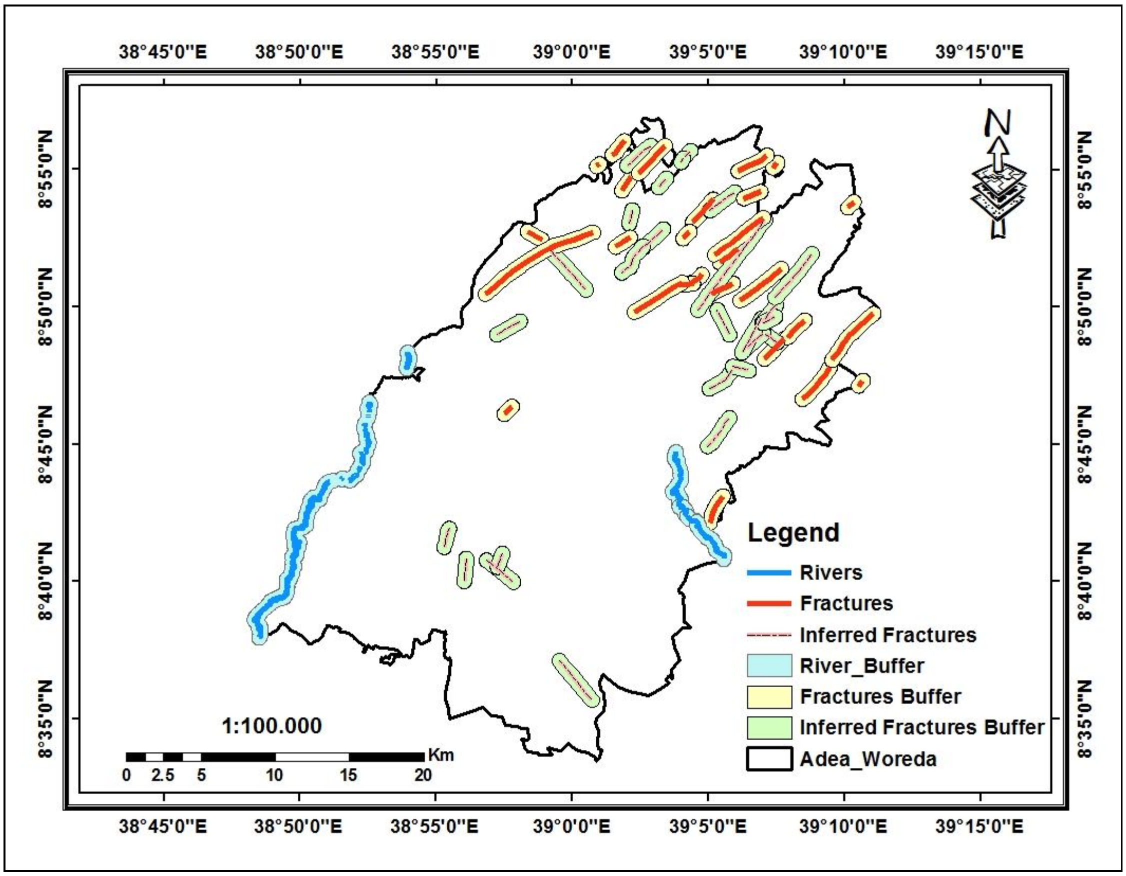


Figure 3. 12 Buffered Obstacle factor map

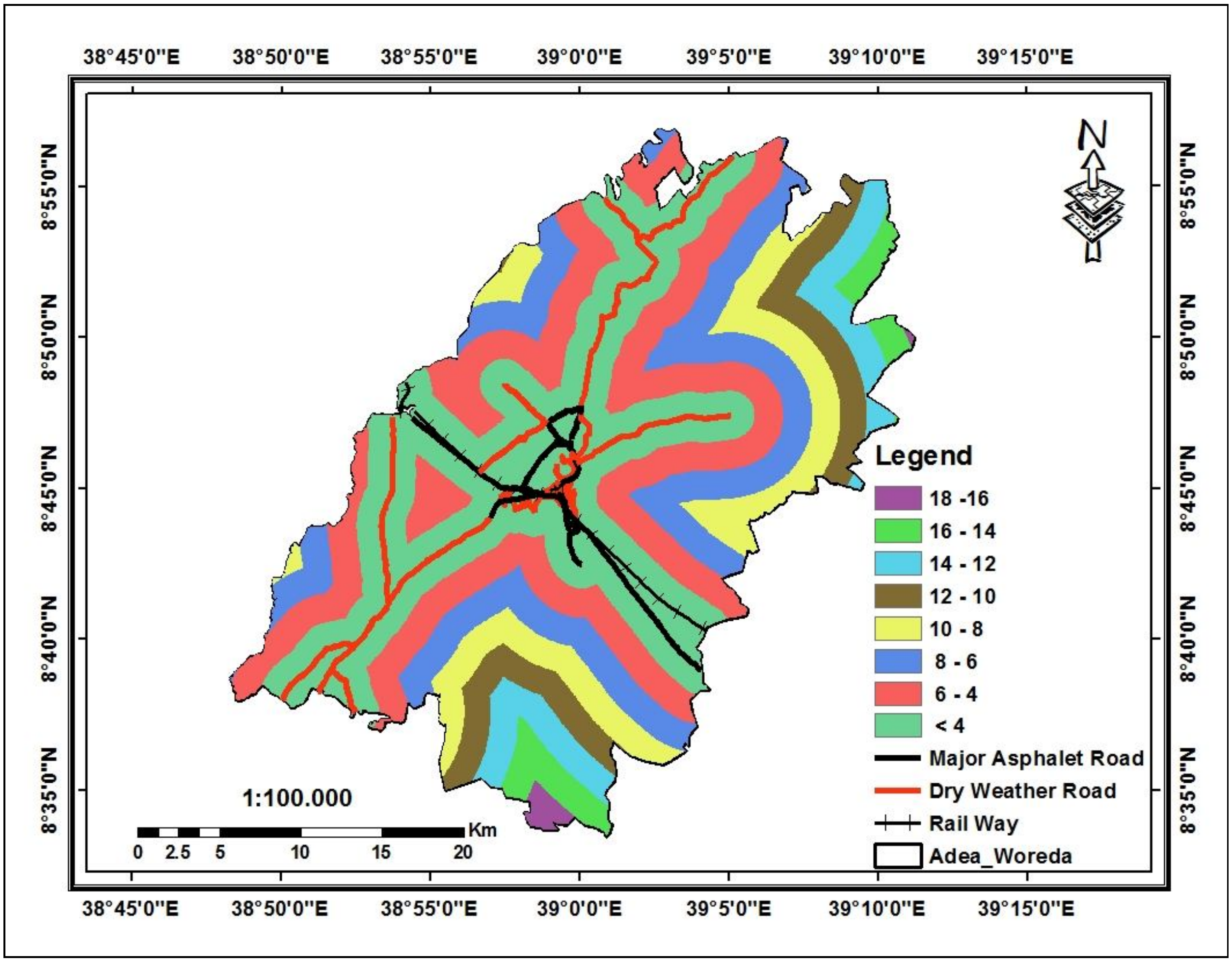


Figure 3.13 Euclidean distance and reclassified distance to roads

3.4.2.7 Elevation and Spot Heights

Elevation and Spot heights helps to determine the altitude of the study area above the sea level, the elevation which spot height is more than 2000m is used and reclassed as below. From 2,063 to 2,877 values are more important and but 1685 to 1937 is less elevation values and less important. In this research the elevation is the most important factor because it used as a main criteria for command post site selection.

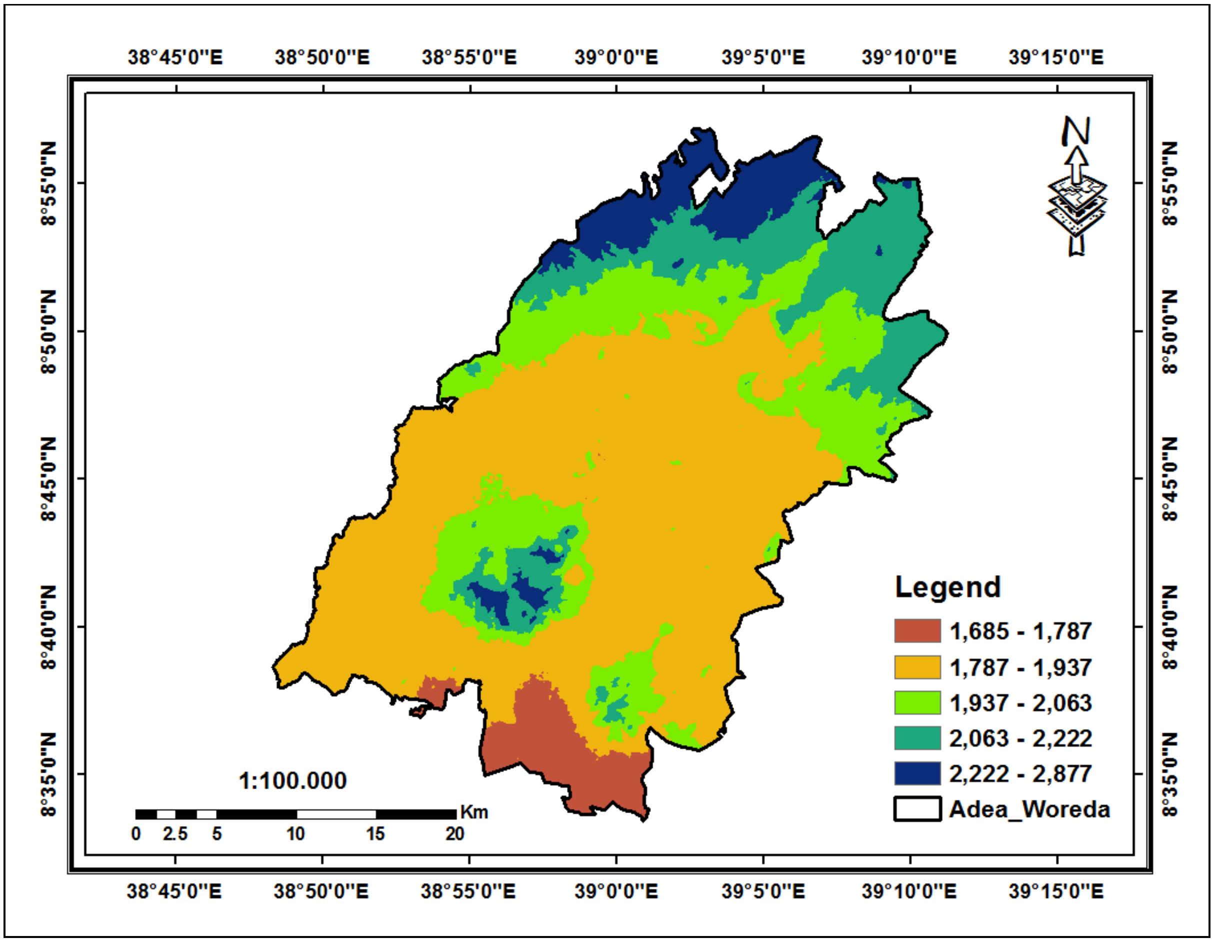


Figure 3.14 Reclassified Elevation factor map

The above site suitability factors are related to military aspect of terrain standardized as OCOKA in (FM 5-33, 1990). After the identification of terrain features the next step is analysis on terrain features (or terrain evaluation) with different parameters using PCM and overlay analysis such as landcover, slope, elevation, surface materials analysis (soil), faults and fractures, river/drainages, roads, lithologic or rock types.

Table 3.6 Military aspects of terrain according to the study area

Data/input layers	Type/Shape	Terrain information	Military Aspects	Terrain analysis results
Land Cover	Vector	- Agriculture -Barren Land - Forest - Grass Land - Built Up - Settlements - Water Body	Cover and Concealment Obstacles	-Potential of covering(density) from attacks and concealing from observation - Potential restricted to placement
Elevation	Point	- Spot Height -Trigonometric Height	Observation	- Placement of command suitability and visibility
Drainages	Line	- Secondary River - Tributary River	Obstacles/Conceal	- Location of Natural obstacles for mobility
Roads	Line	- Asphalt Road - Dry Weather Road - Power Line - Railway - Trail Road	Way of Approach/Transportation	- Identification of paths for movement
Soil Types	Vector	- Chromic Luvisols - Dystric Nitisols - Luvic Phaeozems - Orthic Solonchaks - Pellic Vertisols - VerticCambisols	Obstacles	- Identification of surface materials for the speed of movement
Geological features	Vector	-Soft Sediments(Alluvial cover and Lacustrine deposits) - Basalts, Scoria and tuffs - Rhyolites and Pumice - Ignimbrites	Obstacles	- Identification of Lithologic type of rocks for the purpose of Stability
Faults	Line	- Fractures - Inferred Fractures	Obstacles/Conceal	- Identification of landforms for movement, cover and conceal
Slope	Raster		Obstacles	- identify the degree of surface configuration for mobility; easily passable, passable and difficult to pass

Table 3.7 Criteria Selection and ranking from Experts judgment approach for all types of weather condition

Criteria	Type	Rank in integer	Condition	Weight
LULC	Barren Land	10	More Optimal	0.10
	Grass Land	9	.	
	Agriculture	7	.	
	Forest	5	.	
	Settlements	3	.	
	Built Up	1	.	
	Water Body	Restricted	Not Optimal	
Soil Types	Orthic Solonchaks	10	More Optimal	0.03
	Chromic Luvisols	9	.	
	Dystric Nitisols	7	.	
	Luvic Phaeozems	5	.	
	Vertic Cambisols	3	.	
	Pellic Vertisols	1	Less Optimal	
Geological features	Rhyolites and Pumice	10	More Optimal	0.05
	Basaltic units	9	.	
	Ignimbrites	7	.	
	Basalts, Scoria and tuffs Soft Sediments	5	.	
	(Alluvial cover and Lacustrine deposits)	1	Less Optimal	
Slope		< 5 5 - 10 10 - 20 20 - 25 > 25	Easily passable Passable Passable Slow Difficulty to pass Impassable	0.26
Faults	Distance from Fractures And Inferred Fractures	> = 100 < 100	More Suitable Less Suitable	-
Elevation	Distance from Spot heights	> = 2000 < 2000	More Suitable Less Suitable	0.39
Drainages	Distance from drainages/streams	< 100 > = 100	More Suitable Less Suitable	-
Roads	Distance from roads	< 4 4 -18 > 18	More Suitable Suitable Less Suitable	0.17

3. 5 Weight Determination and Generation of Suitability Map

3.5.1 Determination of Factor Weight

At this stage, ever single map was combined with its own weight using weighted linear combination (WLC) technique in GIS environment (Santa-riviera *et al.*, 2008). In weighted linear combination (WLC) procedure, factors and parameters (f_i) are multiplied by the weight of the suitability parameters (w_i) to get composited weights and then summed. WLC is a straight forward linear method calculating composite weights. This function multiplies and sums up the layers to produce suitability maps. Therefore, the weighted linear technique (Mendoza, 1997 and Mohit and Ali, 2006) was applied to generate a suitability map by the following formula.

In this suitability process f assigns to each individual factor or criteria from i to n and w is represent the weight of factors

Therefore $F = \{f_l, f_2, f_i, ..., f_n\}$...................................... Equation 5.1

Where, f_i, i = 1, 2, ... n, represents each individual factor

$W = (w_1, w_2, w_i, ..., w_{n)}$..................................Equation 5.2

Where, w_i, i = 1,2, ... n, represents the weight of each individual influential factors.

$$F = \sum_{i=1}^{n} wi * fi \text{.................................Equation 5.3}$$

Where: wi = relative importance or weight of factors/parameters i, fi = individual parameters from i to n = total number of parameters related to the study, and F is the suitability.

3.5.1.1 Determining Weights of Criteria by Using AHP

Table 3.8 Linguistic variables used in the study

Linguistic variables	Crisp number	Reciprocal AHP Numbers
Extremely strong	9	1/9
Very strong	7	1/7
Strong	6	1/6
Moderately strong	5,4,3	1/5, 1/4,1/3
Equally strong	1	1
Intermediate	2	½

Source: Saaty (1980)

The Judgment Matrix of the Study (PCM)

Table 3.9 Pairwise Comparison matrix

	Elevation	Slope	Road	Land cover	Soil Type	Geology
Elevation	1	2	3	5	7	9
Slope	1/2	1	2	4	6	7
Road	1/3	1/2	1	3	5	5
Landcover	1/5	1/4	1/3	1	4	4
Soil Type	1/7	1/6	1/5	1/4	1	3
Geology	1/9	1/7	1/5	1/4	1/3	1
SUM	2.287	4.059	6.733	13.5	23.33	29

3.5.1.2 Calculation of Score Weight for Each Criterion

Table 3.10 Criteria Weights *(* C stands for Criteria)*

	C1	C2	C3	C4	C5	C6	WEIGHT	AVERAGE
C1	0.44	0.49	0.45	0.37	0.30	0.31	2.36	0.3944
C3	0.22	0.25	0.30	0.30	0.26	0.24	1.57	0.2630
C3	0.15	0.12	0.15	0.22	0.21	0.17	1.02	0.1731
C4	0.09	0.06	0.05	0.07	0.17	0.13	0.57	0.0944
C5	0.06	0.04	0.03	0.02	0.04	0.10	0.29	0.0461
C6	0.04	0.03	0.03	0.02	0.01	0.03	0.16	0.0291
								1.00

Calculation for consistency vector

Table 3.11 Consistency vector

	Weighted Sum Vector(WSV)	**CV**
C1	(0.39) (1)+(0.26)(2)+ (0.17)(3)+(0.10)(5)+(0.05)(7)+(0.03)(9) =2.54/0.39	6.51
C3	(0.39) (0.5)+(0.26)(1)+ (0.17)(2)+(0.10)(4)+(0.05)(6)+(0.03)(7) =1.71/0.26	6.58
C3	(0.39) (0.33)+(0.26)(0.5)+ (0.17)(1)+(0.10)(3)+(0.05)(5)+(0.03)(5) =1.13/0.17	6.65
C4	(0.39) (0.2)+(0.26)(0.25)+ (0.17)(0.33)+(0.10)(1)+(0.05)(4)+(0.03)(4) =0.62/0.10	6.19
C5	(0.39) (0.14)+(0.26)(0.16)+ (0.17)(0.2)+(0.10)(0.25)+(0.05)(1)+(0.03)(3) =0.30/0.05	6
C6	(0.39) (0.11)+(0.26)(0.14)+ (0.17)(0.2)+(0.10)(0.25)+(0.05)(0.33)+(0.03)(1) =0.18/0.03	6
	CV	37.93

Calculation of a consistency index

CI = $\frac{\lambda - n}{n-1}$ **where is CV/n 37.93/6 = 6.32 ....**Equation 5.4

Therefore CI = (6.32- 6)/) 6 -1) = 0.32/5 = 0.06 is less than 10%

Where CV is consistency vector and CI is consistency index. According to Saaty (1980) the determination of factor weights are very accurate because less than 10%

3.5.2 Executing of Suitability Model

Using the analytical hierarchy process in IDRISI software the calculated factor weights for each criteria and its relative importance (influence)from one criteria to another is combine the raster datasets to execute the suitability model in the weighted overlay table and model builder as shown in the figure respectively. The datasets are reclassified into common measurement scale 1 to 10 by changing the default scale before adding them for example the LULC raster map bare land is higher importance than the others but water bodies are restricted for this analysis. Therefore consistency matrix ratio percentage influence for each factor is adjusted.

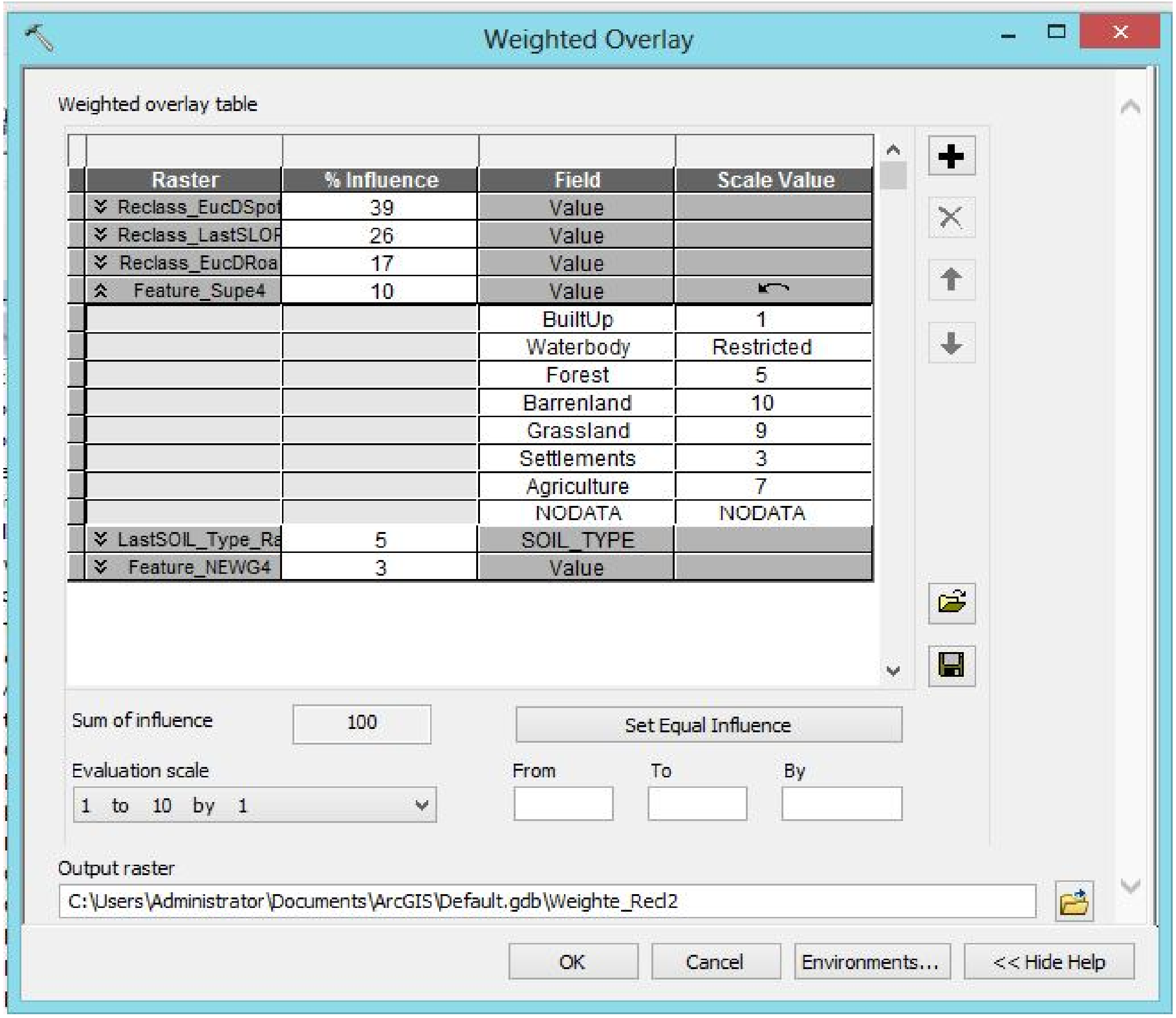


Figure 3. 15 Weighted overlay table

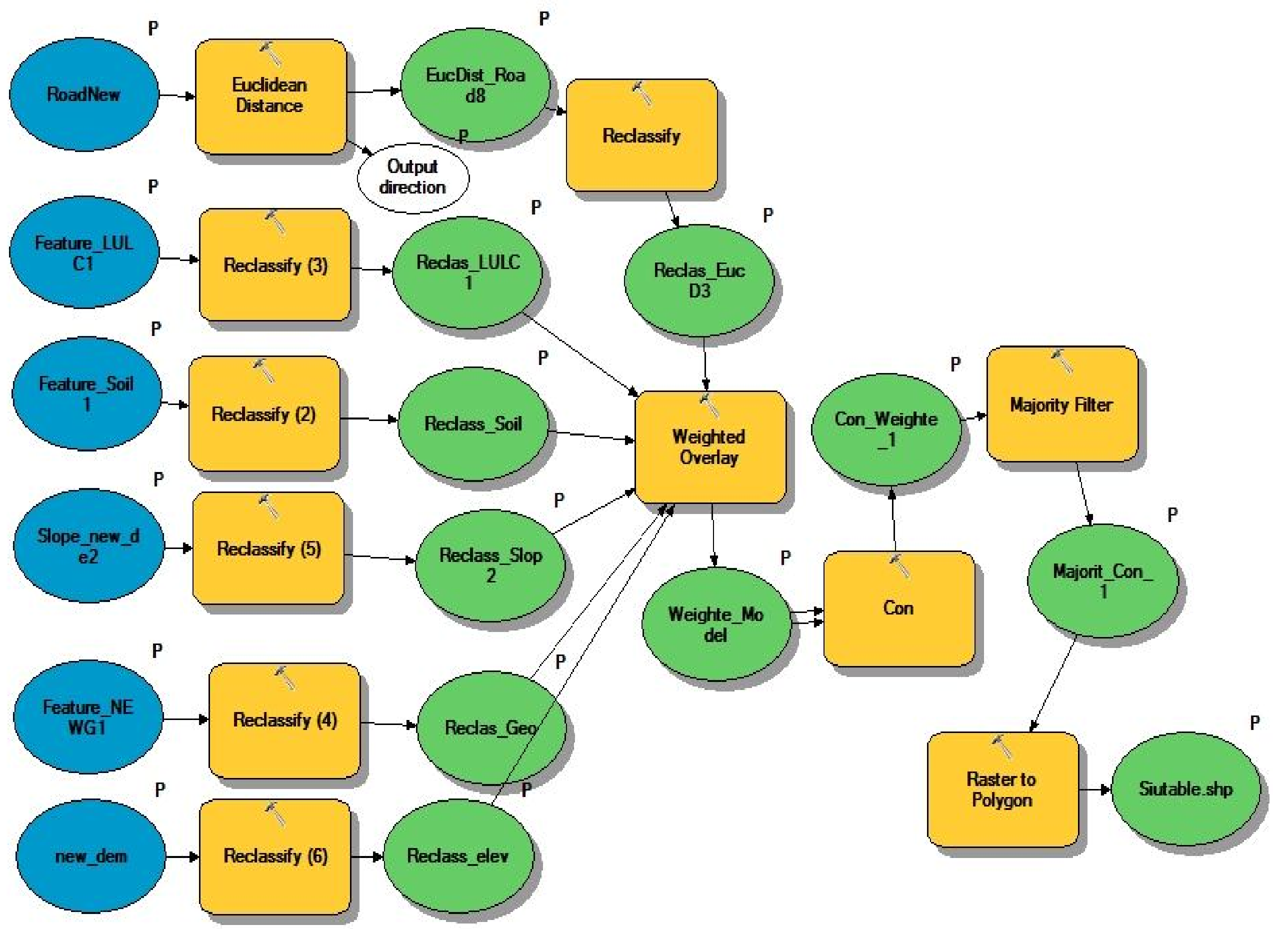


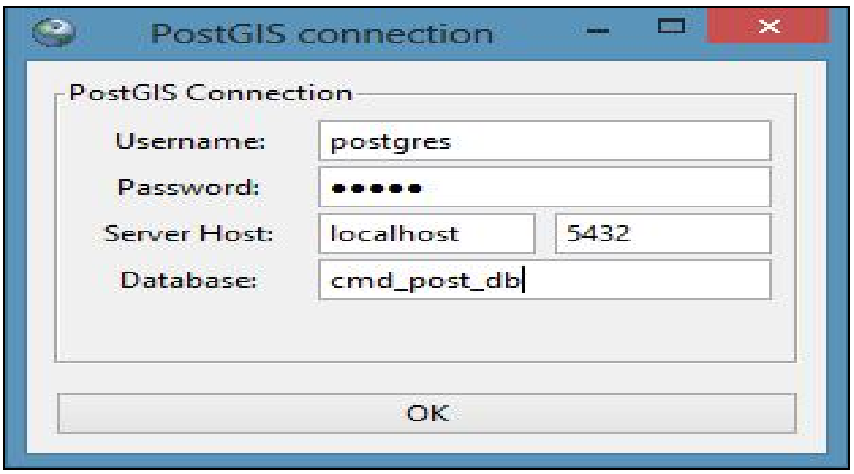
Figure 3. 16 Suitability Model using Model builder

3.5.3 Terrain Evaluation and verification

After generating the final suitability map the specific suitable terrain is evaluated whether the commander can easily see the surroundings from the selected suitable command post by generating the line of site from observer point. The observer points are either the command post itself or other areas but within the selected suitable sites. Visibility can be evaluated by generating the Viewshed and it returns to the visible and not visible area from the observer points. By generating TIN the obstacle areas are identified by dividing elevation into different level of heights and by looking the irregularity of the study area in 3D view, therefore the line of visibility for a distance from the source to the target is verified.

3.5.4 Database Design and Web-Map Customization

Postgres@localhost 5432 is a server to create the cmd_post_db database, then import all the shape files from the ArcGIS geodatabase using PostGIS shape file import/export manager to PostGIS cmd_post_db, although can be select different queries as desired as for map customization. Using GeoServer is done the three main services provides by open source geospatial consortium (OGC) standards such as WCS(web coverage services), WFS(web feature services) and WMS(web mapping services) and using open layers java script the layers or web maps viewable in any web browser.



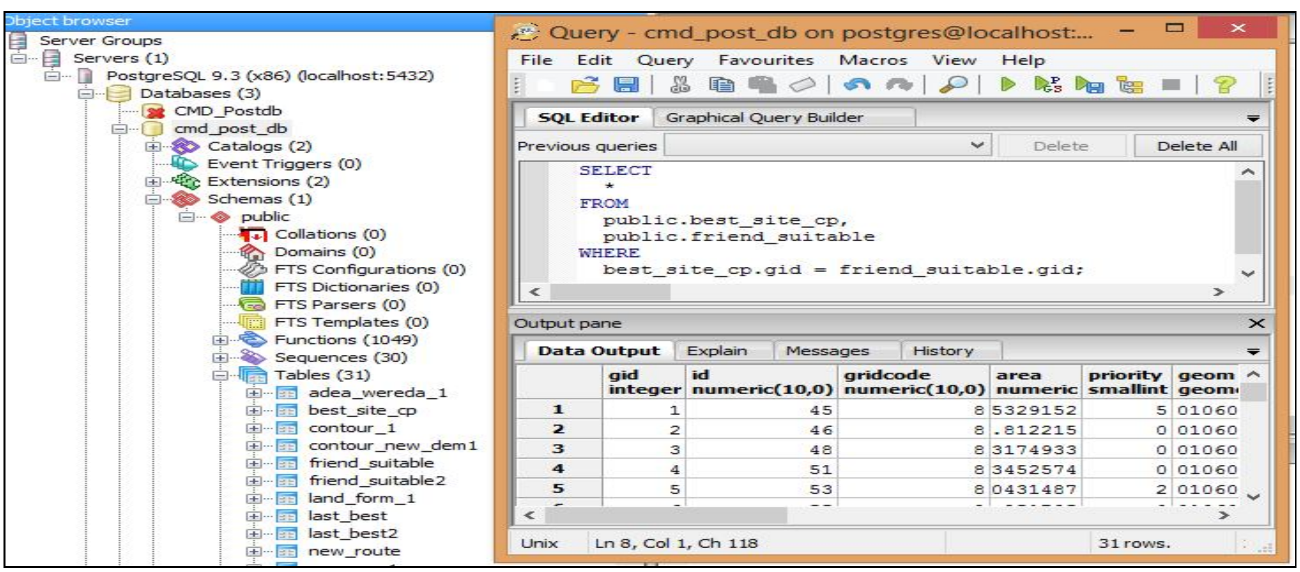


Figure 3.17 Database Creation

CHAPTER FOUR

RESULTS

4.1 Result from application of AHP

AHP is used to evaluate the priority weight of each criteria and sub-criteria (parameters). In this study, to assess the potential of Ada'a Woreda for selecting suitable defense command post locations Six factors(sub-criteria) are considered including slope, elevation, lithologic, soil type, land cover and distance from the road. The two main criteria are (i) geology/geomorphology, and (ii) environmental are used.

Based on the results of the criteria and sub-criteria assessment, elevation heights with a weight equal to 0.39 is the most important in this evaluation and slope, distance from roads and landcover (bare land), soil types and lithologic, layers are the much important respectively.

4.2 Results from weighted overlay

The result map classified from extremely optimal to less optimal and from least optimal to restricted areas. The water bodies or lakes are clearly restricted and marked by red colors, extremely not optimal areas are shown by red brown colors but optimal areas shows light to dark green.

The usual practice from experts' judgment used to help to generate the factor weights and the AHP is used to resolve the conflict of aggregation factors with their relative importance or influence and assigns factor weights to each other. As indicated in the following maps respectively the optimal areas are identified by a conditional if/else evaluation on each of the input cells of an input raster. This is done as if the input raster greater than or equal to the weighted sum select the optimal rater otherwise select the non-optimal one. The exact suitable areas was evaluated and selected by the neighboring cells of similar value for the input raster cell and replaced on the majority of their contiguous neighboring cells using kernel filter.

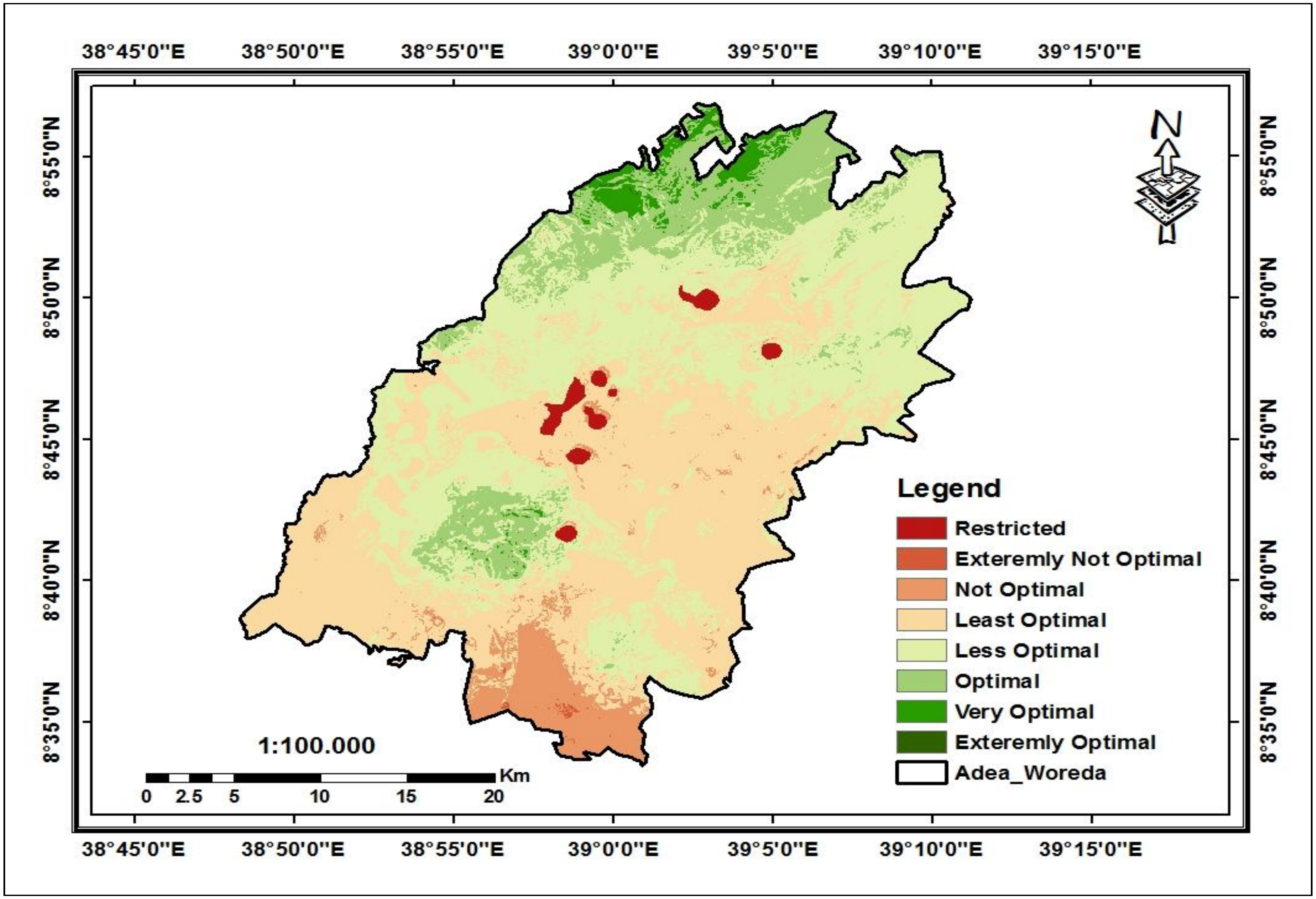


Figure 4.1 Output Map of WOA

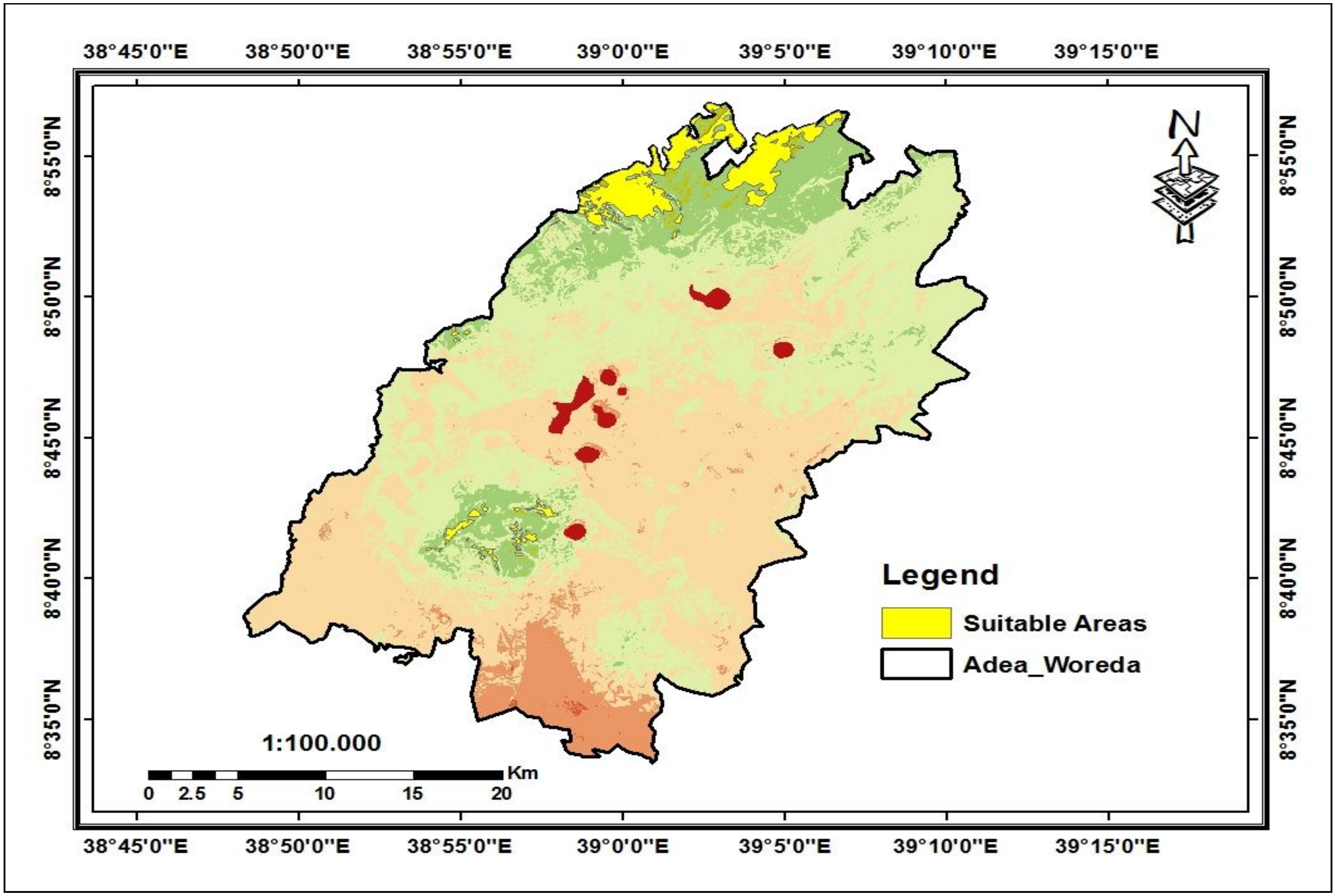


Figure. 4.2. Area of Suitability map

In order to locate the best site for command post, the following points must be considered:-

a. Distance of the command post closer to main roads, and the defence forces such as Air Force, Dejen Aviation and Bishoftu automotive industry,
b. Bare land is the highest priority than others from LULC attributes because it is proposed command post location.
c. Intercalated rhyolite and pumices are the highest priority than other geologic types by their dome shape topography with higher elevation, rock type formation and stability for mobility of armored vehicles.
d. Chromic Luvisols is the dominant soil type next to Orthic Solon chalks in their ability to slipperiness, ability to withstand vehicle passes, and ease of digging.

To identify important operational sites the sites can be classified and assigned as a responsibility zone for friend and enemy from the suitable areas so the following maps shows the selected command post and suitable areas can be assigned as friend and the rest for the enemy site.

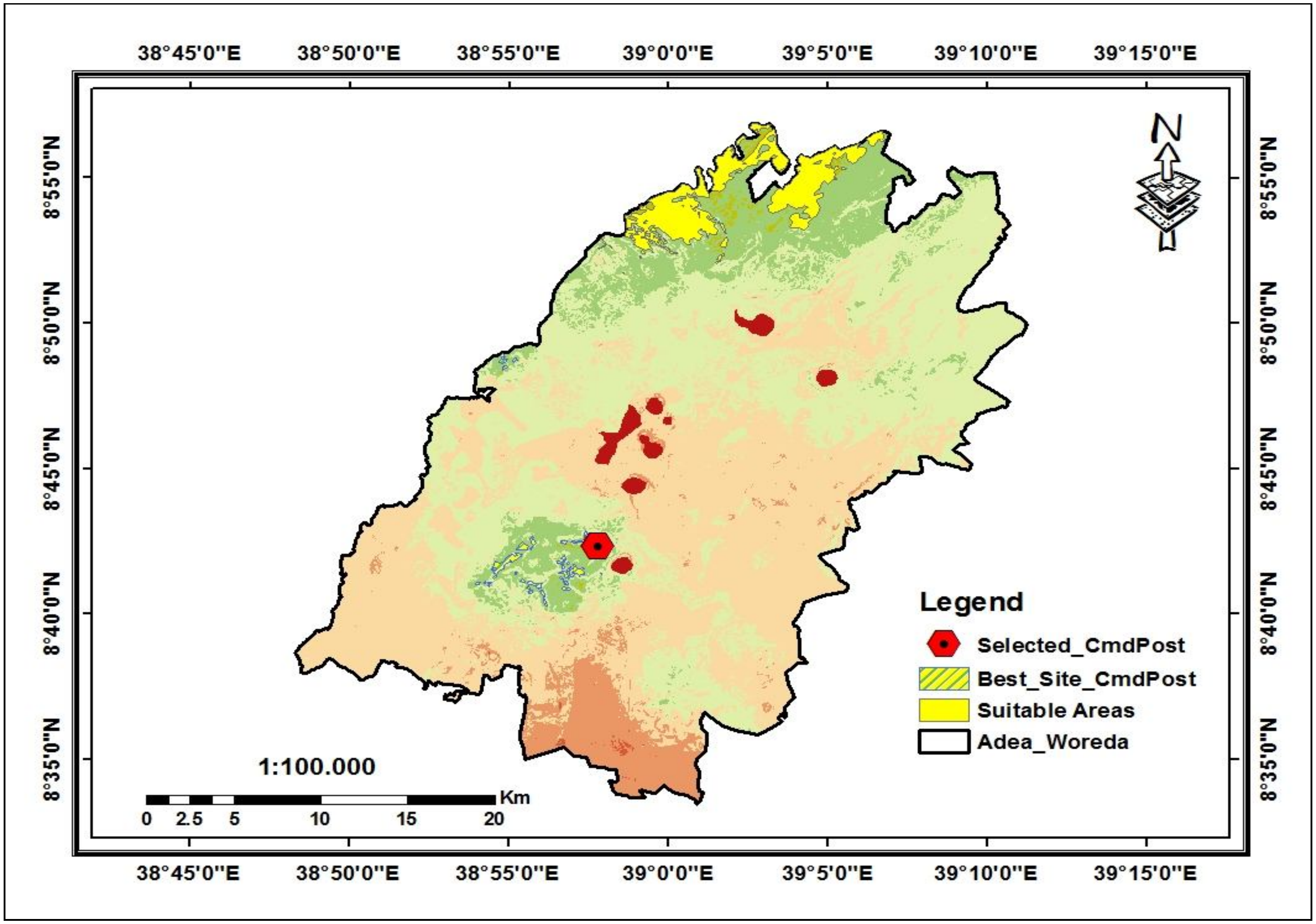


Figure 4. 3 Best Site for Command Post location

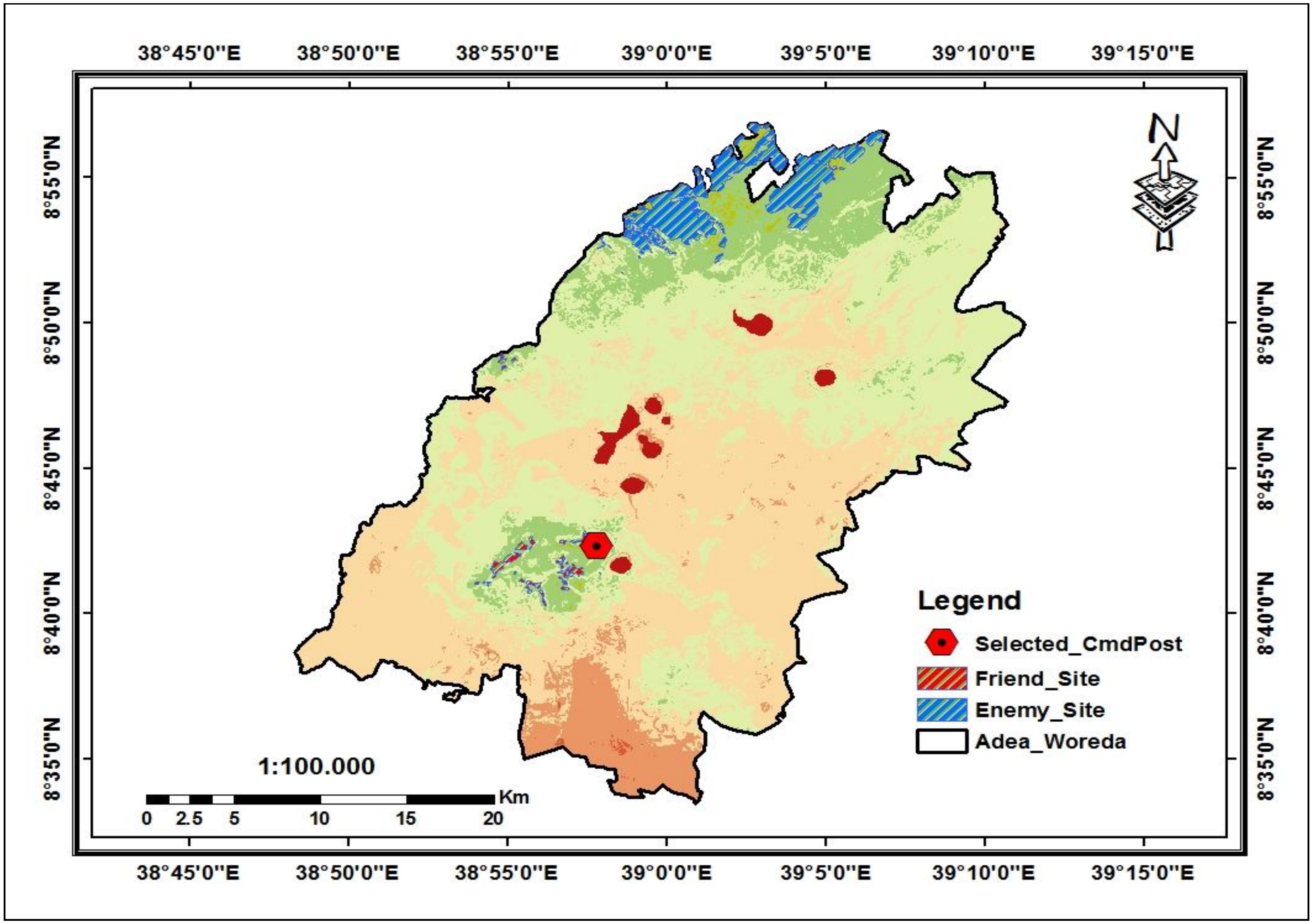


Figure 4. 4 Responsibility zone for friend and enemy

4.3 Results from Visibility Analysis

From the result of the following maps the area which is visible or not visible from the command post is clearly seen by the result of viewshed and TIN. TIN is the triangulated irregular network and one of the visibility analysis proposed it helps to represent continuous surfaces such as terrain elevation. The following TIN maps show from the selected command post which areas are invisible or visible in a single line of sight. It enhances the visibility for the effectiveness of C2 and mission planning applications.

The viewshed map shows that the green color shows the area that can be seen from the command post but not for the pink color areas, similarly the red color lines are the line of sight that cannot be seen by the observer from the command post or from other observer points but, the green lines shows that the line of sight that can be seen from any observer point. Here if the observer cannot clearly visible the target location from the observer point (command post) another observer point can be select from the suitable sites and communicate with the other observer. By adding common war fighting symbology for mission planning can be create the boundary between friend and enemy forces, their mechanized forces with their respective combats as seen below on map.

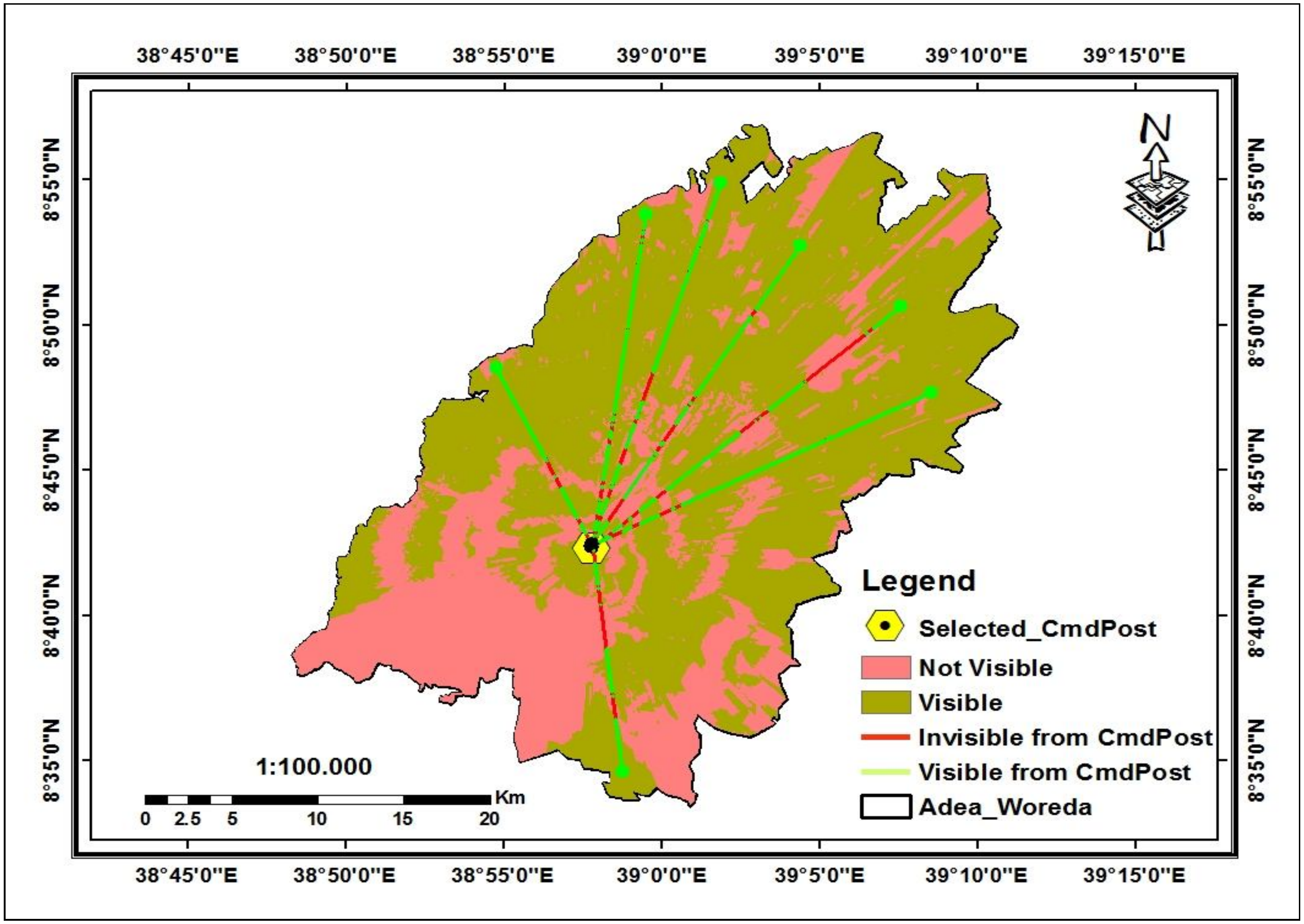


Figure 4.5(a) Visible Areas from the selected command post

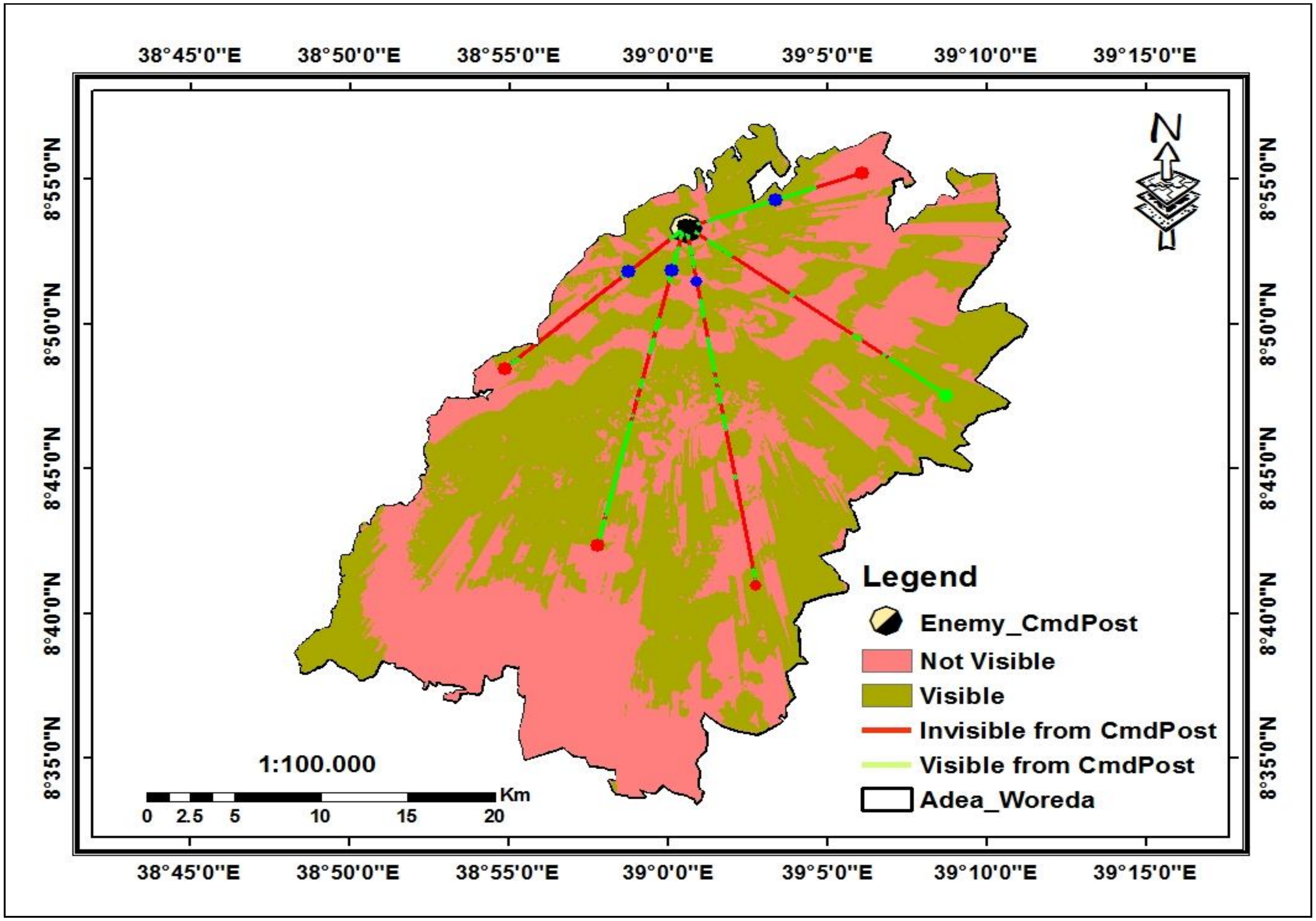


Figure 4.5(b) Visible Areas from the selected command post

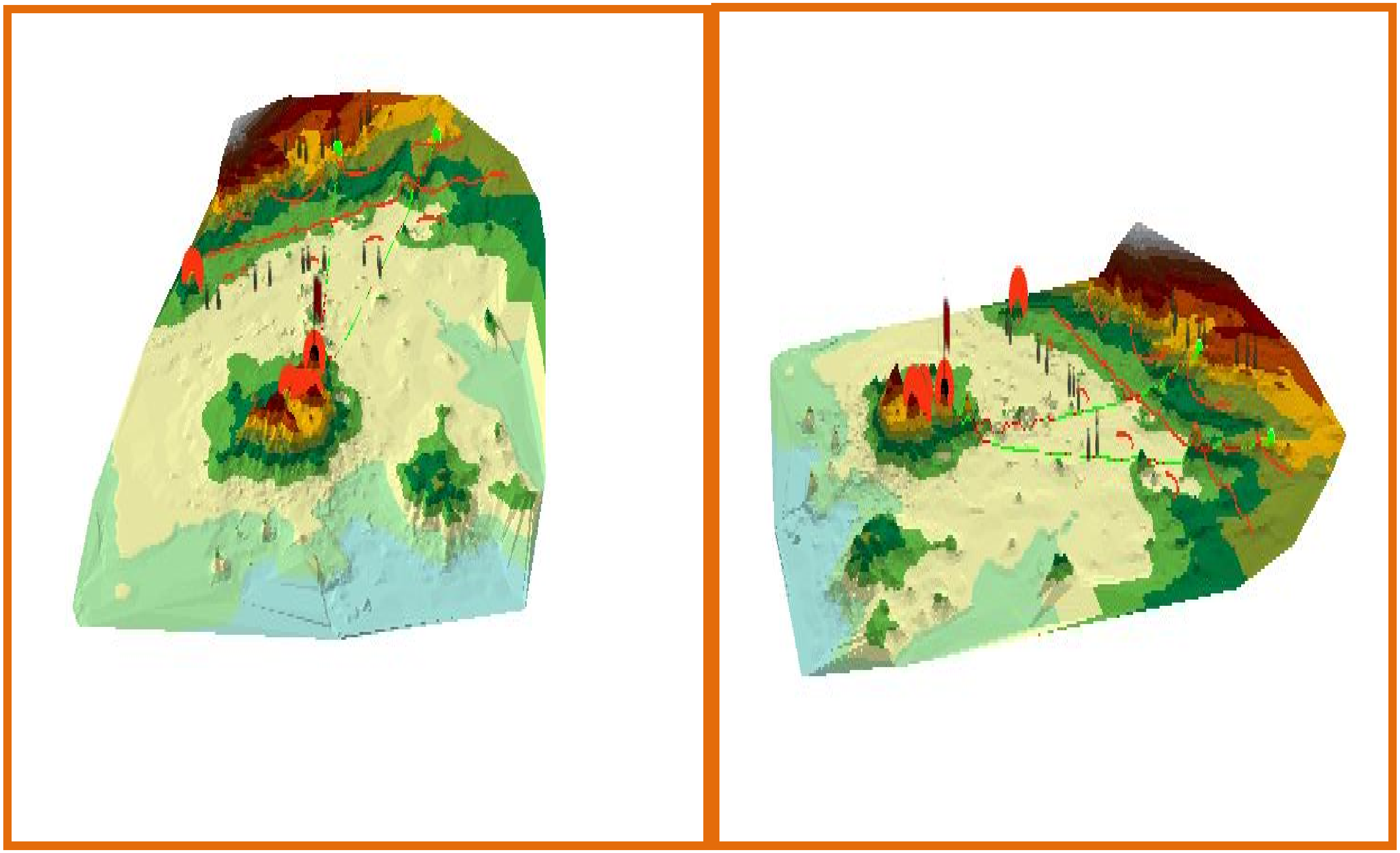


Figure 4.6 TIN generated by Arcscene

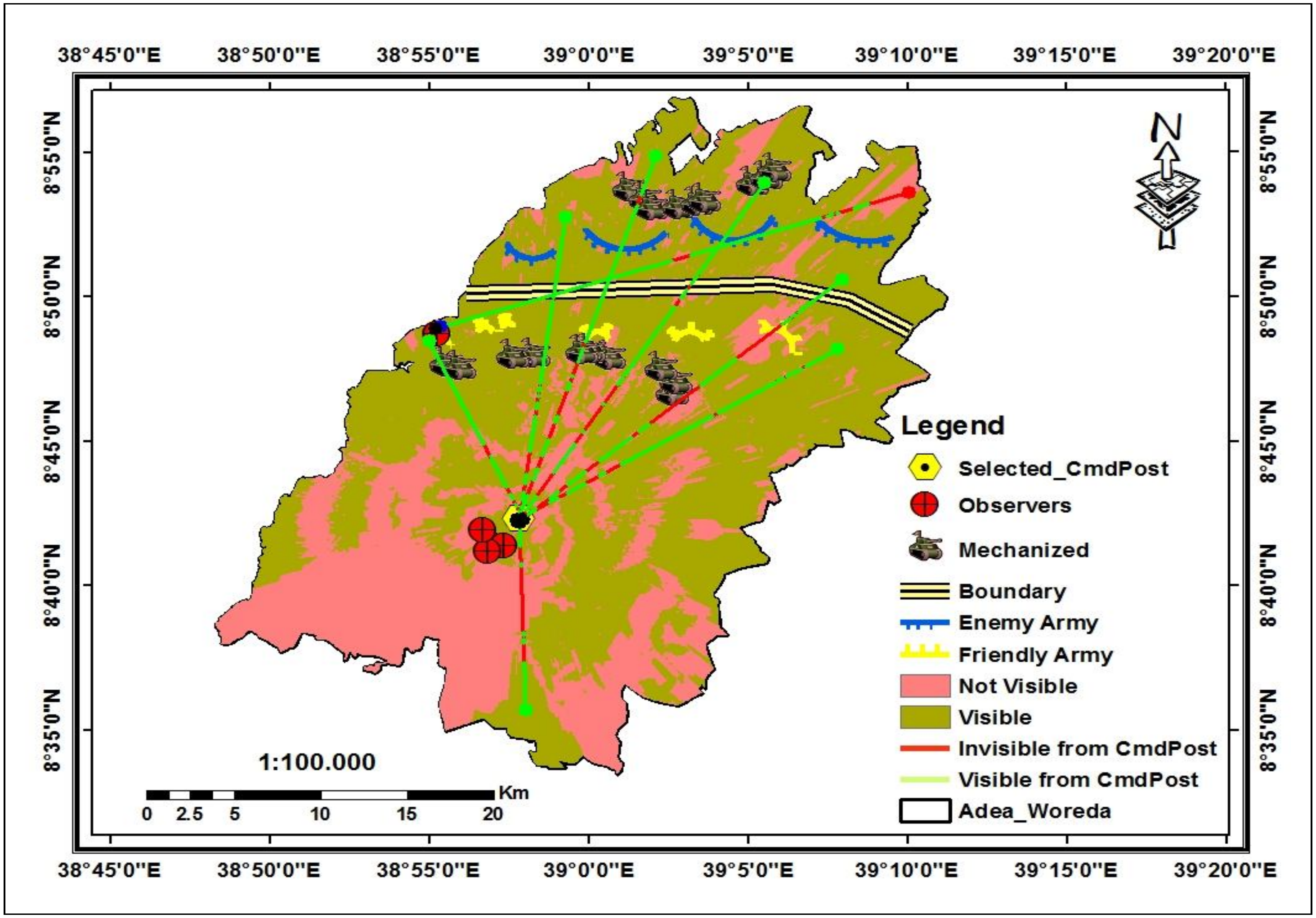


Figure 4.7 Sample Result Maps with Military Symbology

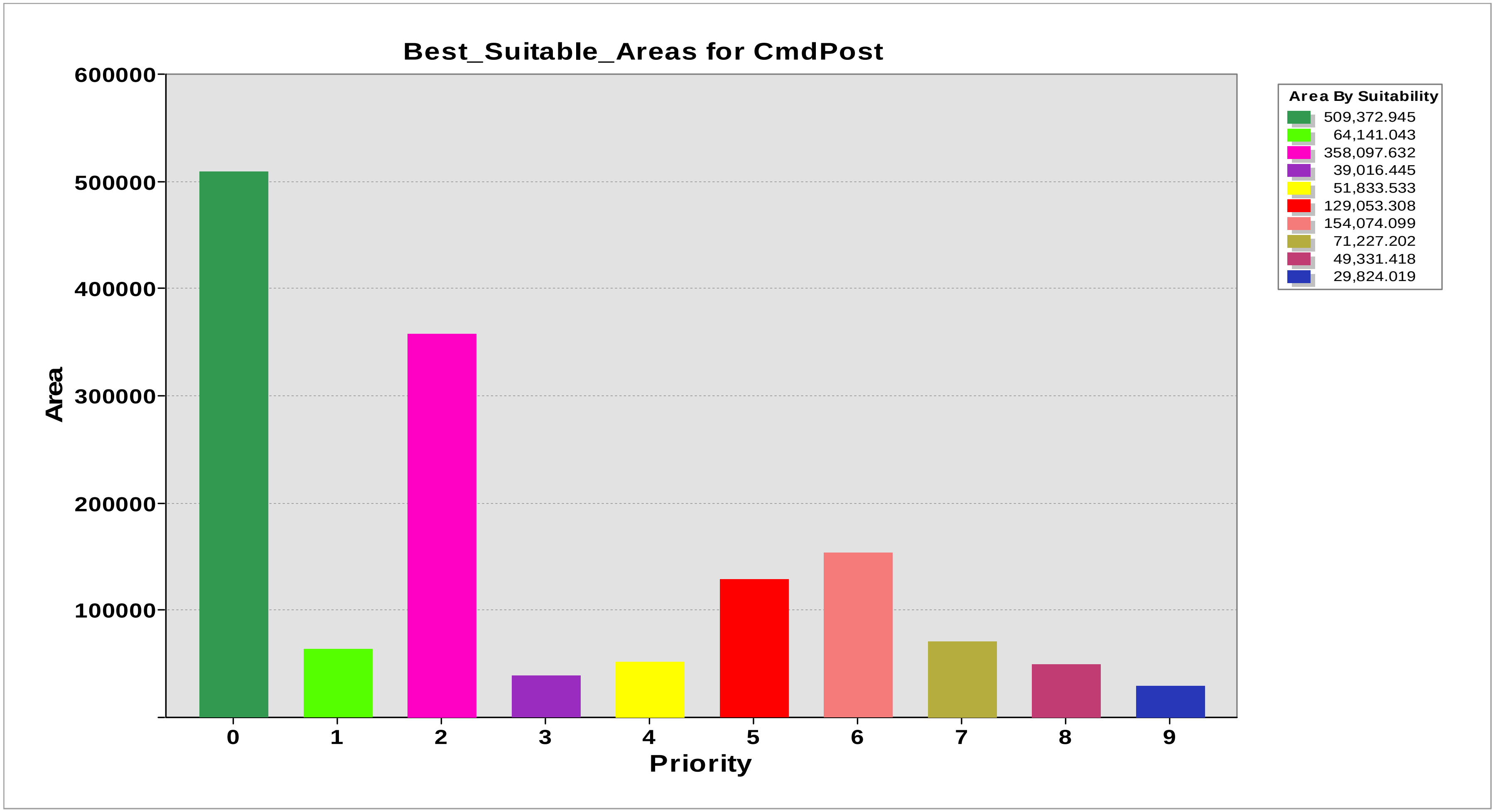


Figure. 4.8 Priority by area of Suitability

Table 4.1 Sample GPS Points from field assessment

No.	Easting (E)	Northing (N)	Type of Soil	Type of Geology	Type of LULC	Height (M)	Lithological Description
1	38^{0}59’14.8”	08^{0}44’09.4”	Pellic Vertisols	Basalts_Scorias_ Tuffs	Built Up	1941	Pyroclastic surge forming rims of Lake Bishoftu
2	38^{0}57’57.0”	08^{0}41’57.2”	Dystric Nitisols	Rhyolite & Pumice	Baren Land	2092	Bede Gebabe rhyolite
3	38^{0}58’34.7”	08^{0}42’07.8”	Pellic Vertisols	Soft Sediments (Lacustrine & Alluvial)	Baren Land	2020	Travertineous carbonates
4	38^{0}58’11.9”	08^{0}40’08.8”	Chromic Luvisols	Rhyolite & Pumice	Baren Land	1930	Pumaceous ignimbrites
5	38^{0}56’35.1”	08^{0}38’50.7”	Pellic Vertisols	Rhyolite & Pumice	Grass Land	1885	Pumice and rhyolite intercalation
6	38^{0}54’38.1”	08^{0}41’39.9”	Chromic Luvisols	Rhyolite & Pumice	Grass Land	2069	Pumice/rhyolite
7	38^{0}57’58.8”	08^{0}41’53.7”	Dystric Nitisols	Rhyolite & Pumice	Agriculture	2079	Rhyolite with distinct flow bands
8	38°57'33.3"	08°40'18.1"	Dystric Nitisols	Rhyolite & Pumice	Forest	2085	Rhyolite
9	38°58'33.7"	08°41'52.4"	Pellic Vertisols	-	Water Body	1845	-
10	38°57'23.6"	08°44'59.2"	Pellic Vertisols	Basalts_Scorias_ Tuffs	Built Up	1905	Scoria
11	38°58'30.6"	08°42'24.6"	Chromic Luvisols	Soft Sediments(Lacustrine & Alluvial)	Settlements	2000	Travertineous carbonates

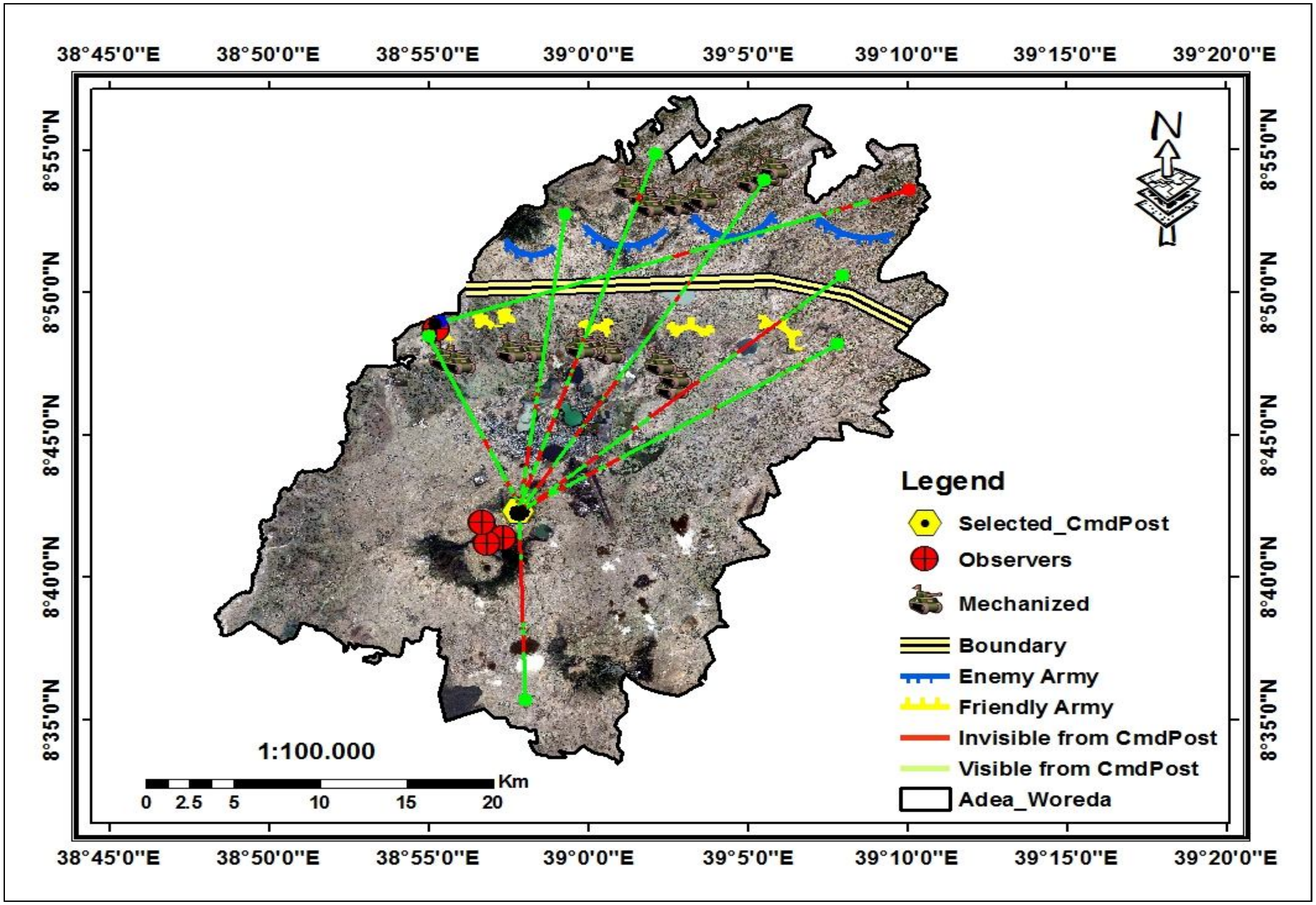
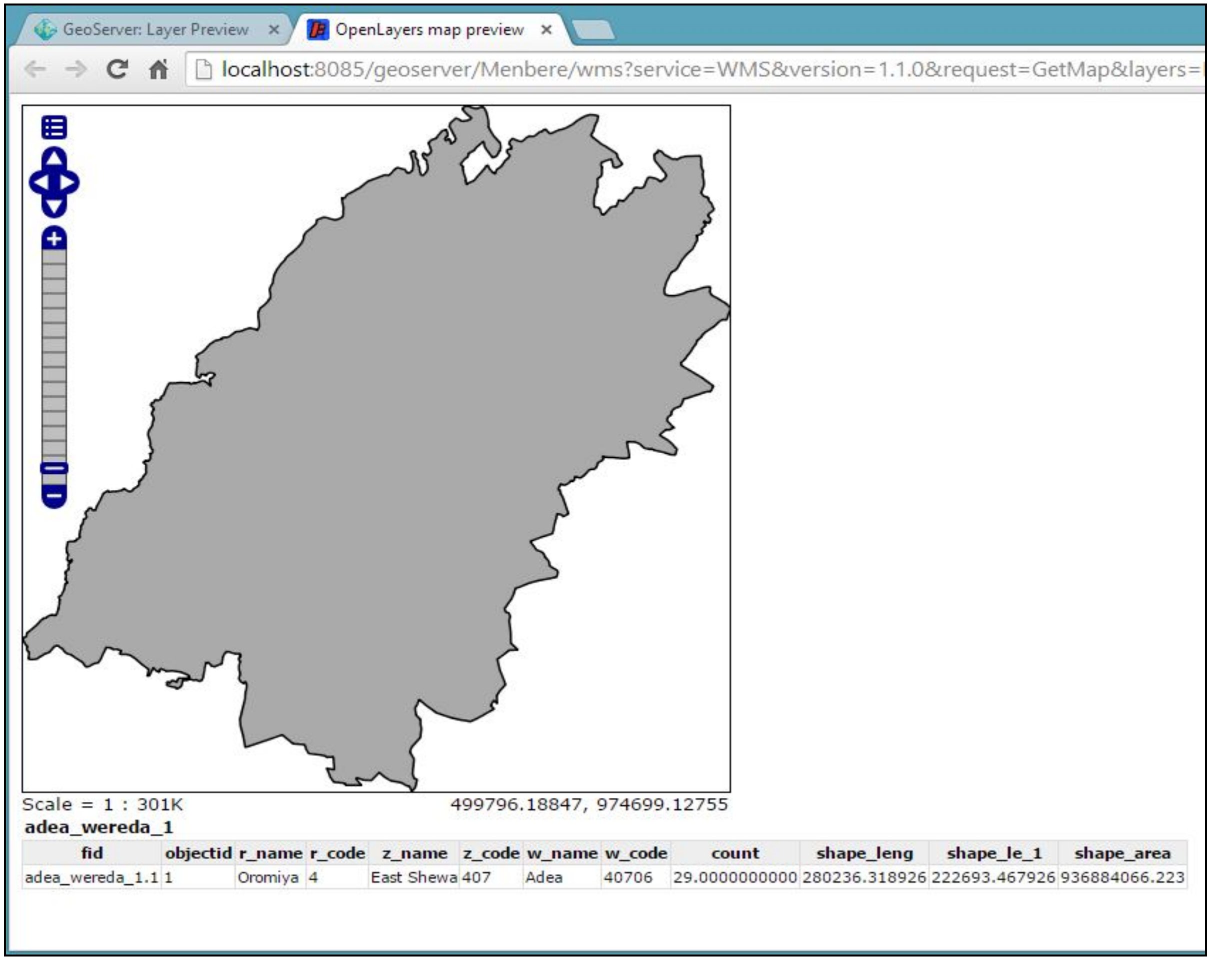


Figure. 4.9 Military command post suitable sites with mission planning elements

4.4. Results from Web-map customization

Figure 4.10 Web-map Customization Using GeoServer

Web-customizing maps



fid	objectid	r_name	r_code	z_name	z_code	w_name	w_code	count	shape_leng	shape_le_1	shape_area
adea_wereda_1.1	1	Oromiya	4	East Shewa	407	Adea	40706	29.0000000000	280236.318926	222693.467926	936884066.223

Figure 4.11 Study Area boundary

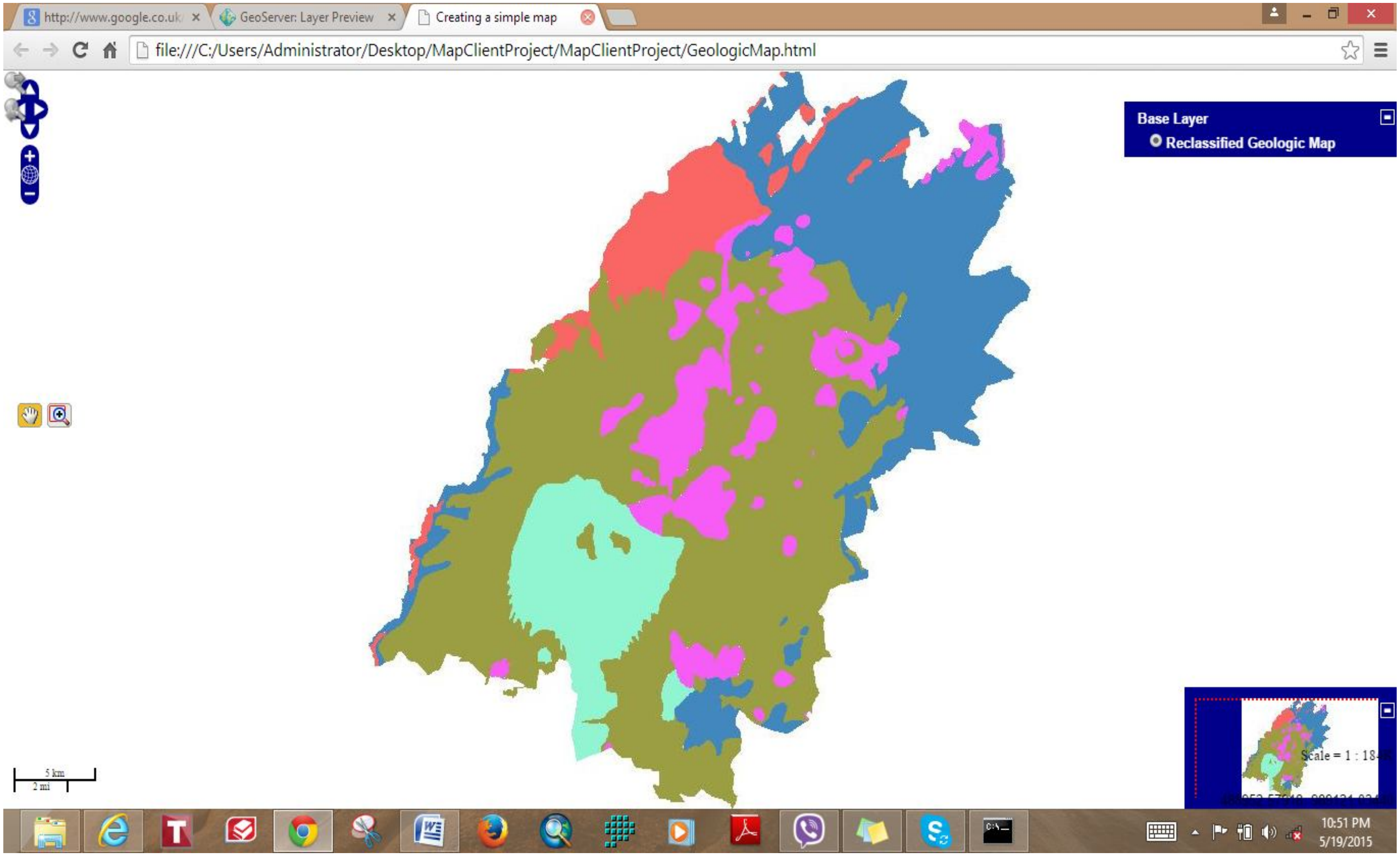


Figure 4.12 Geologic web map of the study area

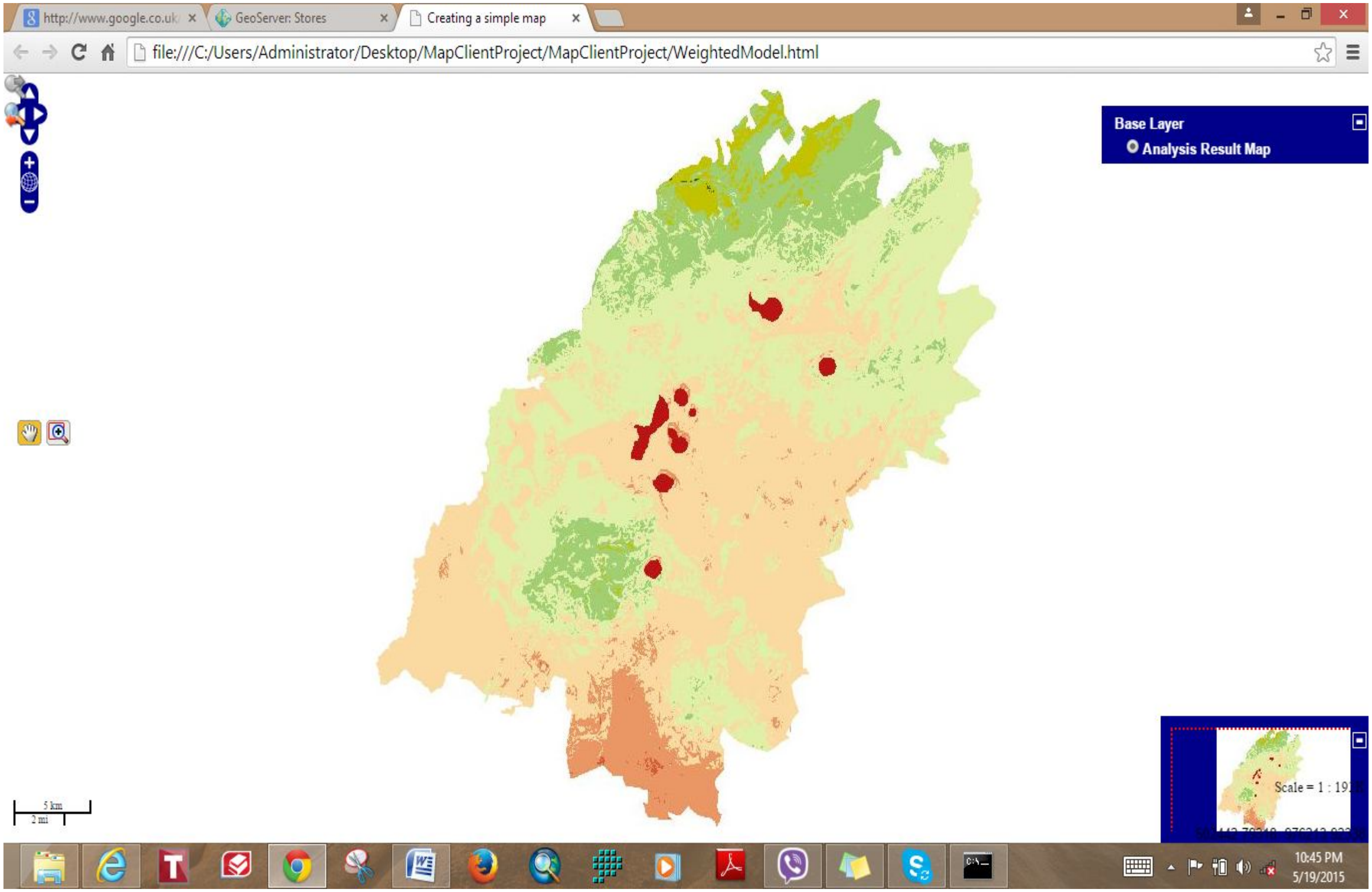


Figure 4.13 Suitability Overlay Map

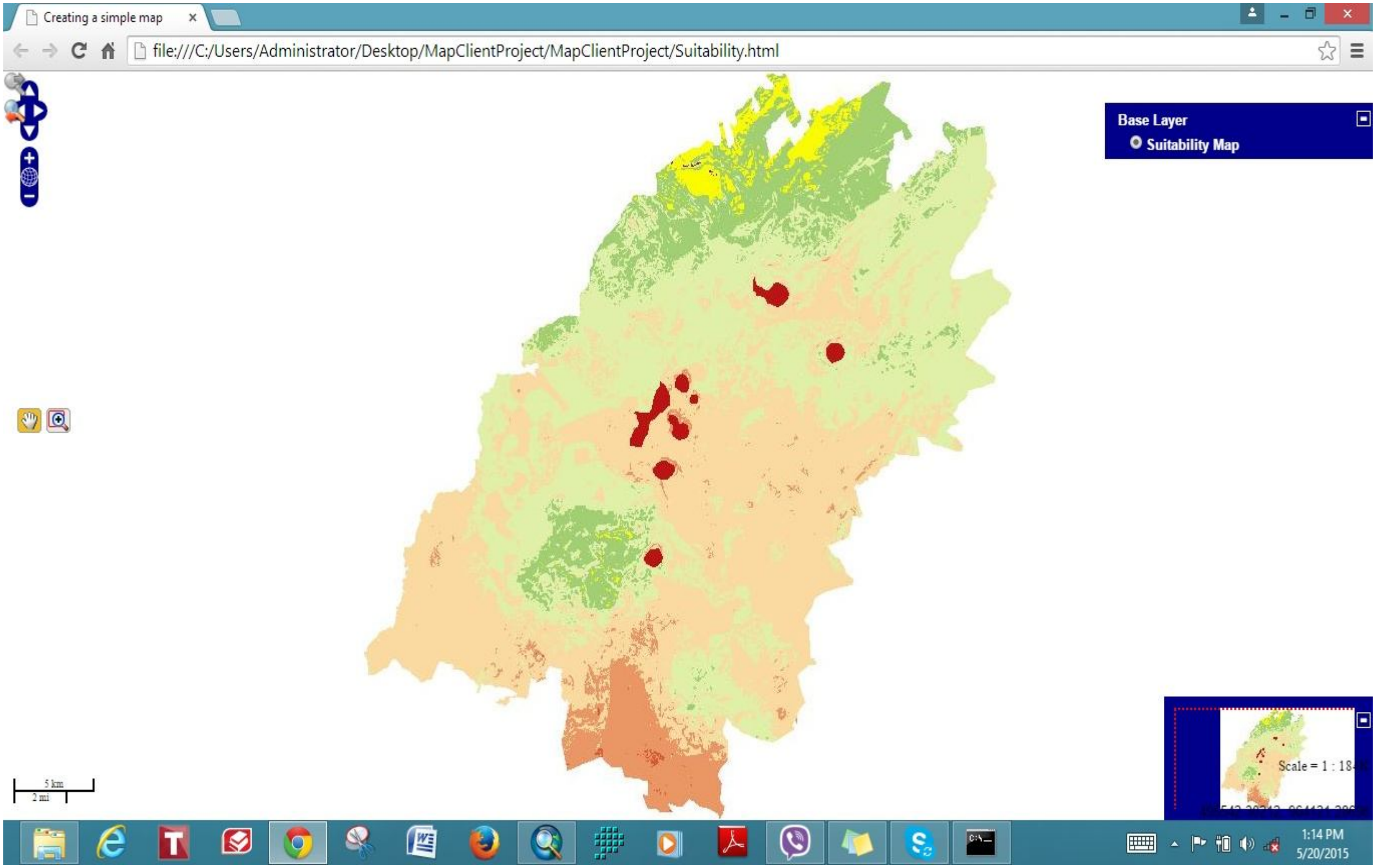


Figure 4.14 Suitable Areas Map

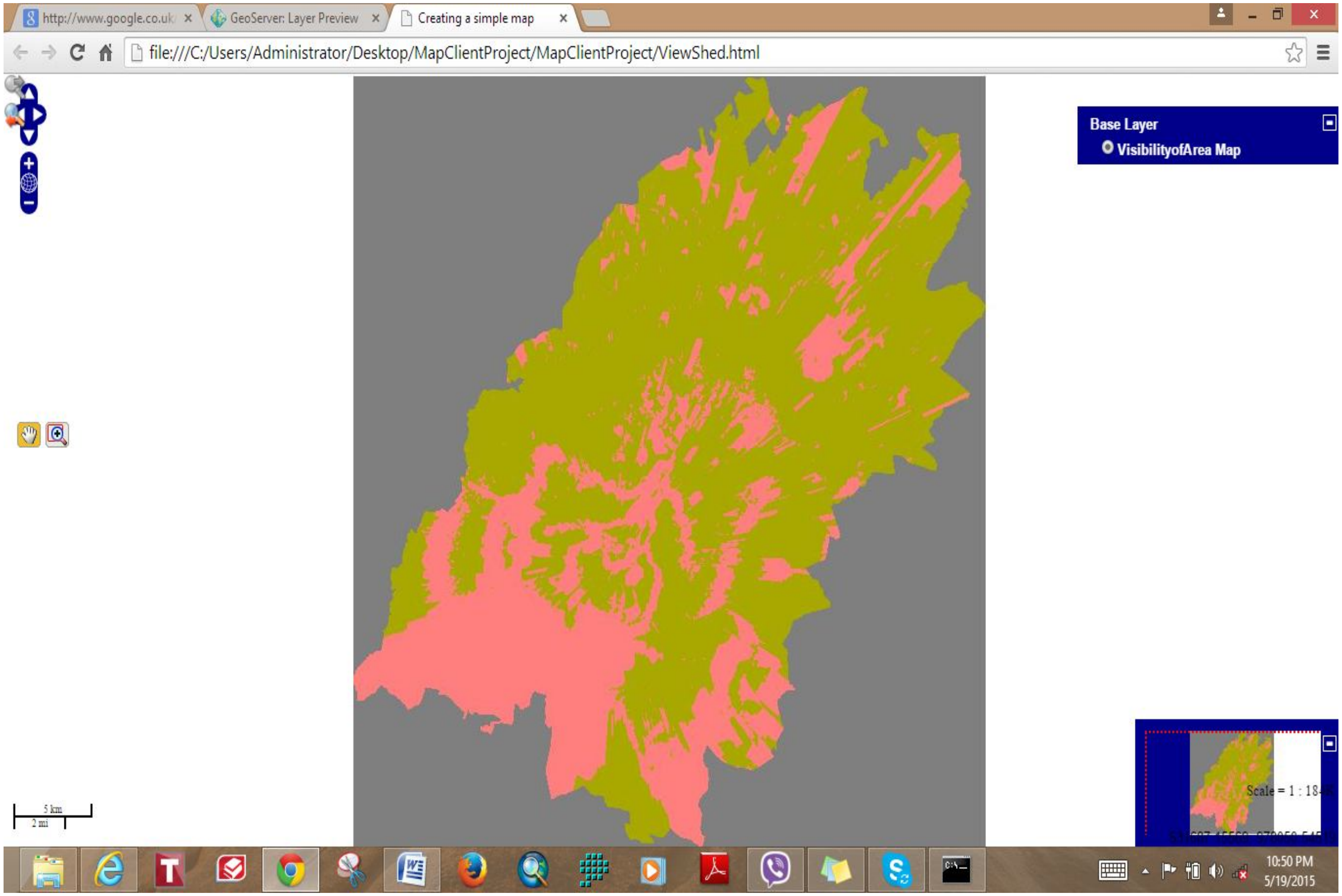


Figure 4.15 Visible Areas Map

CHAPTER FIVE

DISCUSSION

Analytical hierarchy process is used to optimal site selection for the potential military command post in the study area, based on the AHP. Criteria and Sub-criteria were determined and prioritized. Results of the analysis indicates that the six factor including elevation, slope, distance from roads, landcover, soil type, lithologic type and distance from faults and drainages considered as the major factors in this optimal sites selection for the military command post.

The elevation heights is the most important factor and it has the greatest influence on command post potential site selection and the areas where have the maximum height from the sea level, have a higher value. The slope is the second important parameter of the research. However, the elevation is the highest value better for this study but the flat slope is selected with respect to the specific elevation. Road is also the most important factor and the minimum distance is required and Euclidean distance generates to the closest source raster.

LULC mapping results showed that bare land is the most essential parameter from the land cover for the command post site selection. For example forest cover, which shows good potential for concealment and observation, but primarily bare land is preferred than others and has higher value for command post site selection. The areas coverage of 2 to 50 hectare is selected at a required elevation, slope and land cover. From those suitable areas prioritized for field verification from 1 to 10 mainly by the value of the elevation is greater than or equal to 2000m. Regarding the soil type, in this study, used as for the traffic ability determination the stickiness and slipperiness of soils is determined, therefore chromic Luvisols that have higher clay content is the best class and most of the selected sites are on this soil type.

Geologic type, similarly used for traffic ability, it helps to determine the primary landform such as basaltic lava flows, intercalated rhyolite and pumice domes, ignimbrite sheets, scoria cones in the study area. The main reason the Woreda uniquely identified by volcano lakes created by volcanic eruption, basaltic lava flows and domes. Therefore the selected area geologic type is intercalated rhyolite and pumice dome which have the highest priority than other rock types in its stability and elevation height, ability for the movement of vehicles and command post logistics to the selected location. There are structural landforms such as cliffs (vertical faults planes) or structurally controlled fractures leading to narrow but deep trenches. For this study the distance from fractures and rivers or drainages were considered and evaluated as obstacles but in some cases used as trenches or combats. However for the selected military command post, areas with a minimum distance from fractures buffered as fault extent up to 100m away from them.

The results of evaluation for military site selection showed that from the total area of the best suitable areas about 34% of the area has excellent potential for command post. According to the best suitability map for the command post, the western and behalf of the central region of the study area has more capability than other regions. In fact, about 2% (2.982402ha) of the selected area also has excellent potential for military site selection. This is because of the weight and the importance of the elevation, LULC and infrastructure in the study area for locating military command post location.

AHP is the logical way to compare options and select the best option according to all effective parameters, it can create the framework for collective participation in decision making and generate best decisions regarding to prioritization criteria and sub-criteria are using expert's opinions. In studies of Babaie - Kafaky (2009), Jalilvand *et al.* (2011) and Karami *et al.* (2012) expert's opinions were used for comparison of using AHP. In this research AHP has been proved to be a flexible and practical tool to select areas for military command position. This can be due to participation of experts and officials in the determination of the criteria and sub criteria using AHP. In addition, GIS could be utilized to support spatial decision-making processes because of its excellent capabilities for dealing with spatial issues. Therefore, this study can provide a framework for the planning process using GIS and AHP for military site selection and its results can be useful in the planning of military command post and future planning of military site selection in the study area.

Based on the analysis result from the investigation of existing military site selection system in defense, the commanders and experts reading the topographic maps to analyze and identify the location of command post, then they try to control the key terrain and whether the area is optimal for visibility of the attacker unless by moving around for checking the area physically and there is no any choice to select the area. The topo maps are also given to inaccurate information because of the limitations of the experts vision and binocular instruments.

Therefore from the point of view of military professionals or experts there are challenges to identify terrain because of the traditional approach discussed in chapter three. The result of terrain information analysis using GIS helps to solve those challenges by identifying the type of terrain (such as flat/plain ground, hill, mountains with their respective elevation and slope) whether the terrain is natural (like vegetations, growing crops, forests using the landcover factor), artificial (like buildings, villages and cities using land use factor). The type of soil and load bearing capacity is obtained by the amount of clay content and depth of each soil (Gebreslassie, 2009). Results from reclassification and ranking of soil type effect in mobility shows similarity with standards of FAO (2006). The type of rocks undulation or fold and faults also easily classified the suitability based on their rock formation and stability for mobility. To identify the rock type which is more suitable than the other, in how much extent fractures and drainages buffered as obstacles is clearly identified and classified.

The result of the research when related with military aspects of terrain factors formularized as Us Department of Army FM 5-33(1990) field manual OCOKA factors the selected command post site satisfied military aspects of terrain. The observation factor, for selected command post location assured that the commander have an ability to see the threat either visually or through the use of surveillance devices, for Concealment and Cover factors limit or deny observation from the other side or enemy site. For example if the selected area around the enemy side has dense forest the commander cannot see how much the enemy forces power, it also can be an obstacles for mobility, but in the other case Concealment is protection from observation from the attacker. It can be provided by woods, tall grass, and cultivated vegetation. Cover is protection from the effects of direct and indirect fires. It can be provided by ditches, caves, river banks, folds in the ground, but in mobility cases they are obstacles. From the result of the selected command post location which gives good observation over avenue of approaches(AAs) to and into the defensive position.

Enhancement of effectiveness of C2 and mission planning applications by adding common war fighting symbology based on MIL-STD-2525C specification. Visibility also determined by LOS and viewshed. Finally the result from the integration of IT and GIS makes the web-map customization using open source GIS softwares to the enhancement of C4I system for decision makers or military commanders.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1. Conclusion

This study assured that the influential factors for selecting suitable command post location in Ada'a Woreda can be classified into four main parts. The most important factor in selecting suitable command post location which is related to altitude parameters such as elevation and slope can have a major effect on their value. The second important factors are related to the accessibility (roads) and land use land cover. The third factor goes to the landforms of existing terrain such as rock type, soil type and obstacles (rivers, drainages and faults). The fourth factor is related to condition of the terrain which is visible from the command post which evaluates by LOS, viewshed, and TIN.

Therefore in this study, those different features of terrain, such as elevation, land cover, roads, rivers, soil types, rock types, obstacles, slopes were used during analysis. The analysis is based on a number of multiattribute and multicriteria evaluation methods have been customized in the GIS environment including WLC and analytic hierarchy process WLC is based on the concept of a weighted average. The method can be computed using any GIS system having overlay capabilities. Multi factor analysis or Weighted Overlay Analysis is one the components of the methods of spatial modeling using spatial Multi-criteria evaluation. Weighted Overlay Analysis assigns more importance to some criteria over the others.

Finally, the methodology of this study can be used as reference for coming researchers to develop defense intelligence system and will proposed as decision support mechanism for decision makers and commanders. It is one of the studies, which can be followed for the subsequent studies concerning military intelligence.

6. 2 Recommendation

In this research water features are restricted and used as obstacles for research analysis but in other military operation planning water features Like rivers, drainages, lakes, safe water, in sufficient amounts, is strategically and tactically important to Army operations. Commanders must know the width and depth of streams and canals, the velocity and discharge of streams, which areas are subject to flooding. Therefore other researchers can be consider those things and this research leave a room to them.

The methodology of this research approach is an integrated technique of AHP and the Geographic Information System (GIS) and determination of suitable command post took place. The AHP uses pair wise comparison to allocate weights to the criteria of each level, measuring their relative importance by using Saaty's (1-to-9) scale, and finally calculates average weights for criterias. The method also calculates a consistency ratio (CR) to verify the coherence of the judgments, which must be about 0.10 or less to be accepted and according to the result of this research consistency ratio(CR) is equal to 0.6 is acceptable and therefore, it is recommended to use this approach is preferable.

Here recommended that using open source GIS software is most helpful. Most potential users of GIS are viewers. There are personnel right from field commanders to commanding staffs. They need access to a geographic picture, map or photograph to help and assess a situation to carry out planned operations. Earlier GIS packages are proprietary in nature and were restricting the use of data within its confined specifications. An open GIS approach allows choice of the most appropriate product for individual users and at the same time supports command requirements to specify an authorized map for operational reasons.

Extra terrain features can be researched for more detailed studies. Incorporation with military intelligence staff and other factors that affect terrain analysis can be developed. An extensive database should be prepared for the query functions and data processing's. The terrain features should be enhanced with additional attributes. It is known that preparing an extensive database is costly and time consuming processes. Therefore, in this research customizing web pages for users or commanders for querying, viewing, zooming any feature datasets as well as raster maps are done but to be an interactive web-pages a detailed study should be done to obtain perfect results for developing web-GIS.

Air operations in battle environment require the similar inputs as per land operations except they need height information more precisely for targeting. These include the detailed information about the target location, proximity of civilian areas, and terrain evaluation, meteorological conditions besides navigational data and intelligence information from military surveillance devices. Therefore combined air operations to land operations is recommended.

Military commanders and decision makers should enhance the effectiveness of command, control, communication and coordination in military operations using GIS and remote sensing techniques in conducting terrain based decisions rather than depending on paper maps that are inflexible, tiresome, time taking and lack up to date information.

In military RS and GIS application have gone hand in hand throughout the course of history, the military sector has been still new for military technologies in Ethiopia. It can therefore be a good start to the research area in this field.

The research output also will be used to improve this active research area for defense community and it helps to stimulate researchers to come with interest in the field.

According to Gebreslassie (2009) the off-road traffic load analysis, the author is conducted by considering five factors. However, in reality, other important factors like weather condition cover and concealment, line of sight, and location of enemy forces have to be included for real world applications and further researches are necessary to assess all terrain based tasks in military operations planning. This research try to fulfill the gap in this previous research.

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APPENDICES

```
CLASSIFICATION ACCURACY ASSESSMENT REPORT
           -----------------------------------------
Image File : e:/membere newstudyarea/classifiedlulc.img
User Name  : Administrator
Date       : Sat May 23 15:10:31 2015



ERROR MATRIX
-------------

                      Reference Data
                      --------------
Classified Data Unclassifi   LakeHora LakeBishof LakeChelel
--------------- ---------- ---------- ---------- ----------
   Unclassified          0          0          0          0
       LakeHora          0          0          0          0
    LakeBishoftu         0          0          0          0
   LakeCheleleka         0          0          0          0
      LakeGreen          0          0          0          0
      LakeChefe          0          0          0          0
           Lake          0          0          0          0
    LakeBabogaya         0          0          0          0
     LakeKuriftu         0          0          0          0
      grassLand          0          0          0          0
     Settlements         0          0          0          0
      BarrenLand         0          0          0          0
     Agriculture         0          0          0          0
         Forest          0          0          0          0
        BuiltUp          0          0          0          0

Column Total             0          0          0          0

                      Reference Data
                      --------------
Classified Data  LakeGreen  LakeChefe       Lake LakeBaboga
--------------- ---------- ---------- ---------- ----------
   Unclassified          0          0          0          0
       LakeHora          0          0          0          0
    LakeBishoftu         0          0          0          0
   LakeCheleleka         0          0          0          0
      LakeGreen          1          0          0          0
      LakeChefe          0          0          0          0
           Lake          0          0          0          0
    LakeBabogaya         0          0          0          0
     LakeKuriftu         0          0          0          0
      grassLand          0          0          0          0
     Settlements         0          0          0          0
```

BarrenLand	0	0	0	0
Agriculture	0	0	0	0
Forest	0	0	0	0
BuiltUp	0	0	0	0
Column Total	1	0	0	0

Reference Data

Classified Data	LakeKurift	grassLand	Settlement	BarrenLand
Unclassified	0	0	0	0
LakeHora	0	0	0	0
LakeBishoftu	0	0	0	0
LakeCheleleka	0	0	0	0
LakeGreen	0	0	0	0
LakeChefe	0	0	0	0
Lake	0	0	0	0
LakeBabogaya	0	0	0	0
LakeKuriftu	0	0	0	0
grassLand	0	0	0	0
Settlements	0	0	1	0
BarrenLand	0	0	0	1
Agriculture	0	0	0	1
Forest	0	0	0	0
BuiltUp	0	0	0	0
Column Total	0	0	1	2

Reference Data

Classified Data	Agricultur	Forest	BuiltUp	Row Total
Unclassified	0	0	0	0
LakeHora	0	0	0	0
LakeBishoftu	0	0	0	0
LakeCheleleka	0	0	0	0
LakeGreen	0	0	0	1
LakeChefe	0	0	0	0
Lake	0	0	0	0
LakeBabogaya	0	0	0	0
LakeKuriftu	0	0	0	0
grassLand	0	0	0	0
Settlements	0	0	0	1
BarrenLand	0	0	0	1
Agriculture	4	0	0	5
Forest	0	1	0	1
BuiltUp	0	0	2	2
Column Total	4	1	2	11

```
          ----- End of Error Matrix -----


ACCURACY TOTALS
----------------

          Class  Reference Classified Number     Producers  Users
           Name     Totals     Totals Correct     Accuracy  Accuracy
     ---------- ---------- ---------- -------    ---------  -----
   Unclassified          0          0      0          ---     ---
       LakeHora          0          0      0          ---     ---
   LakeBishoftu          0          0      0          ---     ---
  LakeCheleleka          0          0      0          ---     ---
      LakeGreen          1          1      1      100.00% 100.00%
      LakeChefe          0          0      0          ---     ---
           Lake          0          0      0          ---     ---
   LakeBabogaya          0          0      0          ---     ---
    LakeKuriftu          0          0      0          ---     ---
      grassLand          0          0      0          ---     ---
    Settlements          1          1      1      100.00% 100.00%
     BarrenLand          2          1      1       50.00% 100.00%
    Agriculture          4          5      4      100.00%  80.00%
         Forest          1          1      1      100.00% 100.00%
        BuiltUp          2          2      2      100.00% 100.00%

         Totals         11         11     10

Overall Classification Accuracy =     90.91%

          ----- End of Accuracy Totals -----



KAPPA (K^) STATISTICS
---------------------

Overall Kappa Statistics = 0.8804

Conditional Kappa for each Category.
------------------------------------

     Class Name           Kappa
     ----------           -----
   Unclassified          0.0000
       LakeHora          0.0000
   LakeBishoftu          0.0000
  LakeCheleleka          0.0000
      LakeGreen          1.0000
      LakeChefe          0.0000
           Lake          0.0000
```

```
   LakeBabogaya          0.0000
    LakeKuriftu          0.0000
      grassLand          0.0000
    Settlements          1.0000
     BarrenLand          1.0000
    Agriculture          0.6857
         Forest          1.0000
        BuiltUp          1.0000

        ----- End of Kappa Statistics -----
```

Sample Java Script Codes for creating a study area web map to display on GeoServer

```
<!DOCTYPE html>

<html>

<head>

<title>Creating a simple map</title>

<meta http-equiv="Content-Type"

content="text/html; charset=UTF-8">

<!-- Include OpenLayers library -->

<script type="text/javascript" src="OpenLayers.js"></script>

                <script type="text/javascript"src="OpenLayers.js"></script>

<style>

html, body {

width: 100%;

height: 100%;
```

```
margin: 0;

padding: 0;

        }

        .olControlNavToolbar {

top: 0px;

left: 0px;

float: left;

   }

   .olControlNavToolbar div {

float: left;

   }

</style>

<!-- The magic comes here -->

<script type="text/javascript">

functioninit() {

                bounds = new OpenLayers.Bounds(478529.487, 945939.6525, 520587.7365, 989121.034399999);

                varcontrols_array = [

                        newOpenLayers.Control.OverviewMap(),

                        newOpenLayers.Control.PanZoom(),
```

```
                newOpenLayers.Control.ScaleLine(),
                newOpenLayers.Control.Scale(),
                newOpenLayers.Control.MousePosition({
div: document.getElementById('mouseposition')
 }),
                newOpenLayers.Control.KeyboardDefaults(),
                newOpenLayers.Control.NavToolbar({
div: document.getElementById('navtoolbar')
 }),
                newOpenLayers.Control.LayerSwitcher(),
            ];
            map = new OpenLayers.Map("map_element", {
    maxResolution: 'auto',
    maxExtent: bounds,
    projection: new OpenLayers.Projection("EPSG:20137"),
    units: 'm',
    controls: controls_array
      });
```

```
varwms = new OpenLayers.Layer.WMS("Menbere Map",
"http://localhost:8085/geoserver/Menbere/wms",
{
layers: 'Ada'a_wereda_1'
});
map.addLayer(wms);
var navigation = new OpenLayers.Control.Navigation({
div: document.getElementById('navigationsid')
});
var history = new OpenLayers.Control.NavigationHistory({
div: document.getElementById('navigationsid')
});
var panel = new OpenLayers.Control.Panel({
div: document.getElementById('navigationsid')
});
panel.addControls([history.next, history.previous]);
map.addControls([navigation, history, panel]);
varfeatureInfo = new OpenLayers.Control.WMSGetFeatureInfo({
```

```
url: 'http://localhost:8085/geoserver/Menbere/wms',

vendorParams: { QUERY_LAYERS: 'Ada'a_wereda_1', propertyName:
'(fid,objectid,r_name,r_code,z_name,z_code,w_name,w_code,count,shape_leng,shape_le_1,shap
e_area)' },

title: 'Identify features by clicking',

queryVisible: true,

eventListeners: {

        "getfeatureinfo": function (event) {

map.addPopup(new OpenLayers.Popup.FramedCloud(

                        "chicken",

                        map.getLonLatFromPixel(event.xy),

                        null,

                        event.text,

                        null,

                        true

                        ));

        }

    }

  });
```

```
        map.addControl(featureInfo);

        featureInfo.activate();

        map.zoomToMaxExtent();

}

</script>

</head>

<body onload="init()">

<div id="map_element" style="width: 100%;

height: 100%;"></div>

</body>

</html>
```