Hiking Trails Route Selection Using Geospatial Technologies for Erer Mountain Ecotourism Park

Habib Husein Idris

Thesis Submitted to the department of Geomatics Engineering
School of Civil Engineering and Architecture (SOCEA)

Presented in Partial Fulfillment of the Requirement for
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Office of Graduate Studies
Adama Science and Technology University

Adama, Ethiopia
June, 2022

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Name of the Candidate: Habib Husein Idris

Name of the Supervisors:

Roba Gemechu (Ph.D.)

Hika Dinsa (PhD Candidate)

Presented in Partial Fulfillment of the Requirement for

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DECLARATION

I hereby declare that this research thesis entitled "Hiking Trails Route Selection Using Geospatial Technologies for Erer Mountain Ecotourism Park" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Habib Husein Idris	________________	____________
Name of the candidate	Signature	Date

RECOMMENDATION

We, the supervisors of this thesis, hereby certify that we have read the revised version of the thesis entitled "Hiking Trails Route Selection Using Geospatial Technologies for Erer Mountain Ecotourism Park" prepared under our guidance by Habib Husein Idris submitted in partial fulfilment of the requirements for the degree of Master's in **Geoinformatics Engineering**. Therefore, we recommend the submission of revised version of the thesis to the department following the applicable procedures.

Roba Gemechu (PhD)	________________	________________
Name of Major Advisor	Signature	Date
Hika Dinsa (PhD Candidate)	________________	________________
Name of Co - Advisor	Signature	Date

APPROVAL SHEET

We, the advisors of the thesis entitled "Hiking Trails Route Selection Using Geospatial Technologies for Erer Mountain Ecotourism Park" and developed by Habib Husein Idris hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Major Advisor	Signature	Date
Co - Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Habib Husein Idris have read and evaluated the thesis entitled "Hiking Trails Route Selection Using Geospatial Technologies for Erer Mountain Ecotourism Park" and examined the candidate during open defence. This is, therefore, to certify that the thesis is accepted for partial fulfilment of the requirement of the degree of Master of Science in **Geoinformatics Engineering**.

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TABLE OF CONTENTS

Habib Husein Mobile: +251 912 290 952 vii

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

DEM	Digital Elevation Model
EP	Ecological Planning
EEP	Ecological and Environmental Planning
EIA	Environmental Impact Assessment
EMEP	Erer Mountain Ecotourism Park
EP	Environmental Planning
GIS	Geographic Information System
GPS	Global Positioning System
LULC	Land Use Land Cover
LCPA	Least-Cost Path Analysis
MCDA	Multi-Criteria Decision Analysis
MSL	Mean sea level
RS	Remote Sensing
SDGs	Sustainable Development Goals
UN	United Nations

Abstract

Currently, ecotourism is considered as the most attractive subset of tourism industry and stable solution for economic development, particularly in developing countries like Ethiopia if it is properly managed. Ethiopia is embracing ecotourism in its conservation and economic development strategies because it has been perceived potential as an effective tool for achieving the aspired sustainable development needs. For this reason, there is a need for improving the existing ecotourism destinations as well as developing new destinations. Accordingly, this study presents a methodological framework for the determination of the optimal hiking route location by taking Erer Mountain Ecotourism Park as a case study using geospatial technologies. The study adopted suitability modelling approach to combine potential criteria on a scale of 1 to 5 suitability rating scores using raster calculator in GIS environment. And, then grid-based approach of a least cost path analysis method using ArcGIS software was adopted to determine the optimal location for hiking trails route alignment. Furthermore, the study attempted to assess the environmental impacts that may results from the proposed Erer Mountain hiking trails, and the corresponding mitigation measures that would minimize the possible adverse effects. Out of the three optimal hiking trail route alignments, the shortest and most economic route was found to be 99.24KM. The results of this analysis showed the potential and applicability of using geospatial technologies such as GIS as a tool in determining the optimal hiking trail location. Apparently, the proposed methodology can be useful to determine mountain hiking trails in other part of the country by taking into account several criteria deemed important to the local context.

Key terms: *Erer Mountain, Ecotourism, Hiking trails, GIS, Suitability analysis, Least-cost path.*

1. INTRODUCTION

1.1. Background

Currently, ecotourism is considered as the most attractive subset of tourism industry and stable solution, particularly in developing countries like Ethiopia if it is properly managed. Developing countries are embracing ecotourism in their conservation strategies and economic development because it has been perceived potential as an effective tool for achieving the aspired sustainable development goals (CJ Stem et.al., - 2002). It maintains development in the community by providing different alternative sources of livelihood to the local community which is more sustainable (Kiper, 2013).

Globally, ecotourism has been growing at fast pace since the 1990s and generate wealthy of revenues and economic return through the giving back policy. Ideally, ecotourism sector can help maintain sustainable use of resources, conserve the ecological environment, and provide economic benefits to the communities as well as increase awareness of environmental issues based upon the universal sustainable development scheme and ecological principles.

Certainly, the development of any project can have both positive and negative environmental impacts if it is not implemented as per the recommendations of the result of the environmental impact assessment for the proposed project under consideration. Especially the negative impacts of the development, for example ecotourism park in this study, would cause irreversible environmental damage and could also threaten the long-term sustainable development we all aspire for, unless it is implemented by giving due emphasis to the protection of the bio-physical and socio-cultural impacts.

Hence, in order to ensure sustainable ecotourism, it is imperative to integrate the socio-cultural and environment issues into the proposed ecotourism park development process of Erer Mountain and its environs as per the direction of the course instructor. Not only the socio-cultural and environmental issues, but also the socio-economic aspects of ecotourism development should also be given due attentions.

This study deals with assessing the potential sites for the development of Erer Mountain Ecotourism Park (EMEP) and its Environmental Impact Assessment (EIA) by leveraging Geographic Information System (GIS) and Remote Sensing (RS) technologies under the general framework of ecological and environmental planning processes. More precisely, the proposed EMEP will be assessed with the contemporary issues of theory integrated with the practices of ecological planning and environmental planning process.

1.2. Ecotourism Development in Ethiopia

Ethiopia is a land with plentiful, remarkable, and magnificent tourist attractions. The exceptional combination of historical, cultural, and natural attractions marks the country as a unique tourist destination in the region (Yahya et al., 2019).

Since 2012, Ethiopia boasts 13 World Heritage Sites (including the Rock hewn churches of King Lalibela, Simien Mountains national park, Castel of Gondar, Stele of Aksum, Lower Valley ofthe Awash, Lower Valley of the Omo,Tiya, Harar Jugol, Konso Cultural landscape, Mesqel festival, Geda system, Fichhee Chambalaalla and Ethiopian Epiphany, which is more than any other country in Africa. There are also five tentatively inscribed UNESCO heritages including Bale Mountains National Park and Erer Mountain (Taylor, 2021).

In several African countries including Ethiopia, there are numerous attractive sites and natural capital. In spite of the existing potential, the countries lack a number of ecological, economic and social benefits from ecotourism, which is one of the environmentally friendly activities. For example, in prioritizing tourism sector and travel, Ethiopia takes 115th and 125th rank in tourism human resource quality and labor market at worldwide respectively Ethiopia’s wealth in cultural and natural tourism assets gave the country strong potential as a tourism destination. (Stone, J. Micheal Wells, Lindberg, 2002).

Ethiopia’s mountains are almost untouched in any ecotourism activities other than just only mountain-climbing and also stated that despite numerous amounts of natural and cultural resources Ethiopia is endowed with, in terms of tourism revenue the country is rated among the lowest in sub-Saharan Africa. even though the country has huge eco-tourism potential and there are some improvements in roads, trails, and accommodations, most tourism resources are under threat and Ecotourism is still in its infancy stage even the basic infrastructures, accommodations and Facilities for visiting most of the ecotourism sites are extremely limited. (Altes, 2018).

The ecotourism potential site in different part of Ethiopia by using a dominantly qualitative approach. However, their results and findings did not use geospatial techniques and multi-criteria methods. Therefore, this study is an attempt to identify potential ecotourism sites selection using Geospatial techniques and multi criteria methods by creating Erer mountain hiking trails rout planning for ecotourism park development, North of Dukem.

- Ecotourism respects the principles of sustainable tourism referring to the economic, social and environmental impact in Ethiopia.
- Ecotourism actively contributes to the conservation of natural and cultural heritage.
- Ecotourism includes local communities in the activities of planning, development and operation, and it contributes to
- Ecotourism involves complete and interesting explanations for visitors, regarding the natural and cultural resources.
- Ecotourism is intended mainly for individual visitors and small organized group
- Ecotourism should create necessary funds to promote permanent protection of ecological and socio-cultural resources
- Ecotourism should provide a quality tourism experience.

1.3. Erer Mountain

Erer Mountain is located in eastern part of Addis Ababa city and north of Dukem and Bishoftu towns. The mountain is beautiful with amazing view and landscape with so many birds. Mount Erer is a national forest priority area. There are a lot attraction to see in Erer Mountain such as peak mountain, Junipers tree which is endemic to Ethiopia, Ecuplatus tree , African King fisher bird , Blue starling , fantailed Raven ,pied crow, speckled mouse bird, lappet headed vulture, strioletd bunting bird, group of Warthog, Klipspringer, Velvet monkey, Baboon , deer. This is nice magnificent Mountain View, deep canyons, gorges, caves, ridges, highest peak to see the surrounding country such as lake Babogaya and Hora.

Figure 1-1: Erer Mountain in the September, Autumn season

Mount Erer is surrounded by plain agricultural fields which extended to the suburbs of Addis Ababa city, Dukem and Bishoft towns. The Oromo clans that inhabit western side of the mountain belong to the Gelan while those on the east are the Gembichu and the Ada'a who are also found to the south of the mountain.

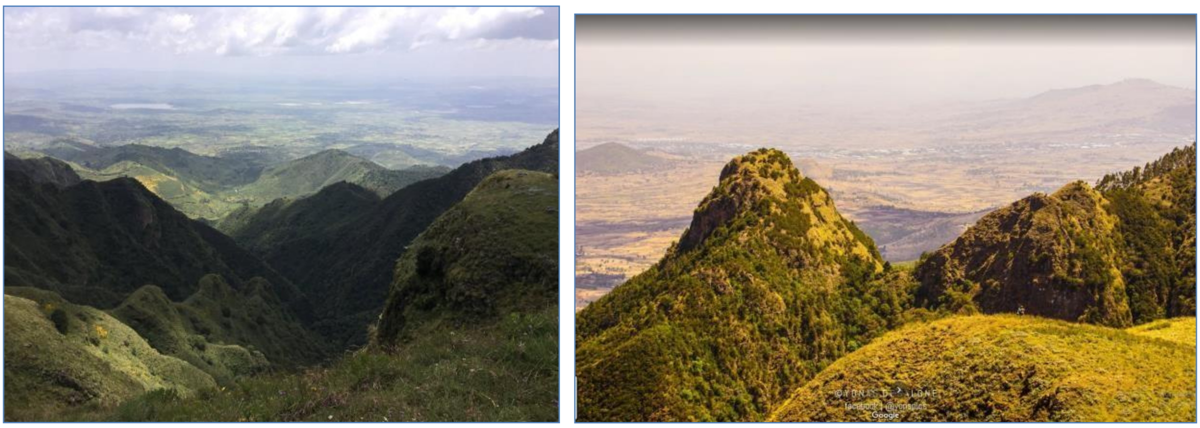


Figure 1-2: South scenery of Erer Mountain (View to Bishoftu Town)

There is a common consensus that a drastic change in the use of land has been clearly identified as a main driver of changes in the abundance and geographic distribution of organisms at scales ranging from local habitats to regions to the entire globe. It is also the major driver of soil erosion of biodiversity. To mitigate this problem most countries use incentive-based policies, such as subsidies, to influence effective agricultural land use.

Agricultural development is observable on and around Erer Mountain. Accordingly, major existing environmental issues in the area including soil degradation and nutrient loss, arising from deforestation mainly on slopes, and consequent flooding in lower-lying areas. In addition, springs are drying up due to poor watershed management and a deforestation fertility loss cycle.

1.4. Hiking Trails

Hiking is a sport or a recreational activity that is increasingly popular among tourists of all kinds, especially in the field of rural tourism and mountain. Whereas, the Victorian Trails Strategy 2014-2024 defines a trail as “an established path, route or track which often traverses natural areas and is used by people for non-motorized recreation, such as walking, running, cycling and mountain bike and horse riding”. So, hiking trails has been considered as nature-based tourist and recreational activities.

This leisure activity has both positive and negative impacts on the environment (Wenjun et al., 2005, Törn et al., 2009). Among other advantages of developing such initiatives, it has evolved and expanded greatly in recent decades because of the low cost involved. Nevertheless, hiking activities in mountainous area has some negative impacts that can outweigh the benefits derived from this activity if not well planned and managed. To this end, Geographical Information System (GIS) and Remote Sensing (RS) are useful geospatial tools to identify the optimal route location by taking into account various factors (Rand, 2004 and Cakir, 2005).

1.5. Problem of the Study

Ethiopia is gifted with several sites of tourist attractions ranging from physical to cultural environment that are potentially important for the country’s tourism development. Our country has a unique feature of land in terms of natural, cultural, historical, and religious tourism assets and unique biodiversity, having enormous potential for tourism. Properly managed tourism has the potential to alleviate poverty, preserve cultural heritage and protect natural resources; and international tourism is a relatively high-growth industry.

However, despite this fact, tourism remains undeveloped due to many reasons. Ethiopia is earning very much less income than what its neighbours earn out of tourism. Ethiopia is characterized by low quality of life, severe unemployment, and absolute poverty. To reduce these problems, there arise a need for diversifying the economy from agricultural sector to the modern sector of industry and service including ecotourism in order to boost investments and development.

Thus, there is a need for the collaborative effort of government, NGOs, private sector and the local communities to develop sustainable solution. To this end, the various contributions of the ecotourism sector are not yet fully studied and not identified. Therefore, this study is an attempt to assess and analyse Erer Mountain ecotourism park development with GIS integrated EIA under the general framework of ecological planning and environmental planning process.

The impacts caused by ecotourism development needs to be identified and assessed to preserve the environment, as well as the biodiversity of the region by promoting the sustainable development of the surrounding communities in systematic way. In order to assess the baseline situation, comprehensive information about the existing land use land cove and preservation of cultural values of the local communities are needed to be integrated into the EIA process and ecotourism development plan of Erer Mountain to reduce the environmental degradation and other associated issues.

1.6. General Objective

The general objective of this study is to identify optimal hiking trails route location for Erer Mountain Ecotourism Park.

1.7. Specific Objectives

The specific objectives of the study are:

- To identify criteria to be taken into account for Erer mountain hiking trails optimal location.
- To determine the optimal route for the development of Erer mountain hiking trails.
- To assess the environmental impacts that may results from the proposed Erer mountain hiking trails.

1.8. Research Questions

- What are the criteria to be taken into account for Erer mountain hiking trails optimal location?
- How to determine the optimal route for the development of Erer mountain hiking trails?
- How to assess the impacts that may results from the identified Erer mountain hiking trails?

1.9. Significance of the Study

The outcome of the study will contribute to the implementation of the UN SDG 11: Sustainable Cities and Communities (sustainable development strategy). Specifically, the study will contribute to the efforts being made to promote environmental conservation. Likewise, the outcome of the study could help to improve methods for site development and eco-system preservation. Furthermore, the outcome of the study could help to raise awareness about urban environmental planning methods to mitigate urban environmental problems and restore and sustain ecological integrity.

1.10. Scope of the Study

- Classification of existing land use and land cover of the study
- Determining the optimal location for Erer Mountain hiking trails
- Collecting baseline data on different environmental parameters.
- Undertaking impact assessment including environmental
- Suggesting mitigation measures to minimize the impacts

1.11. Structure of the Study

This study is organized in five main chapters. Chapter one is an introductory part dealing with the background information of the research, statement of the problem, objectives of the study, significance of the study, scope of the study. Chapter two consists of the related literature on tourism sector, Eco-tourism, Hiking Trails, rout selections and role of GIS & RS. The third chapter illustrate the research design and methodology employed to collect and analyze the data. The fourth chapter is about results and discussion, where chapter five is dedicated to conclusion and suggestions based on the main result of the analysis.

2. LITERATURE REVIEW

2.1. Environmental Planning

2.1.1. Land Use Planning

The general objective of land use planning is the optimisation of land use distribution in a sustainable manner. Promoting sustainability is the overarching goal of land use planning, including planning for conservation, protection and for appropriate use of land and natural resources such as ecotourism (Forman 1995). Land use planning aims at identifying the most appropriate spatial pattern for future land use according to specific requirements, preferences, or predictors of some activity (Collins et al., 2001). It involves economic, social, cultural, environmental and ecological aspects. This study discusses the environmental and ecological planning, part of sustainable land use planning and the application of GIS in environmental and ecological planning that could contribute towards sustainable development in general, and Erer Mountain Ecotourism Park in particular.

2.1.2. Environmental Planning

Several studies have recommended that environmental issues be absorbed into project planning and to fully incorporate environmental issues in the planning stage itself (Mc Donald and Brown, 1995). Incorporating environmental knowledge into planning contributes significantly to sustainable planning (Leitau and Ahern.2002). Environmental planning (EP) occurs early in the planning process and can be incorporated into land use planning to address environmental issues. By addressing environmental concerns early in the project development cycle, environmental planning helps to mitigate environmental impacts.

One of the most fundamental environmental planning tools is site suitability analysis that was first advocated by Ian McHarg at the University of Pennsylvania over 30 years ago (Mc Harg 1981). Suitability analysis is an essential tool in developing comprehensible approaches to, for example large scale regional planning. The basic premise of suitability analysis is that each aspect of the landscape has intrinsic characteristics that are to some degree either suitable or unsuitable for the activities being planned such as ecotourism development. These relationships are revealed through detailed evaluation and assessment by overlaying and compiling thematic maps representing each data. The suitability evaluation allows the identification of certain types of activities (such as recreation, housing, or industry) within a region with particular physical characteristics and limitations (such as towns, floodplains, wetlands, steep slopes, or upland ridges). Ideally, the result is a site arrangement that takes advantage of the landscape's intrinsic attributes while avoiding unsuitable or unsupportable locations for land use activities where obvious site incompatibilities may be expected. Thus, the intent of the sensitivity analysis process is to determine the optimum site location for activities while minimising negative impacts on the environment, such as mountain hiking trails alignment planning in this study.

2.1.3. Ecological Planning

Ecological planning is primarily a method of studying the biophysical and socio-cultural systems of a region to reveal where a specific land use may be best practiced (Steiner and Brooks 1981). While ecology is concerned with functioning of resources, planning is the appropriate use of resources for human benefit. During 1970s, a new branch of ecology known as landscape ecology emerged, which studies ecology of landscapes. Based on three fundamental structural elements i.e. patches, corridors and the matrix; landscape ecology soon established relation with land use planning. One fundamental aspect of landscape ecology was its explicit attention to the spatial dimension of ecological processes, thus providing a common language for stronger interactions between ecologists and planners. Landscape ecological planning helps in identifying areas rich in biodiversity and also in planning connectivity of patches.

The scale of applicability of environmental and ecological planning is extremely wide. The use of GIS-based landscape ecological planning has been recommended at large scales like for ecotourism development, where it is mainly used as a conservation planning tool for biodiversity conservation and recreational purposes. At a smaller scale, the ecological and environmental planning is used for sustainability planning in urban areas, townships and industrial parks.

2.1.4. GIS in Ecological and Environmental Planning

The emergence of GIS during 1970s and the simultaneous development in ecological and environmental planning (EEP) led to a long-term association among GIS and EEP. Given the large amount of environmental data that needs to be compiled for effective suitability analysis, GIS was used as an efficient tool for organising, storing, analysing, displaying and reporting the spatial information. GIS allowed the creation and modification of the analysis that makes the best use of available data. GIS also supported methods to apply guidelines and criteria set by local and national management regulations. Five major steps of GIS spatial analysis for environmental and ecological planning include (but not limited to:

- Defining criteria for the analysis
- Defining data needs and base map
- Acquisition and preparation of the data as thematic maps
- Creating GIS model/overlays
- Evaluating results and refinement of the mode

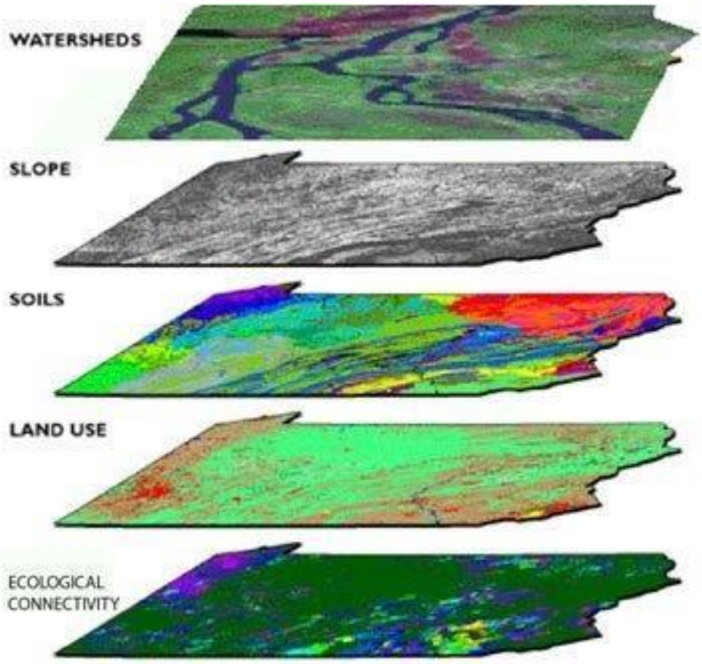


Figure 2-1: A typical overlay analysis of various GIS layers

Key sources of information include topographic maps, aerial photos, satellite images and data derived from GIS like land use, slope, water features and environmental risks.

Site development suitability analysis will be based on an environmental sensitivity assessment and considers constraining factors for certain developments in the site, for example a wetland of ecological importance or land having high slope. Suitability levels will be first tested based on individual factors which are later overlaid to indicate overall development suitability. This approach considers existing natural resources at the site and aims to protect environmentally and ecologically sensitive areas. The overlay procedures play a central role in many GIS applications (O'Sullivan and Unwin, 2003). Several advanced techniques that are in the forefront of the advances in the land-use suitability analysis have come up such as: multi-criteria decision analysis (MCDA), geo-computation methods, visualisation methods and Web GIS.

For any development project, for example the protection of water resources is extremely important. Construction over the drainage path or watershed can affect the water resources of the region. The establishment and maintenance of buffer zones along streams is a common management practice used in ecological planning. The buffer analysis tool in GIS helps in setting buffer zones for the water bodies.

Environmental planning also addresses risks of natural hazards and disasters. Floods are one of the most common hazards in the world and the use of environmental and GIS data to construct a flood hazard map has been done for many projects. By combining data of topography, water resources, surface runoff and rainfall data, possible flood risk within the site area can be predicted. Also, hazard areas like high slopes, soil erosion and landslides can also be incorporated in GIS-based environmental planning.

2.1.5. Towards Sustainable Development

To achieve sustainable development, the impact on environment and biodiversity due to urbanisation needs to be carefully assessed at regional and landscape level. GIS analysis helps in evaluating large data at landscape and regional level easily and helps decision makers to visually understand the environmental consequences of the project. Environment planning and ecological planning can be incorporated into both large- and small-scale development projects such as ecotourism development and will help in choosing the best available land that helps to reduce environmental impacts and preserve biodiversity. Landscape ecological planning can provide a conceptual framework for the assessment of consequences of long-term development processes like urbanisation on biodiversity components and helps in evaluating and visualising the impacts of alternative planning scenarios (Mortberg et al 2007).

In recent decades, GIS-based ecological and environmental planning has contributed immensely to sustainable development. GIS based environmental planning is being practiced in many developing nations with developed nations already in advanced stages of using GIS in sustainable land use planning.

2.2. Ecotourism

2.2.1. Concepts and Definitions

Ecotourism is defined as "responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education" (TIES, 2015). It is a sustainable form of natural resource-based tourism.

While the details vary, most definitions of ecotourism boil down to a special form of tourism that meets three criteria:

- Ecotourism provides for environmental conservation;
- Ecotourism includes meaningful community participation; and,
- Ecotourism is profitable and can be self-sustained.

2.2.2. Principles of Ecotourism

Some of the fundamental principles of ecotourism are:

- Environmental conservation,
- Cultural preservation,
- Community participation,
- Economic benefits, and
- Empowerment of vulnerable groups.

2.2.3. Potential Risks of Ecotourism

Ecotourism may cause negative impact depending on the type and nature. Typically, it may cause three major negative impacts: economic impacts, cultural or social impacts, and environmental impacts. The negative impacts from ecotourism occur when the level of visitor use is greater than the environment's ability to cope with this use within the acceptable limits of change as it poses potential threats to the environment. Table below summarizes the potential risks of ecotourism on the biophysical environment.

Table 2-1: Some of the potential risks of ecotourism

Element	Examples of risks from ecotourism activities
Ecosystems	The construction of accommodation, visitor centres, infrastructure, and other services has a direct impact on the environment
Soils	Soil compaction, removal, and erosion can occur
Vegetation	vegetation removal, weed transmission, etc.
Water	Disposal of sewage, release of fuel, etc.
Air	Motorised transportation may cause pollution from emissions
Wildlife	Impacts occur on insects and small invertebrates, from effect of transportation, noise, visual or harassing behaviour.

Some of the most common sociocultural effects of ecotourism include:

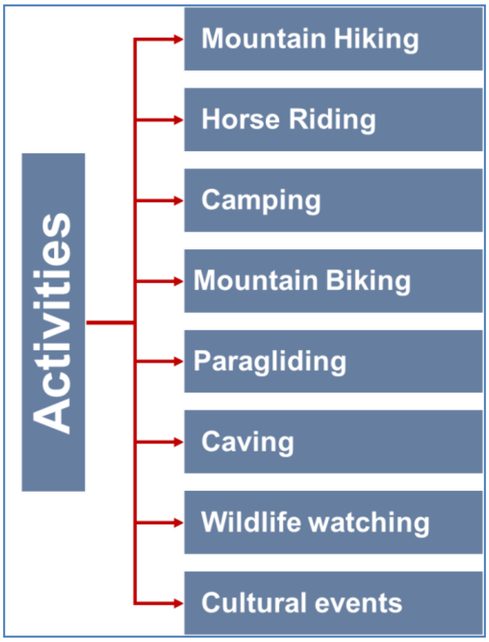
- Exploitation of local workforce
- Instability
- Displacement of local people from their land
- Land use conflict
- Cultural change
- Increase in crime, thefts, muggings and expansion of HIV/AIDS

2.2.4. Interventions to Minimize Impacts of Ecotourism

Government intervention at different levels is needed in the following ways in order to minimaze4 the side effects of ecotourism. These include,

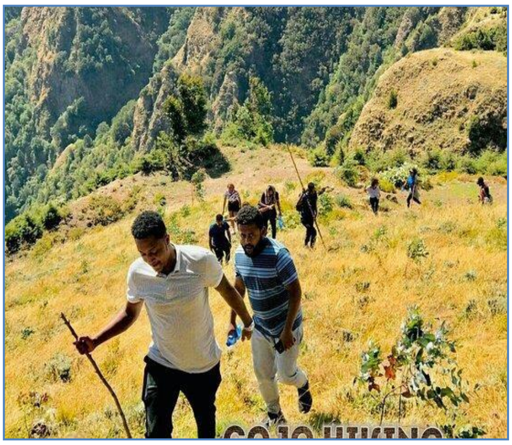
- Limiting the number of tourists and tourist operators based on the carrying capacity of the area,
- Improving the patterns or logistics of tourism movements to reduce environmental damage or adverse effects,
- Providing appropriate environmental education to tourist operators and tourists.
- Imposing restrictions on constructions.

2.2.5. Ecotouristic Activities



These are some of the potential ecotouristic activities that could be adapted in Ethiopia.

Mountain Hiking: Walking outdoors on a trail for recreational purposes. It requires a certain degree of physical effort.



Horse Riding: Recreational activity using horses to access wild zones using identified routes.

Camping: Outdoor recreational activity involving overnight stays on a portable shelter.

Mountain Biking: Riding bicycles off-road, often over rough terrain, using specially designed mountain bikes.

Paragliding: Recreational sport that consist in the use of paragliders to make flights.

Flora/Fauna Watching: Wildlife watching in their natural habitat.

Cultural Events: Family gate together, picnic events, photography

Note:

- From feasibility perspective and the purpose of the assignment, and as well as by considering the remaining limited time, this study will focus only on mountain hiking ecotouristic activities.

2.3. Geographic Information Systems (GIS)

GIS is one of many information technologies that have transformed the ways scientists and planners conduct research and contribute to society. In the few past decades these information technologies have had tremendous effects on research techniques specific to the discipline, as well as on the general ways in which scientists communicate and collaborate (Foote and Lynch, 2000). These systems allow people to collate and analyse information far more readily than would be possible with traditional research techniques.

Most of the objects and events of the real world are located in certain place on Earth or at least, they are somehow related to it. These objects do not exist in space alone but together with many others. They are mutually related, intertwining and influencing each other. An understanding of the position and spatial relation between these objects plays an important role in solving the problems that occur in many areas of human activities. In the real world it means that we need to work both with information about the object and also with information about its location. These types of data are called geographical or spatial data and can be maintained by Geographic Information Systems.

2.3.1. Definitions of the Term GIS

Geographic – GIS work primarily with geographic or spatial features. As was mentioned previously, these are objects which can be referenced or related to a specific location in space, no matter whether they are physical, cultural or economic in nature. Features on a map for instance are graphic representations of spatial objects in the real world. Symbols, colours and line styles are there to stand for the different spatial features on a two-dimensional map. Computer technology has been able to assist in this mapping process through the development of automated cartography and computer assisted design. Computer programs can now accomplish a broad variety of tasks in a much shorter time than it would take cartographers and draughtsmen to complete (Foote and Lynch, 2000).

Information–Information in GIS represents the large volumes of data which are dealt with. All real-world objects have their own particular set of characteristics or descriptive attributes. These types of non-spatial alphanumeric data are called attribute data and they need to be, together with locational information, stored and managed for all spatial features of interest. Historically maintained as paper files, computer technology has enabled much more efficient handling and management of information within automated database management systems (GDI, 1993).

Systems–Whereas complex environments are broken down into their component parts for ease of understanding and handling, they are considered to form an integrated whole. The term system is used to represent the system approach taken by GIS. Computer technology has aided and even necessitated this approach so that most information systems are now computer based. Computer systems are becoming indispensable for the storage and manipulation of the increasing volumes of data, the handling of complex spatial algorithms and the integration of data of different scales, projections and formats. All of which are essential to GIS (GDI, 1993).

2.3.2. Raster Analysis

ArcGIS Spatial Analyst provides a broad range of powerful spatial modelling and analysis features. Using ArcGIS Spatial Analyst, it is possible to create, query and analyse cell-based raster data, derive new information from existing data, query information across multiple data layers and fully integrate raster cell-based data with a traditional vector format (ESRI, 2001).

In a raster GIS the map data files are arranged as a matrix of evenly spaced grid cells or raster. The cells are ordered in a rectangular array of rows and columns (Cho, 1995). The identity of each cell is thus referenced by its pair of row and column numbers. All map overlays in a single database are registered and referenced to the same grid matrix. The map matrix is also tied to real-world locations and features on the earth's surface. This matrix representation of real-world locations will thus allow GIS functions and operations to be performed on the data.

A map layer contains data that describes a single characteristic (e.g., roads, streams, vegetation etc.) for each location within an area. Only one item of attribute information is available for each pixel within a single layer so that multiple items of information will require multiple layers.

2.3.3. Map Algebra

Map algebra is a language that is used for performing spatial analysis. It is a relatively new expression for processes based on working with layers that represent the surface of the Earth. The layers interact according to mathematical models. Applying map algebra to input layers produces a new layer, which may be a paper map sheet or an electronic dataset displayed on a computer screen. Regardless of the mechanism, the result allows the users to explain complex phenomena, predict trends, model what-if scenarios, etc. (Bruns and Egenhofer, 1997).

The term map algebra embodies the process of combining map layers, representing distinct but coincident themes according to a mathematical model. Map algebra in the GIS environment is considered to be originated by Tomlin (1979, 1983, 1990) and is composed of variables, expressions and functions, using exact syntax. In order to perform advanced spatial analyses, it applies conventional statistical and mathematical operations to the grid cell data sets. Some examples of these manipulations and transformations include the following:

- **Reclassification:** Data sets may be reclassified by dividing up a continuous range of values into discrete levels of classes. Based on contiguity, cells with the same values are classed into similar classes.
- **Distance and connectivity:** Paths define the line of progress along contiguous cells in any direction and a measure of distance is given by the number of cells so traversed. Connectivity on the other hand simply is a measure of linkage of the paths so defined. A further use is that of viewsheds — to assess inter-visibility among locations.
- **Characterising neighbourhoods:** This operation seeks to determine slope, aspect and orientation of cells. From these data it is also possible to produce profiles of the grid cells.

- **Overlay:** This can include set-theoretic ideas of intersection and union or cover. Thus, areas may be reformed based on given values of cells at different map levels. Alternatively, arithmetic operations such as add, subtract, multiply and divide may also be performed on the cellular data.

2.3.4. Spatial Modelling

By means of map algebra analytical operations, ArcGIS Spatial Analyst provides a robust tool for creating sophisticated spatial models for many different geospatial problems. Spatial modelling types can be divided into the groups of representation and process modelling. The first ones describe stationery phenomena of the environment, the second may emphasize the process point of view but is often use to predict what will happen if some action occurs (ESRI, 2001). Some examples of spatial models include:

- **Distance Modelling:** for instance, involve finding optimum or shortest way from one place to another;
- **Hydrologic Modelling:** may predict where the water in some area will go;
- **Surface Modelling:** may include prediction of certain types of pollution level in specific region; and
- **Suitability Modelling:** (the modelling this study mainly deals with) might help to calculate optimal site locations by identifying possible influential factors, creating new datasets from existing data (e.g., slope, etc.), reclassifying the data to identify areas with high suitability, and finally aggregating these into one logical assessment of optimal suitability.

2.4. Empirical Review

2.4.1. Optimal Route Alignment

Optimizing route alignments is a complex combinatorial problem that finds the best alternatives (usually the most economical path) of a new route connecting specified points or locations (Min-Wook Kang, 2012). The route alignment design problem is traditionally a very complicated task in infrastructure engineering, due to the several and heterogeneous skills required to the engineers for the analysis (Nicola Bongiorno, 2019). Since traditional approaches are too slow and error-prone, in recent years many efforts have been made for developing original tools and algorithms that can actually support the designers in these tasks.

Naghdi et al., (2008), investigated the capability of utilizing GIS in improving the accuracy in quality of forest route planning based on soil stability. The author uses PEEGER software to determine route on land crossing capability map. Then GIS planned road network was compared with current road network that planned by using PEGER Software. The results show that the GIS planned road network crosses 75.5% of stable areas, while the current road network covers 60% of stable areas. With regards to drainage, the GIS planned road network covers 70% of good drainage areas while the current road network only covers 55.8 %).

Godwin Muriki et.al (2019), employed Geographic Information System (GIS) techniques and the Least Cost Path Analysis method to achieve viable results that were useful in determining a feasible road corridor. The route analysis parameters contained different weighted overlay factors where each factor is influenced by various criteria such as slope, soil, population, and land use-land cover. This implies that, least cost path analysis (LCPA) has the ability to reduce the overall cost of route alignment, road construction and minimize the negative impacts of such projects on both the macro and micro environments.

In Ethiopia difficulties face on road construction sites during construction due to inadequate attention to the initial selection of the route (URS, 2012). Optimal route identification is usually undertaken by consultants on behalf of Ethiopian Road Authority and should take into account avoidance of environmentally protected areas and other sensitive habitats (ERA, 2013) but as all EIA report shows that all the damage is passed simply by compensation and rehabilitation agreements. Planning a new route is an expensive and time-consuming process. Since, there are numerous environmental issues that need to be addressed. Even, the problem and challenges will depend up on the characteristics of the study area. The issues need to be addressed with the help of remote sensing and GIS, as they are a powerful tool for the compilation, management and display data associated with geographic space than the conventional methods such as ground surveying which are difficult, time consuming and expensive. In this study the researcher aims to select the optimum routes by using GIS least cost path using environmental parameter. This study employs LCPA with AHP spatial multi-criteria analysis to determine optimal hiking trails using different criteria.

2.4.2. GIS Based Multi-Criteria Decision Analysis

The utilization of GIS-MCDA choices gives the likelihood of prioritization joining spatial gauges from various areas and points of view is portrayed, and at last aides in settling on far reaching choices (A. Laskar, 2003, and Bernard Amponfi Gyabeng, 2020). There are several characteristics of spatial decision problems are evaluated on the basis of multiple criteria. The spatial multi-criteria decision analysis involves analysis of geographical events supported criterion values and therefore the decision maker’s preferences to a group of analysis criteria. The large number of factors necessary causes difficulties in making spatial decisions, difficulties in attempting to acquire and process data to obtain information for making decisions manually. Therefore, using GIS and MCDA techniques to support the decision maker achieves greater effectiveness and efficiency of solving spatial decision problems. The combination of GIS capabilities with MCDA techniques provides the decision maker with support in all stages of decision making, that is, in the intelligence, design and choice phases of the decision-making process (Bernard Amponfi Gyabeng, 2020). The overall framework for decision-making in route planning is based on the following steps:

- Intelligence: The identification of problems for decisions. According to defined problems to evaluate criteria and generate criteria maps based on GIS functions
- Design: Evaluate the relative importance of given criteria based on one of the MCDM methods.
- Choice: Evaluation alternative options and making decisions of problems by applying the corresponding multi-criteria decision rules.

2.4.3. Analytical Hierarchy Process (AHP)

Due to the negative effects of road projects to the environment, considerably, the cost of the projects is getting increased. The environmental and cost priorities of route alignmnet must be considered when examining the most suitable hiking trails. The environmental or cost oriented route alignment can be defined with Analytical Hierarchy Process (AHP). AHP is the most mentioned methods in multi-criteria analysis and is a general term that refers to the applications used to determine the most suitable solution to the real problems by providing a selection from different data clusters (Arentze and Timmermans, 2000). AHP is an MCDA method, developed by Saaty (Saaty, 2008), for pairwise comparisons in order to do the ranking. This approach is associated with a consistency ratio (Wang,2001). Assuming that there are a number of criteria and alternatives, the weights of the criteria are computed through pairwise comparisons using Saaty’s scale shown in table below. The consistency level of the comparison matrix can be computed considering its maximum eigenvalue, namely λ_{max}. Since λ_{max} is substituted for the order of the matrix (n), its difference from n is used to compute the Consistency Index (CI) and the closer to n, the more consistent the judgments

$$CI= \frac{\lambda max - n.}{n-1}$$

The principal eigenvalue of the matrix is divided by the average of the principal eigenvalue of a certain number of matrices filled in a random way (RI). If the result is smaller than 0.1 (the threshold), the comparisons are confirmed (perfect comparisons lead to CR = 0)

$$CR= \frac{CI}{RI}$$

Values for RI are as presented in Table below where the order of a matrix increases to more than three; their consistency issue arises and increases exponentially as the number of the criteria and alter-natives grows. If CR is more than 0.1, the user is blamed for providing inconsistent comparisons and the tables are returned to them for improvement.

Table 2-2: Saaty's scale

Rank	Description
1	Equally importance
3	Moderate importance
5	Strong importance
7	Significant importance
9	Extremely importance

Table 2-3: Consistency of random matrices

Matrix order	1	2	3	4	5	6
CR	0	0	0.52	0.89	1.11	1.25

For determining the optimal hiking trail's locations, AHP includes flexible, effective and adjustable structure to provide user-defined solutions. Thus, the results can be adjusted, evaluated and measured both environmental and cost oriented approaches (Kara and Usul, 2012) AHP provides cost surface to the LCPA such as environment, economic and social, thus, the routes can be determined with LCPA according to the desired parameter-oriented approach (Kang et.al., 2012).

2.4.4. Conceptually Framework

Traditional route alignments require experienced engineers to repetitively evaluate various alternatives in order to determine the most suitable areas which satisfies the needs, optimal in its location for minimizing the costs of its construction, and avoiding any environmental constraints in the area. The conventional method of route alignment refers to the calculations and analysis of the elements of routes that are visible to human eye. AL-Hadad et al., (2018) successfully applied algorithms for optimizing route alignments. Genetic algorithms are very effective at finding good solution in a complex search space with many local optimal. His representation of the area was in a matrix format. However, the method is time consuming and in efficient in geographical complex arena. Recently, many researchers recommended GIS as powerful tools for optimum route selection. Since, several costs of route alignments are sensitive to geography, using GIS as a tool to calculate these costs is very efficient and time saving. So, this study decided to use GIS least cost path analysis optimum route selection since the literature reveal the method is user friendly and highly powerful to select the least cost routes for mountain hiking trails, too. With GIS Least cost path because of its reliable and standardized processes allows the output to be shown in a quantitative manner (Godwin Muriki ,2019). The concept behind least cost analysis is to determine a route that is cheap and would have a less negative impact on the surrounding environment (Nayana Padmani and Sudath, 2017). This study uses weight overlay analysis function to integrate the criteria in GIS environment. AHP spatial multi-criteria evaluation pair comparison will be used to evaluate the alternative defined. The remote sensing and data are used to extract different factory used for selecting least cost paths. For this reason, this study decides to use the integration of different geospatial technology for route optimization as one fills the gap of the others.

2.5. Environmental Impact Assessment (EIA)

2.5.1. Definitions of EIA

Environmental impact assessment is a formal process for identifying the likely impacts of specific activities or projects on the biological and physical environment, and the socioeconomic environment as well. Similarly, EIA encompasses the development of mitigation means to address these identified effects, and proposed approaches for implementing mitigation and monitoring measures. This is because EIA helps identify environmental factors and values, i.e., both beneficial and adverse environmental effects, to be integrated into the decision-making process in a way that improves the design and sustainability of proposed projects. There is no doubt about the validity and usefulness of examining the environmental impacts of any development projects though there has been criticism and misconceptions. Nowadays, EIA is a legal requirement in several developing countries for major development projects. Besides, timely EIA has several tangible potential benefits such as lowered project costs, consideration of alternative designs, identification of mitigation actions, and increased project acceptance by the public among others leading to development projects that are more sustainable: environmentally, socially, and economically.

2.5.2. Key EIA Concepts

There are key environmental impacts assessments concepts that ought to be clearly defined. These concepts include but not limited to, the environment, impact, assessment, baseline situation, and an activity.

The environment– includes three closely associated components. The first one is the physical components, which include the geology, topography, soils, water resources, and air quality of that particular area. Secondly, the biological components, including fauna, flora, biodiversity, and ecosystems. And thirdly, the social components, including culture, religion, and local values.

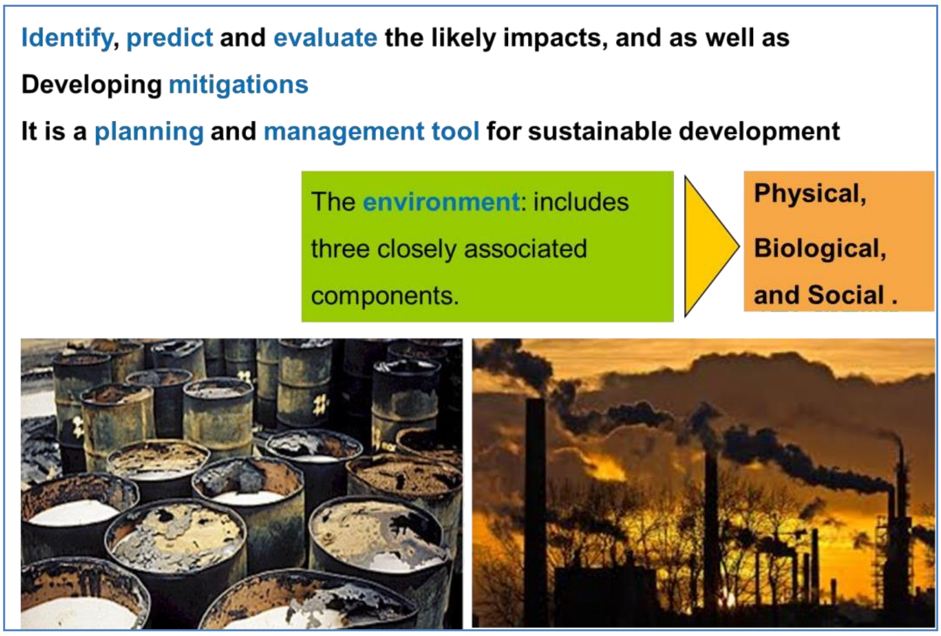


Figure 2-2: Components of environment in EIA context

Impacts– are deviations from a baseline situation, or the likely future conditions in the absence of the proposed activity. In other words, the impact of an activity is the change from the baseline situation caused by the proposed activity or project. The EIA process is concerned with all types of impacts and may describe them in a number of ways. Types of impacts could include, but not limited to, direct and indirect impacts, short-term and long-term impacts, adverse and beneficial impacts, and cumulative impacts. Their attributes may include intensity, direction, spatial extent, duration, frequency, reversibility, and probability. But it is worth noting that all impacts are not treated equally. In other words, it is essential to focus on the most significant impacts as absolutely there is no time and resources to analyse and discuss in detail the less important ones. Besides, it is essential to recognize that the baseline condition is dynamic, and that situations may be improving or deteriorating regardless of whether a proposed action is undertaken.

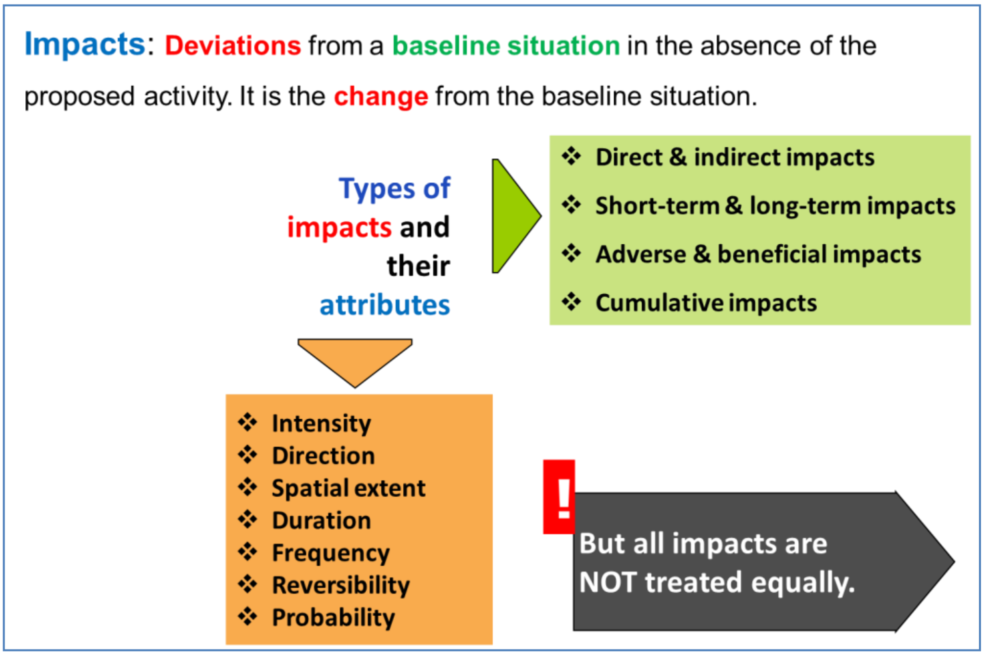


Figure 2-3: Types of impacts and their attributes

Assessment– is identifying the impacts likely to arise from the proposed activity or project, forecasting or quantifying them, and assessing their significance. These activities are the technical heart of the EIA process. Environmental information should be gathered and analysed using rigorous scientific methods. However, environmental data are often lacking, analysis can never be complete, predictions are always uncertain, and outcomes are not guaranteed. The interpretation and evaluation of the results requires judgment; choices inevitably involve the subjective weighing of costs and benefits and of the varied interests of different stakeholders.

Assessing impacts involves far more than science alone. Indeed, to measure an impact, you must know what the baseline situation is.

The baseline situation– is the existing environmental situation or condition in the absence of the proposed activity or project. Accordingly, identifying and characterizing the baseline situation is a key concept in EIA. For example, the environmental components of interest such as water, soil, fauna and flora, health and ecosystems are likely to be affected by the proposed development and should be given special attention while conducting the EIA.

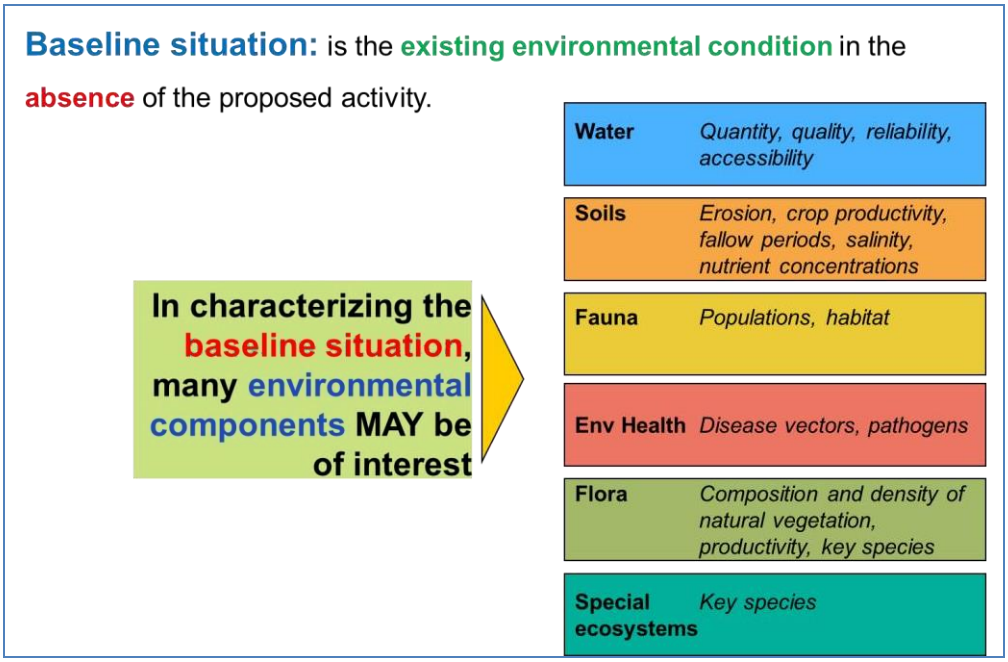


Figure 2-4: Key environmental components in characterizing baseline situation

An activity– is a desired accomplishment or output. For example, activity can be a road, seedling production, or river diversion to irrigate land. A project or program may consist of several activities. And accomplishing an activity (road rehabilitation) requires a set of actions (survey, grading, culvert construction, compaction, etc.).

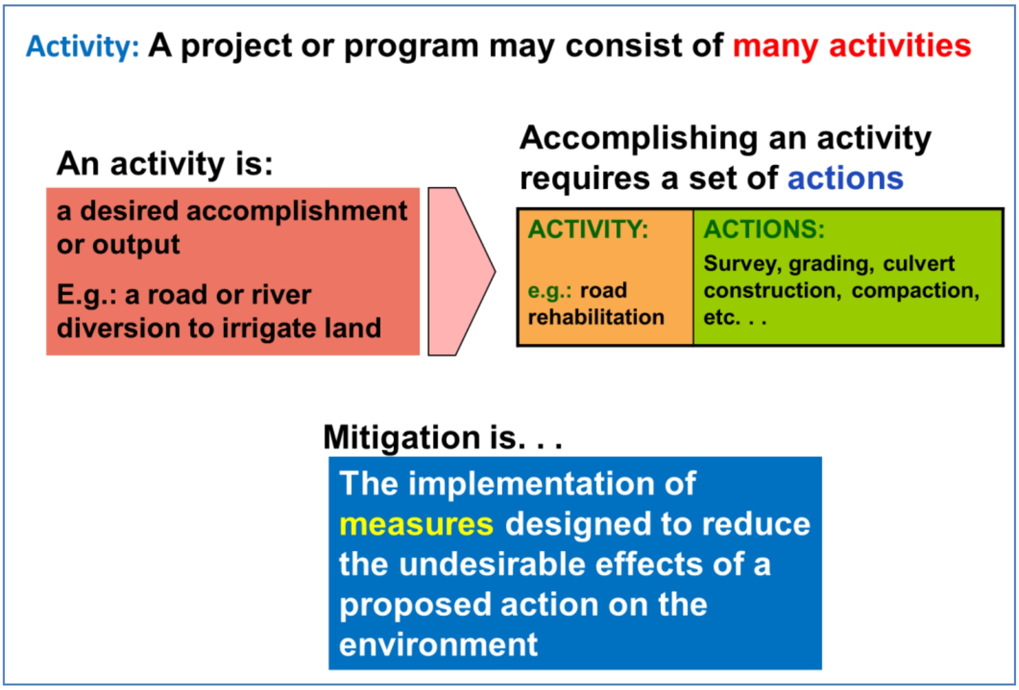


Figure 2-5: Example of activity and the corresponding actions

2.5.3. The EIA Principles

Certainly, any new development, redevelopment, or remedial action will change the existing environment. This is why EIA attempts to ensure that the adverse environmental impacts of a proposed activity are kept to a practicable minimum. The EIA should consider a number of appropriate alternatives that could meet the purpose and need of the proposed project and explain the justification for the preference of one alternative over another.

Therefore, EIA should identify and concentrate on issues or natural resource limitations that could affect the feasibility of a project (UNEP, 1988); appraise the probable environmental impacts of projects; develop means to reduce the effects and propose means to improve the project's relevance for its proposed environment (UNEP, 1988); and, present and communicate in a manner that enable understanding of both positive and negative impacts to decision-makers and the public before irreversible decisions are made.

Plausibly, the EIA process itself should be systematic to ensure that all reasonable alternatives are considered and compared in the planning process. The EIA process, too, should be reproducible to allow independent approval of the findings and conclusions. Likewise, the EIA process should be interdisciplinary to make sure that relevant experts in associated disciplines contribute their expertise and experiences to the overall and comprehensive assessment and analyses. And, EIA process should be public to give communities a say in issues that maybear directly on their health, welfare, and quality of life in the earliest phases of project planning and continue through the decision-making and implementation process.

2.5.4. The EIA Process: Phase I

The EIA process is aimed at attaining and fulfilling the principles highlight in the preceding section. Broadly, there are two generic environmental impact assessment processes. Namely, Phase I of the EIA process and Phase II of the EIA process, where the former one is the initial inquiries in order to determine whether a full EIA study is required as briefly explained below.

Phase I of the EIA process consist of collecting information to understand the proposed project, screening, preliminary assessment, and scoping.

Understanding the project– the EIA process commences by collecting the necessary information about the proposed activity or project and characterizing and the purpose and examining need for a project or an activity. In other words, comprehending what is being proposed and why is the activity being proposed.

Screening–determines the type of environmental review the project will require based upon the basic characteristics or nature of the project. The results of the screening process or the level of the environmental review could fall into one of the three outcomes: the project demands a full EIA i.e. the proposed activity has high risk; the project is unlikely to have any significant environmental impacts i.e. the proposed activity has low risk; the project is of moderate or unknown risk.

Preliminary assessment–is basically a rapid, simplified EIA study using more generic tools and simple methods such as checklists and matrices. Preliminary assessment is conducted when the screening determines that further environmental scrutiny of a proposed project is necessary, but that the project does not automatically demand a full EIA. The preliminary assessment may be sufficient itself if significant adverse impacts are very unlikely, or it may indicate that a full EIA study is needed in case significant adverse impacts are likely.

Scoping – the scoping process is commenced to determine the key boundaries, issues, and impacts that the assessment should address, once a decision to conduct a full EIA is made. It is recommended to proceed to Phase II of the EIA process if Phase I confirm that a full EIA study is necessary.

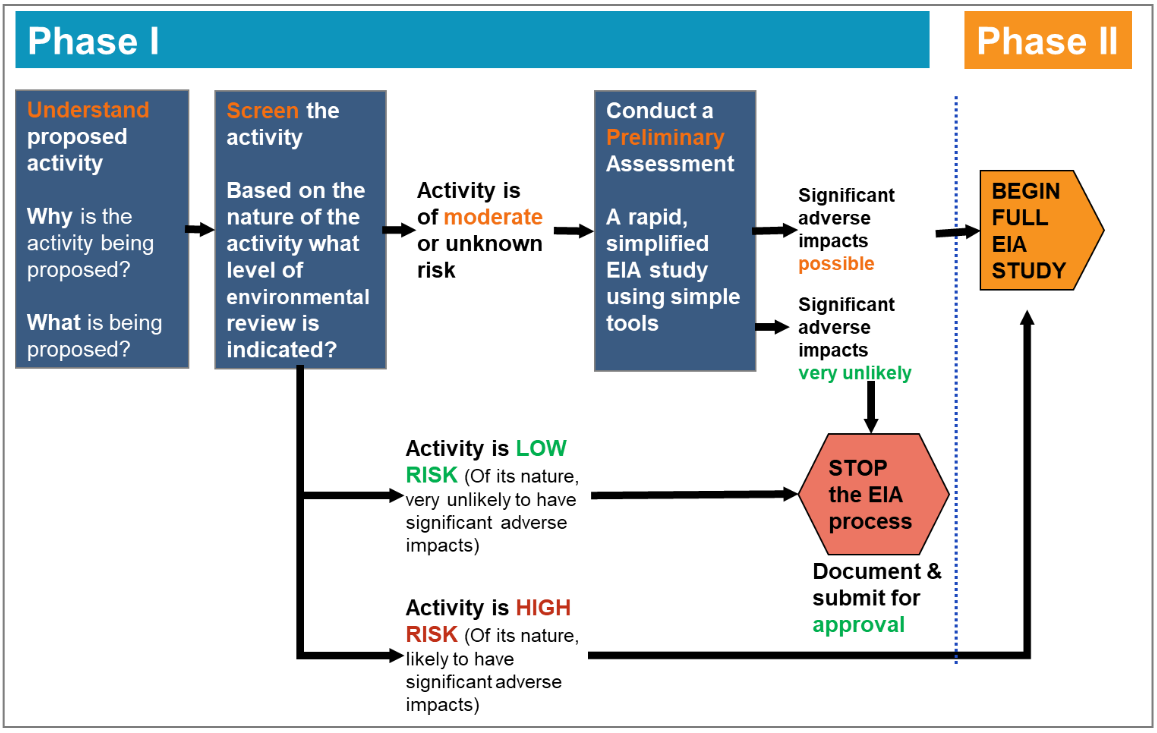


Figure 2-6: Phase I and Phase II of the EIA process

2.5.5. The EIA Process: Phase II

The full EIA study has very similar purposes and structure to a preliminary assessment; yet, the full EIA study differs in important ways. Firstly, a formal scoping process precedes the study to identify issues to be addressed. Secondly, analysis of environmental impacts is much more detailed. Thirdly, alternatives: the project as proposed; the no-action alternative; and, at least one other real alternative must be formally defined in order to meet the purpose and need of a proposed project. The impacts of each alternative must be identified and assessed, and the results compared and evaluated. Lastly, public participation and formation of professional EIA team are required to identify, prepare, test and implement practical mitigation options and monitoring work plans.

3. METHODOLOGY

3.1. Study Area

The study was conducted in the Eerer Mountain and its environs, which is located in the Oromia Regional State, East Shewa Zone. Eerer Mountain is situated at about 40 km southeast of Addis Ababa and 17 km north of Bishoftu town.

The study area is located between 8° 51’18’’ to 8° 55’12’’ North latitude and 38° 55’19’’ to 38° 58’48’’ East longitude. The altitude of this mountain ranges from 2000 meter at the southeast slope to the highest peak at 3099-meter from MSL. There are about five peaks which rise above 2900 metres. The mountain covers a total area of 4749.56 hectares of which 3500 hectares are designated as a forest land, under the management of Oromia Forest and Wildlife Enterprise (OFWE).

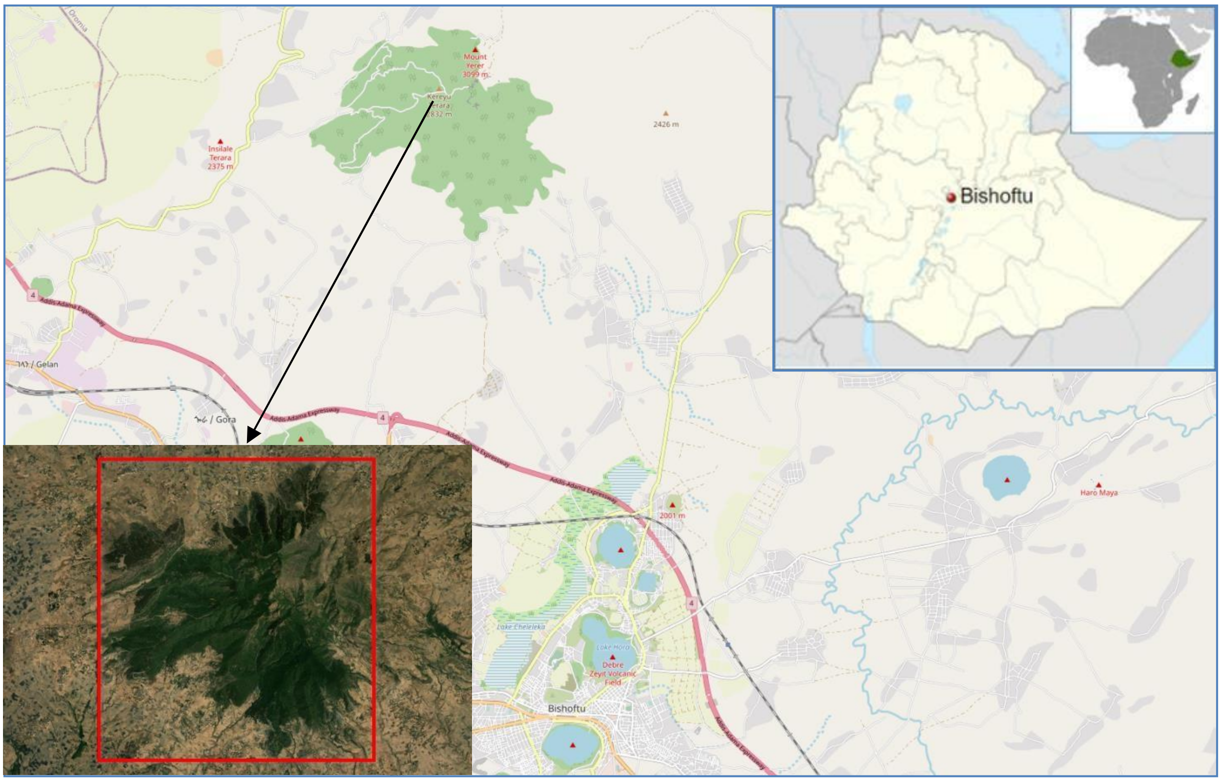


Figure 3-1: Location of study area

3.2. Sources of Data

Digital Elevation Model (DEM) Unit (m): This was obtained from (https://earthexplorer.usgs.gov/). It Contain elevation information of the country Ethiopia in 30mx30m grid size, this data is projected to WGS-1984 UTM zone 37N. DEM of the study area is prepared by clipping the obtained DEM of the country within the study area boundary this is done by using the "clip" function in the geo-processing tool of ArcGIS.

Environmental Data: Environmental data is necessary to specify natural and built-up environment surrounding the study area. This data is to be divided into several classes and each class of them is to be represented in a separate layer this include; Slope, Stream waters, existing road, LULC and soil type.

In general, the spatial data are in two data formats, namely Vector data model and Raster data model. Some of the available data mentioned are in vector data model, they were interpreted and digitized to the format acceptable for the analysis, and this digitized data were then converted into raster data models. The geographic space is represented as grid and spatial data are developed as tiles of a given dimension for display and analysis. The cell size selected is 30mx30m, all the raster are prepared with grid size of 30mx30m and all the analysis are done in this grid size. For accuracy of geographic location and analysis, the data sets were correctly positioned with respect to each other. For the analysis to be exact, the coordinate system of the data sets is checked using Arc Catalog. Arc Toolbox projection wizard was used to make a permanent projection for all layer into local datum.

Table 3-1: Sources of data and format type

Input Files	**Format**	**Source**
Digital Elevation Model (DEM)	Digital Elevation Model (*.dem)	https://earthexplorer.usgs.gov/
Georeferenced Image	Tiff	Google Earth
Land use and land cover	shapefile	https://LivingAtlas.arc.gis.com/
Road, settlement and waterway	Shapefile	https://extract.bbbike.org/
Selected Site Boundary	shapefile	ArcGIS and Google Earth
Soil type	shapefile	https://Fao.org/

3.3. Data Preparation and Pre-processing

The data are in two data formats, namely Vector data model and Raster data model. ArcGIS uses the data in either vector or raster or in combination. Some of the available data mentioned are in vector data model, they were interpreted and digitized to the format acceptable for the analysis, and this digitized data were then converted into raster data models. The geographic space is represented as grid and spatial data are developed as tiles of a given dimension for display and analysis. The cell size selected is 12.5mx12.5m, all the raster are prepared with grid size of 12.5mx12.5m and all the analysis are done in this grid size. For accuracy of geographic location and analysis, the data sets were correctly positioned with respect to each other. For the analysis to be exact, the coordinate system of the data sets is checked using ArcCatalog. ArcToolbox projection wizard was used to make a permanent projection for all layers into the coordinate system of Adindum zone 37 N.

All layers are added to a new empty map in ArcMap, a study area is created by forming a boundary, source and destination raster are prepared by point grid function of the software, then the clipping function is used to clip all of the layers into the boundary created. This way, the search space for the new optimal location is created.

3.4. Data Analysis Methods

Intensive review of literatures, document search, archives, aerial photo and land use maps were used as a secondary data. Similarly, geospatial data analysis tools such ArcGIS, QGIS, Erdas Imagine, GPS and other tools like Microsoft excel, power point, word, were used spatial analysis and compilation of the study. Apparently, each specific objective would have a designated section that explain thorough techniques and procedures employed to achieve each research objective. Data collection techniques and analysis methods as well as the procedure used for achieving each specific objective and addressing the corresponding questions is described in the proceeding sections.

3.4.1. Parameters of Suitability Modelling

The following criteria were taken into consideration to identify the optimal hiking trails route using suitability modeling approach in ArcGIS environment.

- **Slope:** How steep the trail is, or the difference between its lowest and highest points, will impact the difficulty of the hike and steeper slopes are much more hazardous and difficult to construct large linear features and comes a greater likelihood of erosion.
- **Existing Road Networks:** -the location should be close to existing road networks because it has least cost path.
- **Soil Types: -** if the soil types are the same, it is suitable for the hiking trail.
- **River Networks**: -the optimal location should be far from the hiking trails.
- **Forest: -** the mountain hiking trail should include the forest area.
- **Existing Settlements: -** the optimal location should be far from the existing built-up area.
- **Agriculture: -** the mountain hiking trail should exclude the agricultural area.

3.4.2. Optimal Route

The weighted overlay tool and the least-cost path to the ideal point determined based on the current potentials of hiking activity on the research region are employed. The Weighted Overlay tool is one of the most used approaches for overlay analysis to solve multicriteria problems such as site selection in suitability models. In this study, the weighted overlay tool to was used to the suitability models for the selected multicriteria problems.

The Weighted Overlay tool lets you implement several of the steps in the general overlay analysis process within a single tool. The tool combines the following steps:

- Reclassifies values in the input raster into a common evaluation scale of suitability or preference, risk, or some similarly unifying scale
- Multiplies the cell values of each input raster by the raster's weight of importance
- Adds the resulting cell values together to produce the output raster

The tool only accepts integer raster as input, such as a raster of land use or soil types. Continuous (floating-point) raster must be reclassified to integer before they can be used.

Generally, the values of continuous raster are grouped into ranges, such as for slope, or Euclidean distance outputs. Each range is assigned a single value before it can be used in the Weighted Overlay tool. The Reclassify tool allows for such raster to be reclassified. With the correct evaluation scale chosen, we add the raster to Weighted Overlay. The cells in the raster will already be set according to suitability.

The Weighted Overlay tool was used for suitability modeling (to locate suitable trails), higher values generally indicate that a trail is more suitable. The input raster to the weighted overlay is slope, LULC, Existing roads, stream water and soil type. The weighted overlay model is displayed in the image below as a process in GIS:

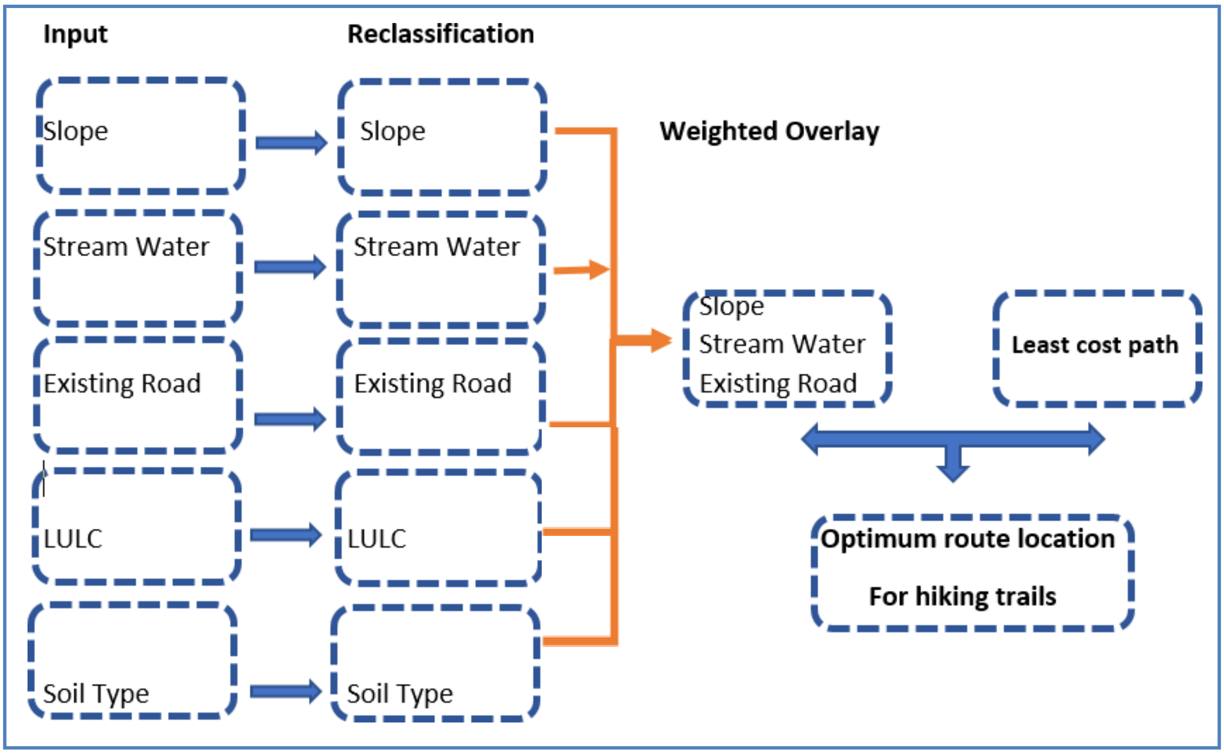


Figure 3-2: Suitability Analysis

To plan or select a hiking route requires an extensive pre-feasibility route analysis over the study site. Finding the optimal route between two locations has been a spatial problem encountered by engineers and road designers over the years. Least cost path because of its routine and standardized processes allows the output to be shown in a quantitative manner.

The Cost-Path tool determines the least-cost path from a destination point to a source. The concept behind least cost analysis is to determine a route that is cheap and would have a less detrimental impact on the surrounding environment. It is a spatial analysis function that employs raster data sets rather than vector data. The least-cost path travels from the destination to the source. This path is one cell wide, travels from the destination to the source, and is guaranteed to be the cheapest route relative to the cost units defined by the original cost raster that was input into the weighted-distance tool. Use the Cost Path tool to find the optimal route for a new trail or selecting the optimal route for the existing trails in terms of construction costs or to identify the path to take from several suburban locations (sources) to the mountain (destination).

If there are multiple cells or zones as input destinations:

- The least-cost path can be calculated from each cell (resulting in multiple paths, one path for each cell),
- Each zone (one path from each zone), or by
- Best single path (only one path, the cheapest from any zone).

Hence for this study, multiple paths were used from input source with a single destination.

A parameter in the tool specifies which process should be utilized.

Source and destination selection. As a criterion to select source and destination of the rout trails the study uses:

- The sources (starting points) of the hiking route trails are fed by the limited existing local roads. Saying this to plan/ select the optimal hiking routs, the easy way to study is using the existing sources.

- The selected destination point has the potentials for a maximum surrounding view and the elevation helps to achieve that, which in turn helps hikers to take magnificent pictures and enjoy the area. It is also the existing destination preferred.

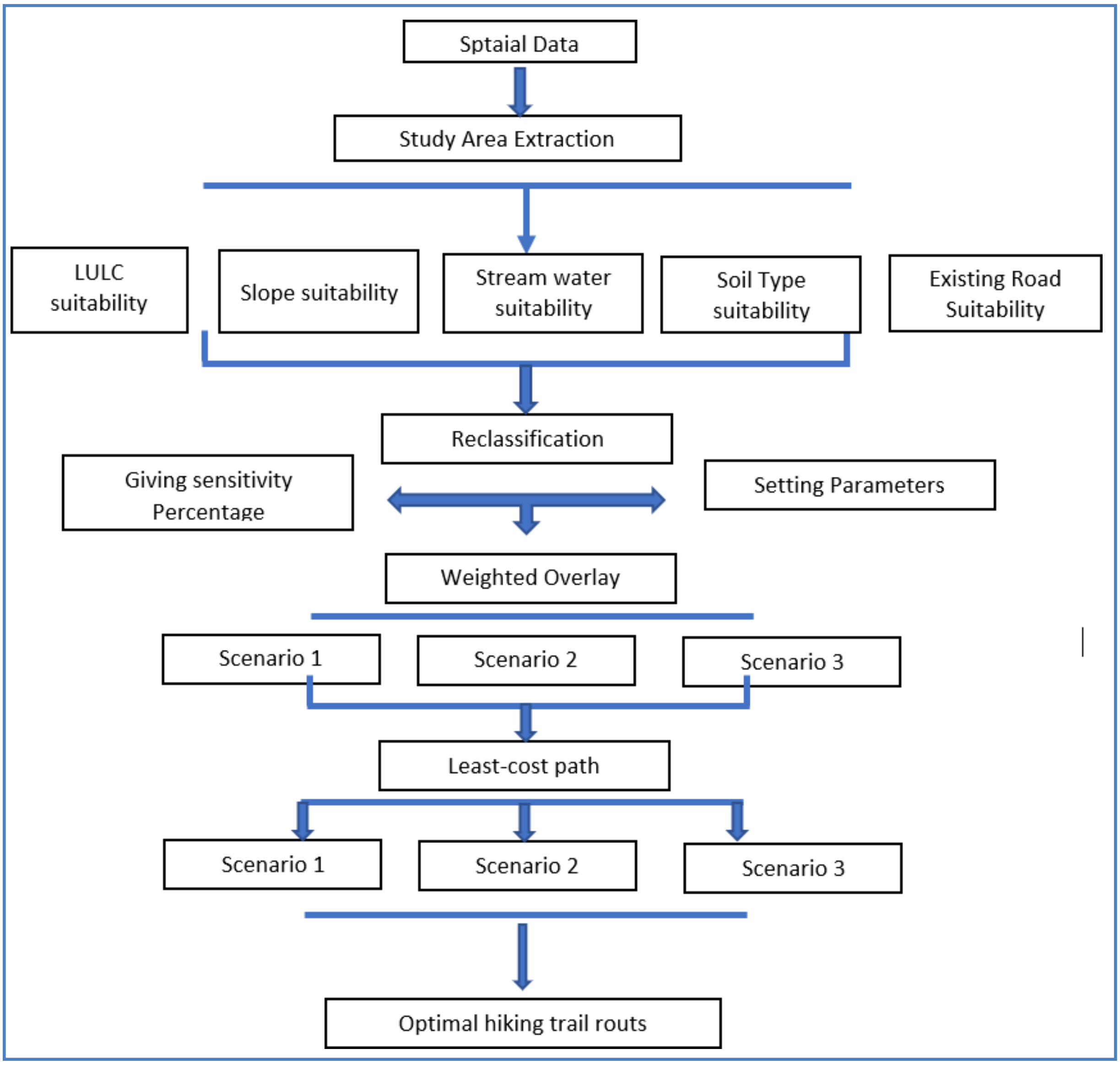


Figure 3-3: General Procedure for the identification of Hiking Trails

3.4.3. Least-Cost Path Analysis

A least-cost path analysis (LCPA) algorithm was used to determine the optimal location for hiking trails route alignment. LCPA provides users to find a cheapest route that connects two locations with using a cost surface that is determined by considering multiple criteria (Hassan and Effat, 2013). The cost surface can be produced via GIS and the cost criteria can be evaluated and weighted with AHP. Some of the studies on LCPA involve a selecting the fastest path with the least slope (Sarıi, 2017). AHP provides cost surface to the LCPA such as environment, economic and social, thus, the routes can be determined with LCPA according to the desired parameter-oriented approach (bernard amponfi gyabeng, 2020).

The point of origin (starting point) was identified and selected manually by using exploring Google Earth and existing hiking trails, while the point of destination (vantage point) is selected based on the highest elevation so that it has the maximum possible surrounding view.

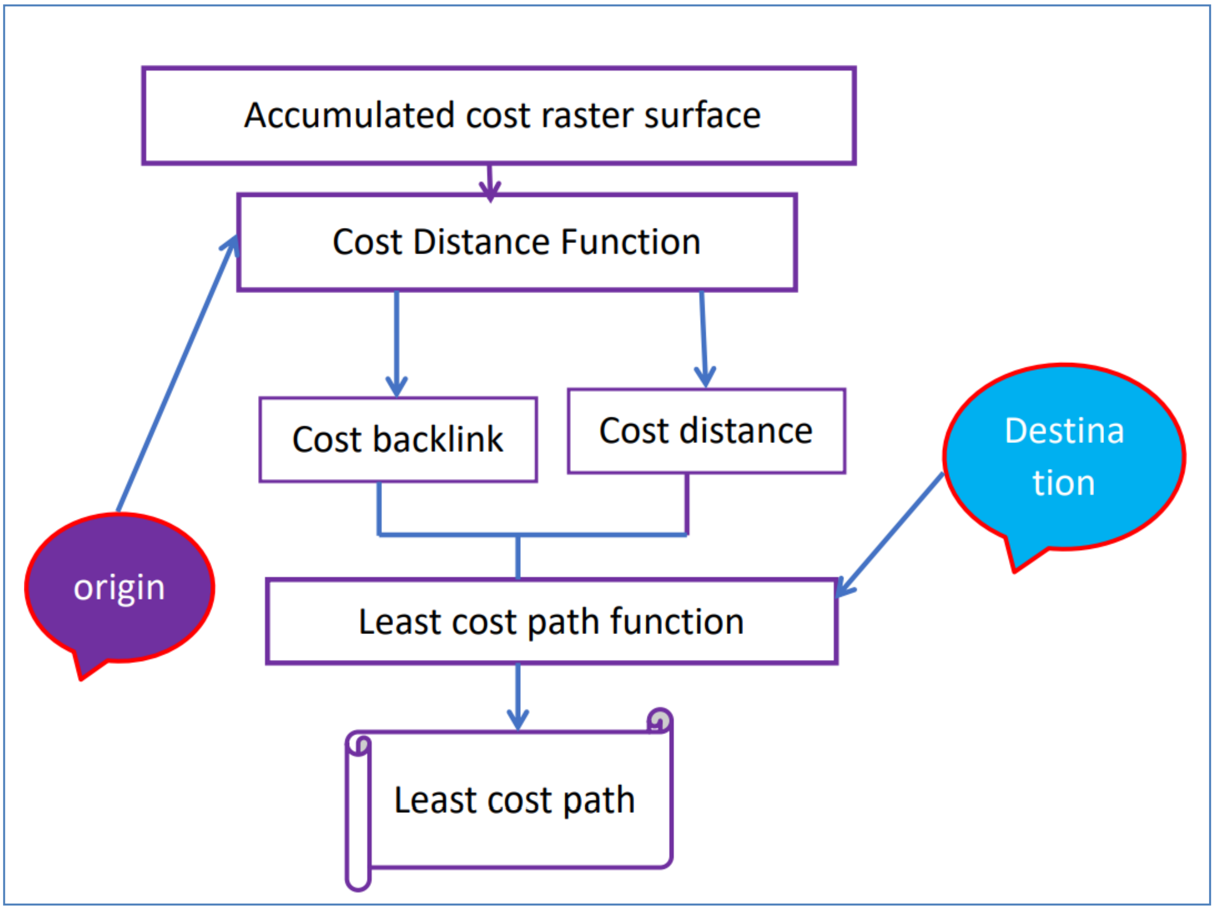


Figure 3-4: Methodological flowchart of the least-cost path analysis using GIS

3.4.4. Impact Assessment

Primary data collection such as site visits, interviews, and questionnaires were not employed to assess the impacts. However, secondary data sources such as site pictures and some maps, and national and international guiding principles were analysed as the proposed hiking trails will have a very unlikely adverse impact of the environment.

The following are the criteria that were chosen as a guideline:

- ONTARIO TRAIL DESIGN GUIDELINE 2006
- THE 1994 CONSTITUTION OF ETHIOPIA
- PROCLAMATION ON THE ESTABLISHMENT OF ENVIRONMENTAL
- PROTECTION ORGANS (NO. 295/2002)

The documents were utilized as a bench mark to analyze the environmental consequences that may emerge from the newly proposed hiking trails after filtering the guide lines and determining the criteria. Following the assessment, a mitigation report and mapping will be developed, which will indicate the enhanced strategy for dealing with any expected adverse impacts caused by the new hiking trails.

4. RESULTS AND DISCUSSIONS

4.1. Suitability Analysis

Suitability analysis is a general process which helps to evaluate optimal use of a certain place or area by identifying those factors likely to have an influence on it. Criteria for the performed analyses as well as the methodology are described in chapter three. In this chapter some of the study area's characteristics are briefly explained and the concepts and procedures of the individual analyses are also documented.

Apparently, the location for mountain hiking trails needs to be carefully selected to provide the maximum benefits and to maintain a healthy environment. GIS has been widely used as spatial decision support tool to select the best locations for the alignment of hiking trails. In this study, a set of factors and constraints were selected as criteria to identify the most suitable location for the best trail route. To select the optimal location for mountain hiking trails alignment planning the following criteria were taken into account among others.

- Existing roads,
- Slope,
- Soils or geology,
- Hydrology,
- LULC

4.2. Suitability Rating Scale

The suitability rating scores for each reclassified layers were on a scale of 1 to 5 where 1 and 5 indicate the least and most suitable areas, respectively. See table below for further information. The layers were combined using Raster Calculator with different weight. The detailed analysis and results were shown in the proceeding sections. Indeed, hiking trails was be determined by reclassifying the values derived from the Raster Calculator into five classes based on the Jenks natural breaks method in order to minimize the variation within classes statistically.

Table 4-1: The reclassification scale used in this study

Scale	Ranking	Description
1	Worst	The **least suitable area** for determining hiking trails
2	Bad	
3	Average	
4	Good	
5	Best	The **most suitable area** for determining hiking trails

4.3. Suitability Analysis procedures

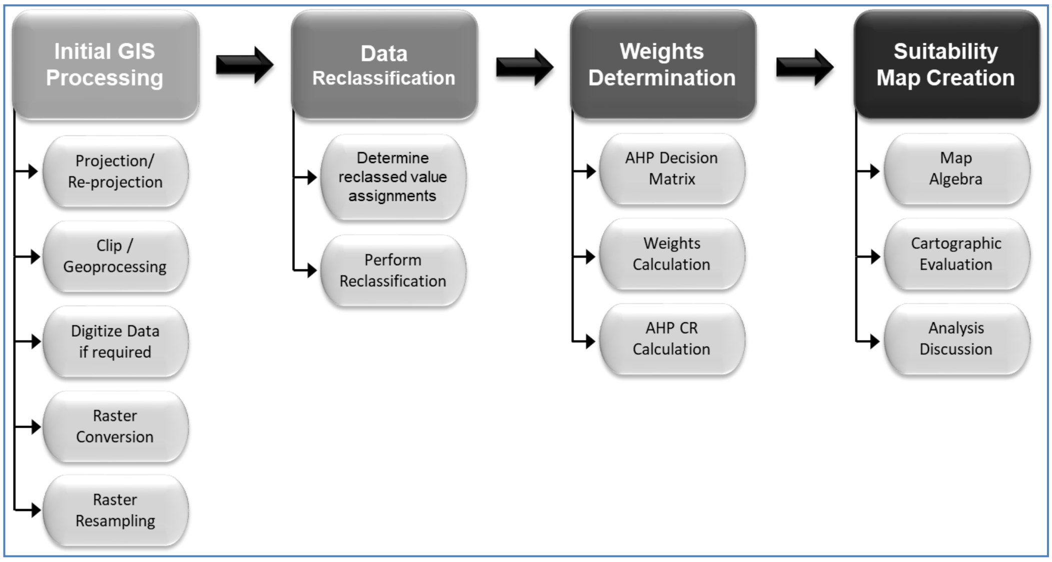


Figure 4-1: Flowchart illustrating the general suitability analysis

4.4. Slope Analysis

In GIS environment, the slope model can be generated by the slope function of surface analysis in ArcGIS Spatial Analyst. It calculates the maximum rate of change between each cell and its neighbours. For example, the steepest downhill descent for the cell (the maximum change in elevation over distance between the cell and its eight neighbours is generated). Every cell in the output raster has a slope value. The lower the slope value, the flatter the terrain is; the higher the slope value, the steeper the terrain. The output slope dataset can be calculated as per cent slope or degree of slope.

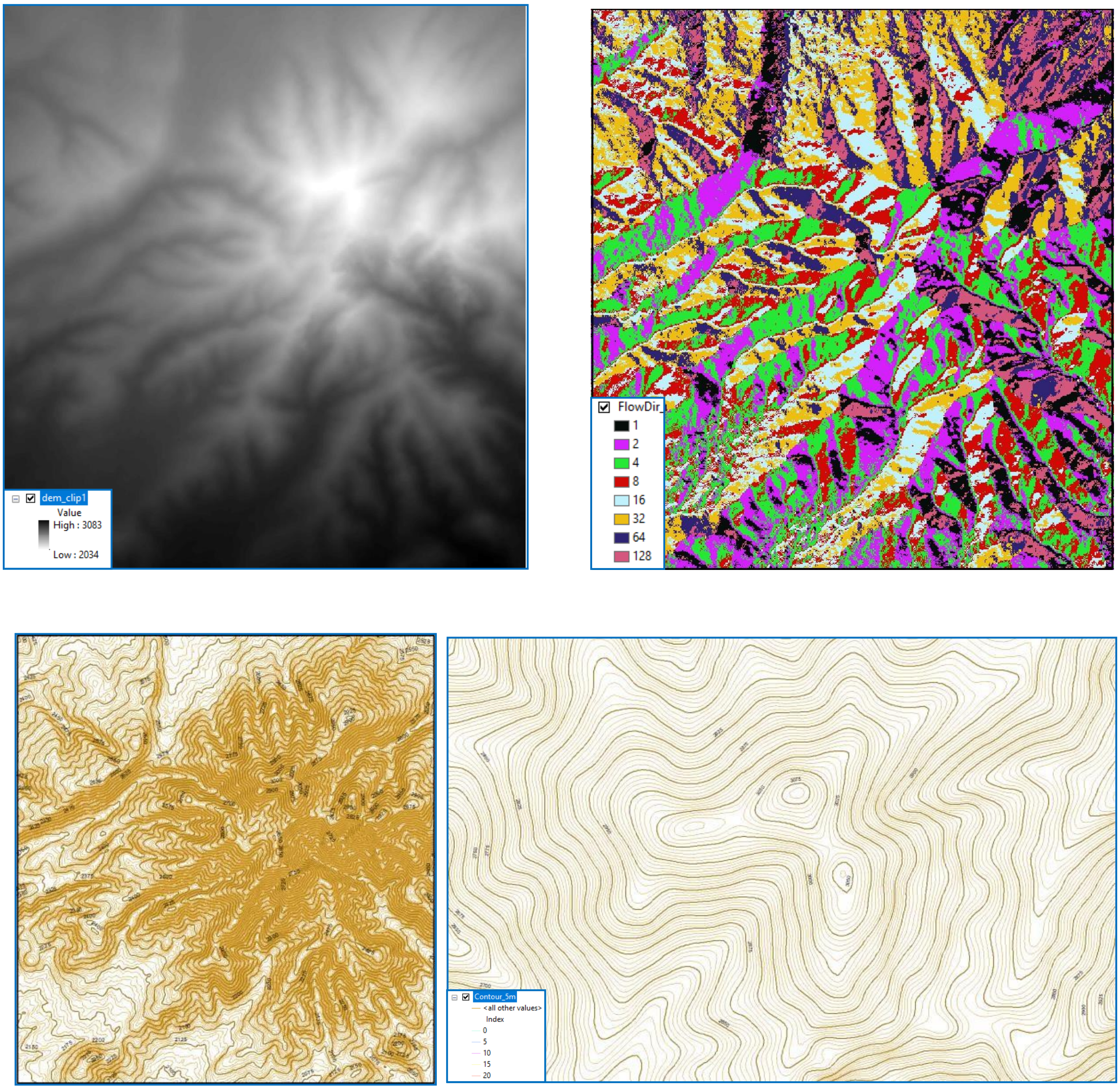


Figure 4-2: DEM and 5-meter interval contour line

Slope is created from digital elevation model that was prepared for the sturdy area. This file contains elevation information for the study area in 12.5m x 12.5m grids size. Elevation values are in meters and the coordinate system is projected coordinate system WGS1984 UTM37N. The tool used is the slope function of spatial analyst extension, the Input raster is DEM of the area, the output measurement used is degree, the output raster produce is the slope raster of the study area as shown in Figure 4 5. The co-ordinate system of this raster is checked to make sure that it is similar to the rest of the raster's, the slope is been reclassified by manual method into five classes according to degree rise.

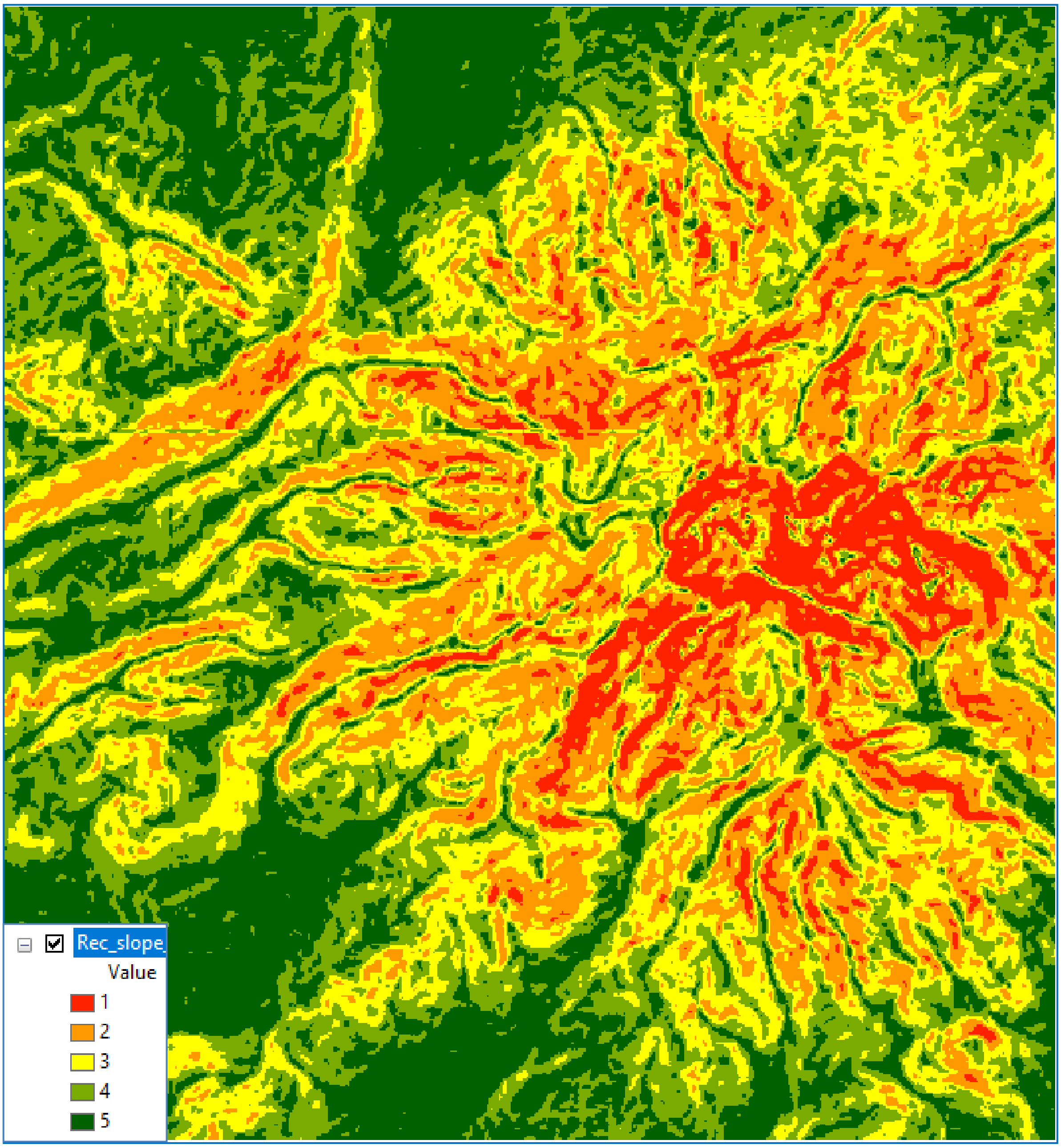


Figure 4-3: The reclassified slope in degree

Based on the above guide lines and criteria the most suitable areas are shown in dark green. Light Green areas are next, followed by yellow. Orange areas are least suitable, and red areas are restricted. Each value class in the input raster is assigned a new, reclassified value on an evaluation scale of 1 to 5, where 1 represents the very low suitability and 5 the highest suitability. Hence gentle slope (0-15) is highly suitable, while steep slope (60<) is showing very low suitability. Implies that routes should be given priorities when planned/selected following the given range of suitability.

4.5. Watershed Delineation

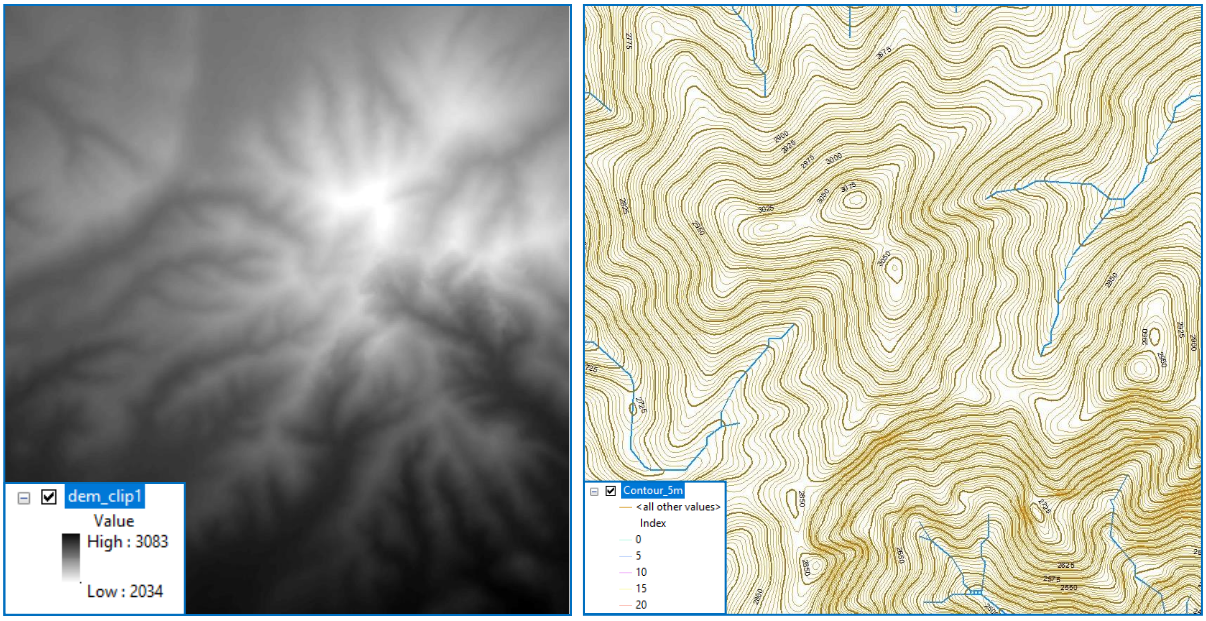


Figure 4-4: DEM and 5-meter interval contour line

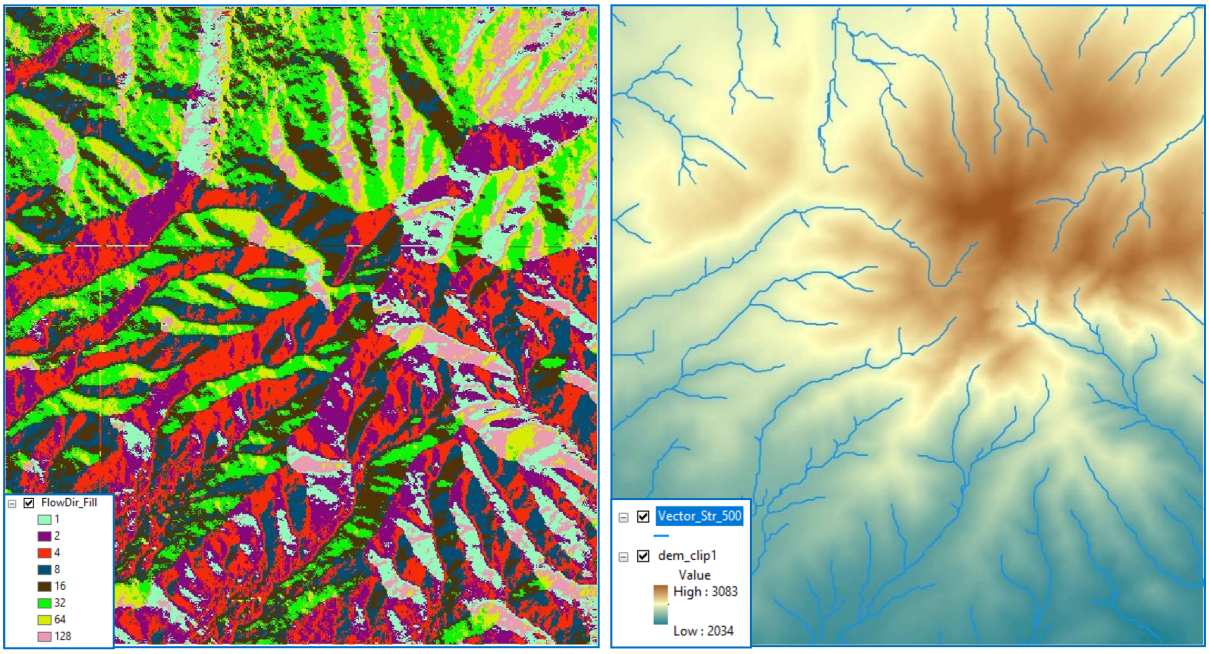


Figure 4-5: Flow direction and stream threshold

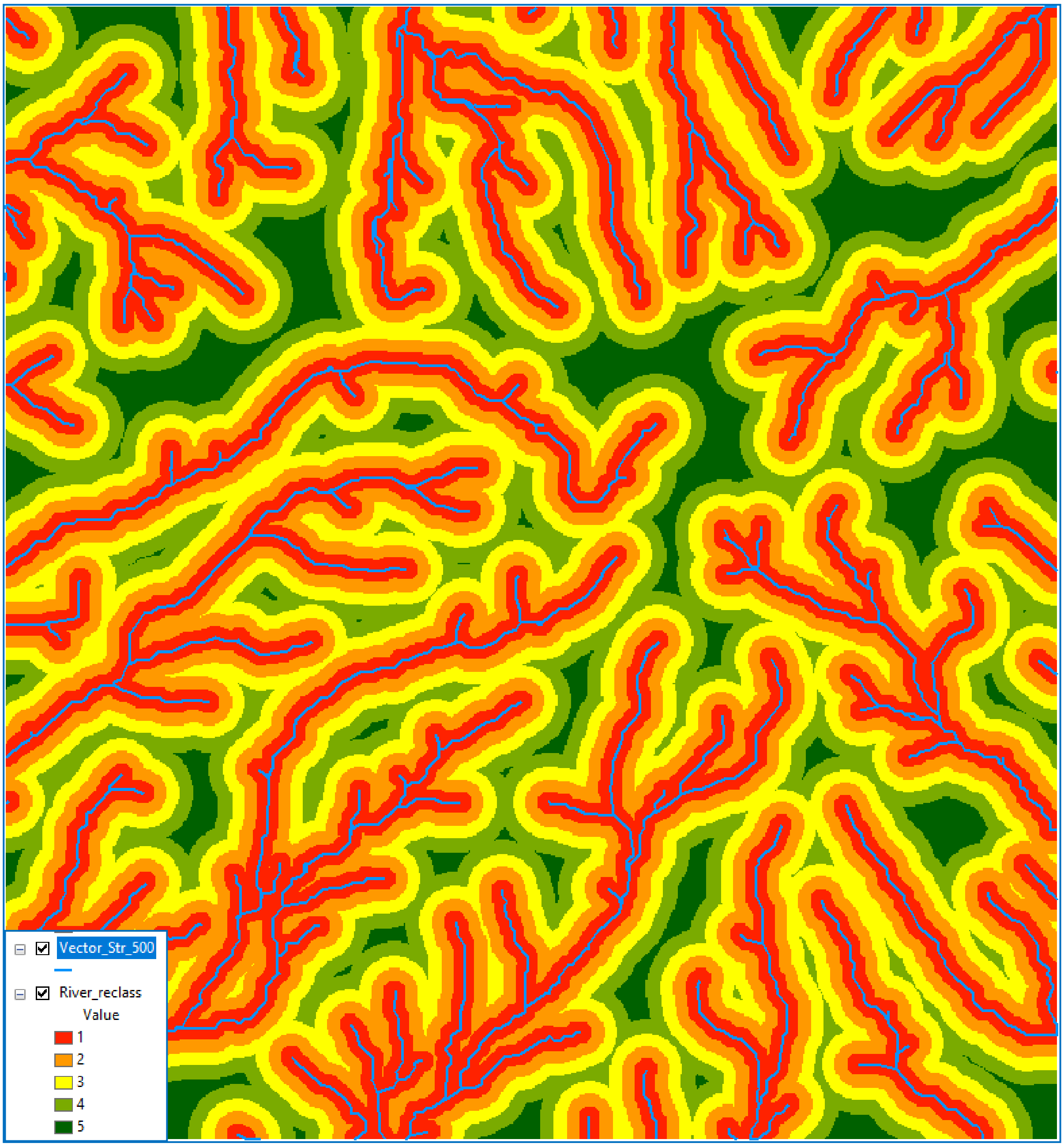


Figure 4-6: The reclassified watershed

Swampy and wet areas require considerable expense in the planning of any routes. Hence, it is recommended to avoid such a swampy and wet areas as much as possible. That means, the far from those stream water routes the better is the hiking trails. As stated on the reclassified data the most suitable areas are shown in dark green while the light green areas are next, followed by yellow. Orange areas are least suitable, and red areas are restricted which are the swampy and wet areas.

Each pixel value class in the input raster is assigned a new, reclassified value on a rating scale of 1 to 5, where 1 represents the very low suitability and 5 the highest suitability. Hence land far from stream water is highly suitable, while land adjacent to stream water is showing very low suitability.

4.6. Existing Trails

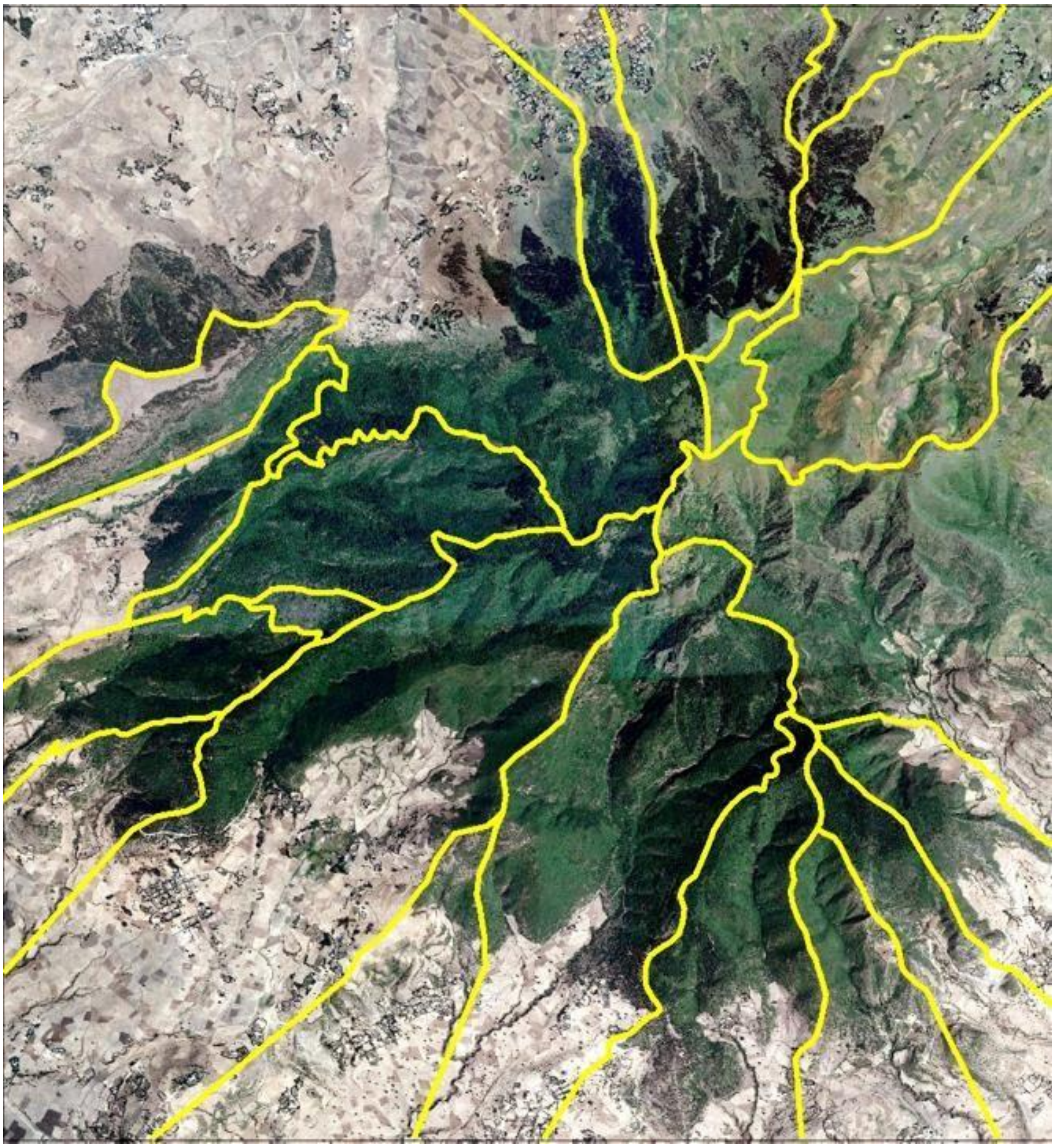


Figure 4-7: The existing trails

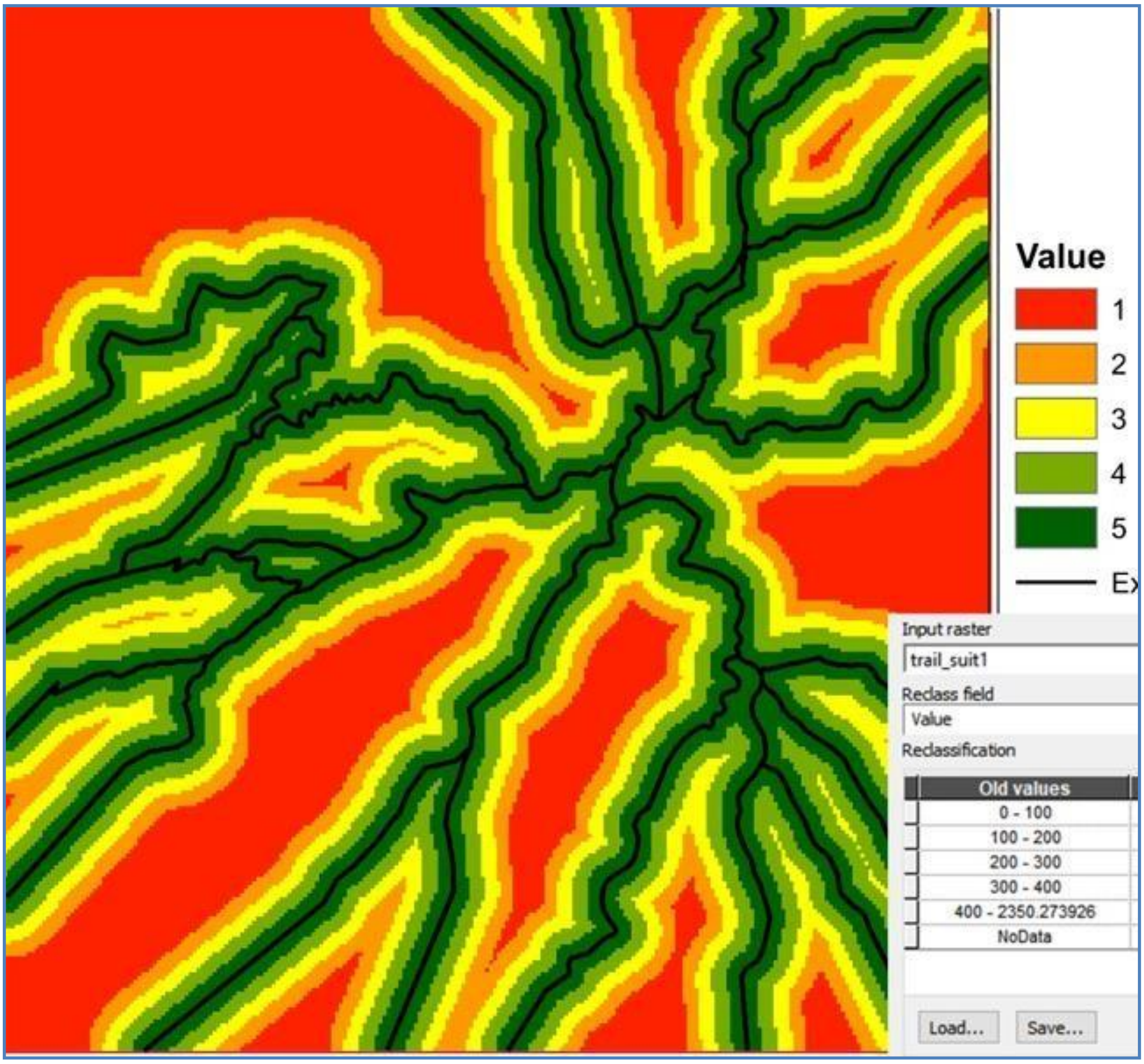


Figure 4-8: The reclassified existing trails

Selecting the most suitable existing routs is more economical and cost efficient than planning a new one. The reclassified data for existing road suitability shows that the most suitable areas are shown in dark green which are the nearest areas to the existing roads. Light Green areas are next, followed by yellow. Orange areas are least suitable, and red areas are restricted which have no connection with the existing roads. The above value class in the input raster is assigned a new, reclassified value on an evaluation scale of 1 to 5, where 1 represents the very low suitability and 5 the highest suitability. Hence areas adjacent to existing routs/roads is highly suitable, while areas far from the existing routs/roads are showing very low suitability.

4.7. Land Use Land Cover

The land use and land cover change detection of the study area was planned to assess. However, due to lack of very high-resolution satellite imagery, this factor was not considered in determining the optimal location of Erer mountain hiking trails alignment planning. Figure below was downloaded https://livingatlas.arcgis.com/landcover/ for the general information

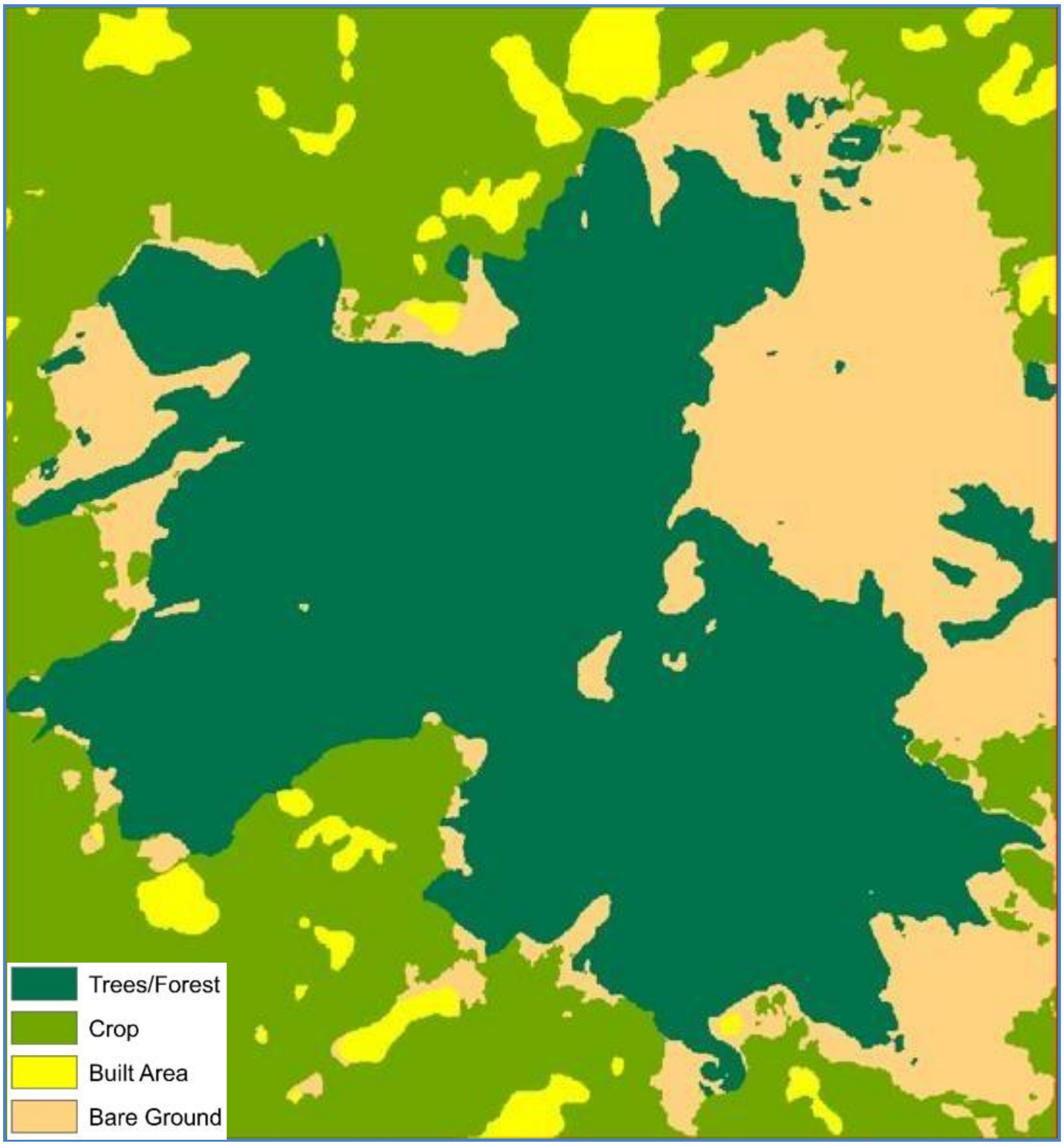


Figure 4-9: Land use land cover

The existing LULC shows that there is no change in land use and land cover. Mostly covered by bare ground at the bottom of the mountain and will change into forest while climbing up. Hence it left us no choice. This input data has a minimum or no effect on the planning/selection of optimal rout trails because of the monotony of the LULC.

4.8. Soil Type

Erer mountain have two types of soil Nitisol and vertisol soil both are **clay soils** that have deep, wide cracks for some time during the year. A nitisol in the World Reference Base for Soil Resources (WRB) is a deep, red, well-drained soil with a clay content of more than 30% and a blocky structure. Nitisols correlate with the kandic alfisols, ultisols and inceptisols of the USDA soil taxonomy. A vertisol, or vertosol, is a soil type in which there is a high content of expansive clay minerals, many of them known as montmorillonite, that form deep cracks in drier seasons or years. In a phenomenon known as argillipedoturbation, alternate shrinking and swelling causes self-ploughing, where the soil material consistently mixes itself, causing some vertisols to have an extremely deep A horizon and no B horizon. (A soil with no B horizon is called an A/C soil). This heaving of the underlying material to the surface often creates a microrelief known as gilgai. Likewise, the LULC input data, the soil type input data also have no effect on the output. The data shows that there found a single soil type which is clay soil. Even if it is observed that there are two types of clay soils on the study area, yet both share same soil characteristics and have no contribution for the planning/selection of rout trails. In conclusion from the above reclassifications, it is observed that slope suitability, water shade suitability and road suitability had a significant impact on planning/selecting rout trails. While LULC suitability and soil type suitability are insignificant. Keeping this in mind, we selected the above mentioned three classes for the overlay analysis.

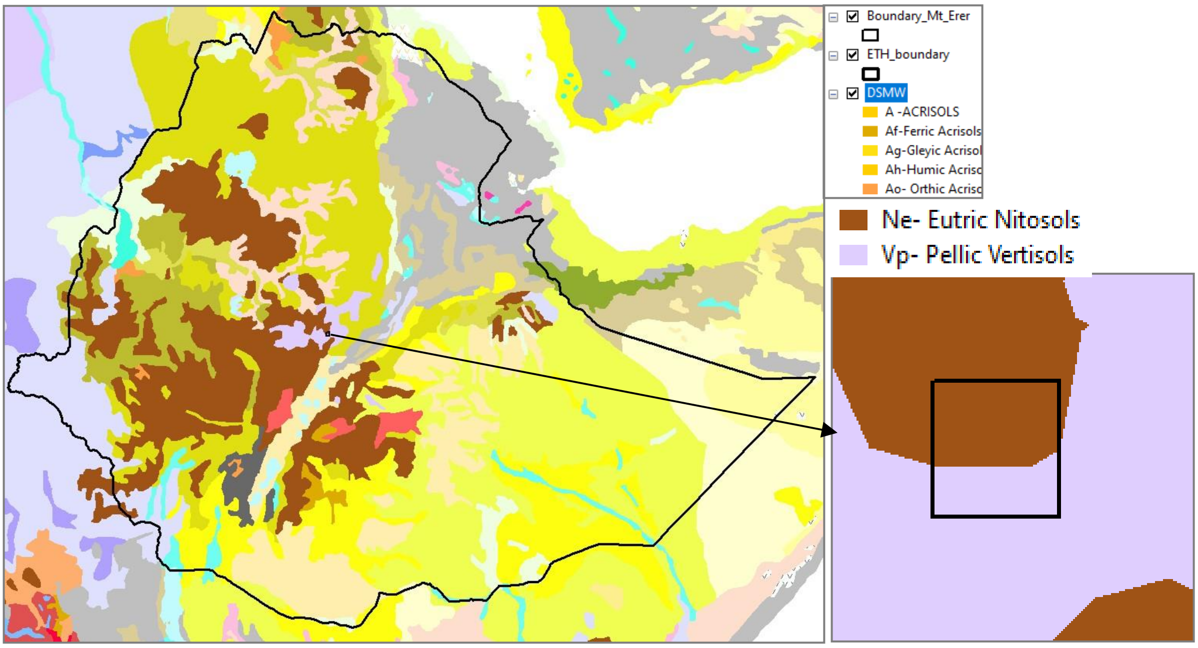


Figure 4-10: Soil map of Ethiopia and Erer mountain area

Source: FAO Soils portal - https://www.fao.org/soils-portal/data-hub/en/

4.9. Weighted Overlay

Weighted Overlay is the method of modelling suitability that combines all the identified criteria together after assigning different percentage to each parameter. In this study, there are three different weighted overlays as per the following percentage.

Table 4-2: The three scenarios and their respective weights

Options (Scenarios)	The Parameters	Assigned Percentage	Result
1	Slope	Equal weight	Suitability Layer One
	River	Equal weight	
	Existing trails	Equal weight	
2	Slope	25%	Suitability Layer Two
	River	25%	
	Existing trails	50%	
3	Slope	50%	Suitability Layer Three
	River	25%	
	Existing trails	25%	

4.9.1. Suitability Layer One

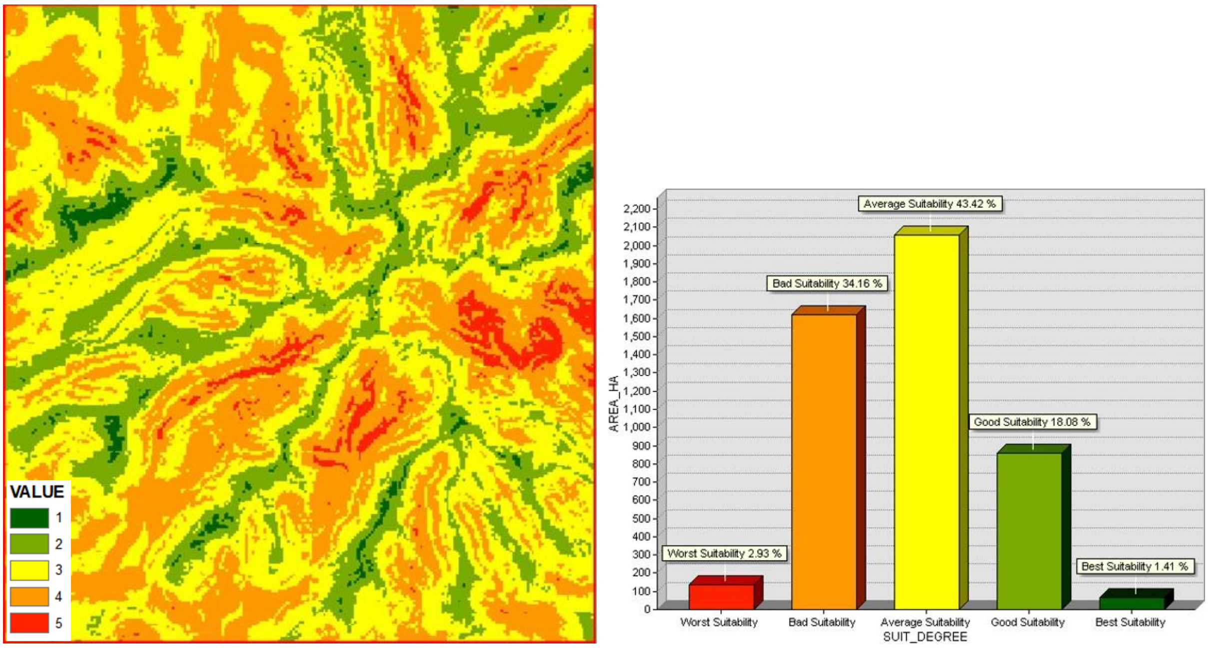


Figure 4-11: Suitability layer one

And it is shown in the figure above, about 2.93% (138.965 ha) of the area is the least suitable area for hiking trails, while about 1.41% (66.864 ha) of the area is the most suitable area for determining hiking trails where the three-input reclassified layers were given equal weight.

4.9.2. Suitability Layer Two

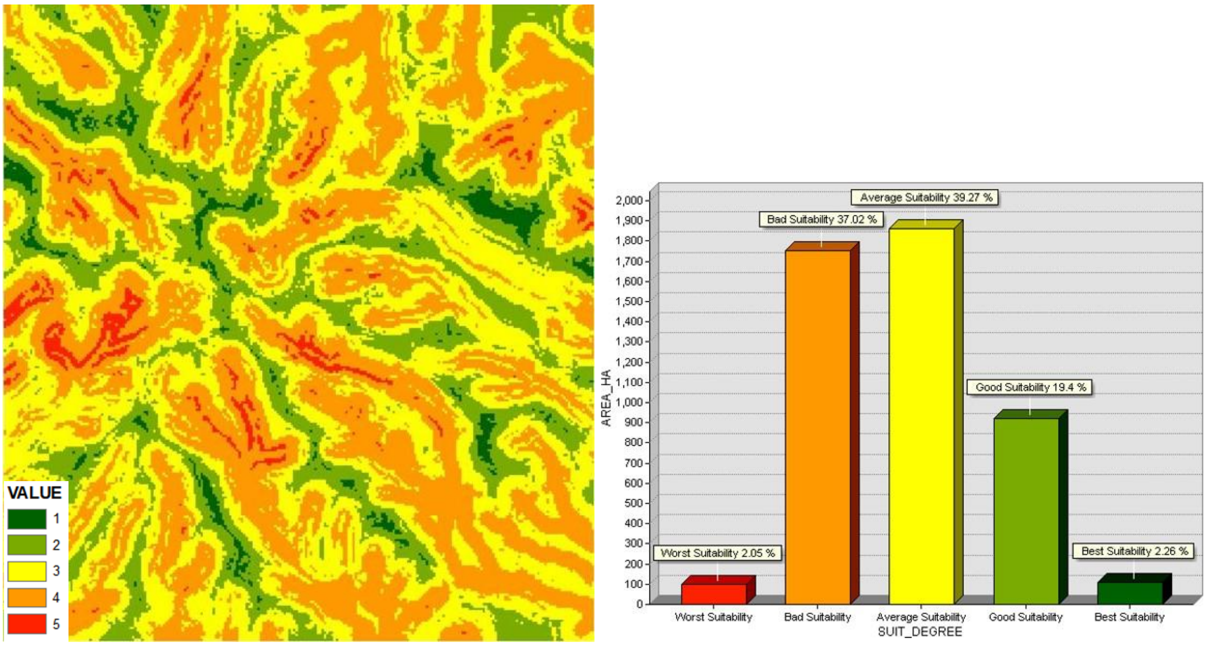


Figure 4-12: Suitability layer two

And it is shown in the figure above, about 3.55% (168.116 ha) of the area is the least suitable area for hiking trails, while about 1.41% (66.864 ha) of the area is the most suitable area for determining hiking trails where the existing trails was given 50% and the remaining layers (slope and river) were given 25% each.

4.9.3. Suitability Layer Three

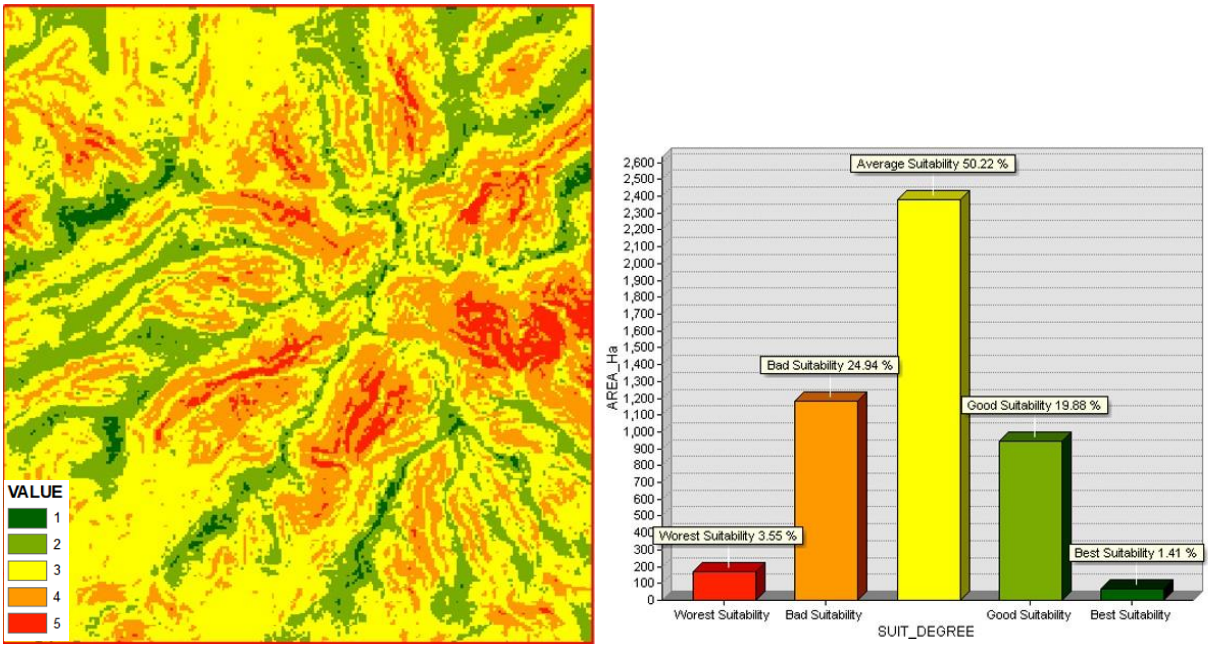


Figure 4-13: Suitability layer three

And it is shown in the figure above, about 3.55% (168.116 ha) of the area is the least suitable area for hiking trails, while about 1.41% (66.864 ha) of the area is the most suitable area for determining hiking trails where the reclassified existing trails was given 25%, the reclassified river network was given 25% and the reclassified slope was given 50% as the study area is predominately mountainous.

4.10. Results of Least-Cost Path Analysis

A least-cost path analysis (LCPA) algorithm was used to determine the optimal location for hiking trails route alignment. LCPA provides users to find a cheapest route that connects two locations with using a cost surface that is determined by considering multiple criteria (Hassan and Effat, 2013). The cost surface can be produced via GIS and the cost criteria can be evaluated and weighted with AHP. Some of the studies on LCPA involve a selecting the fastest path with the least slope (Sarıi, 2017). AHP provides cost surface to the LCPA such as environment, economic and social, thus, the routes can be determined with LCPA according to the desired parameter-oriented approach (bernard amponfi gyabeng, 2020).

The point of origin (starting point) was identified and selected manually by using exploring Google Earth and existing hiking trails, while the point of destination (vantage point) is selected based on the highest elevation so that it has the maximum possible surrounding view.

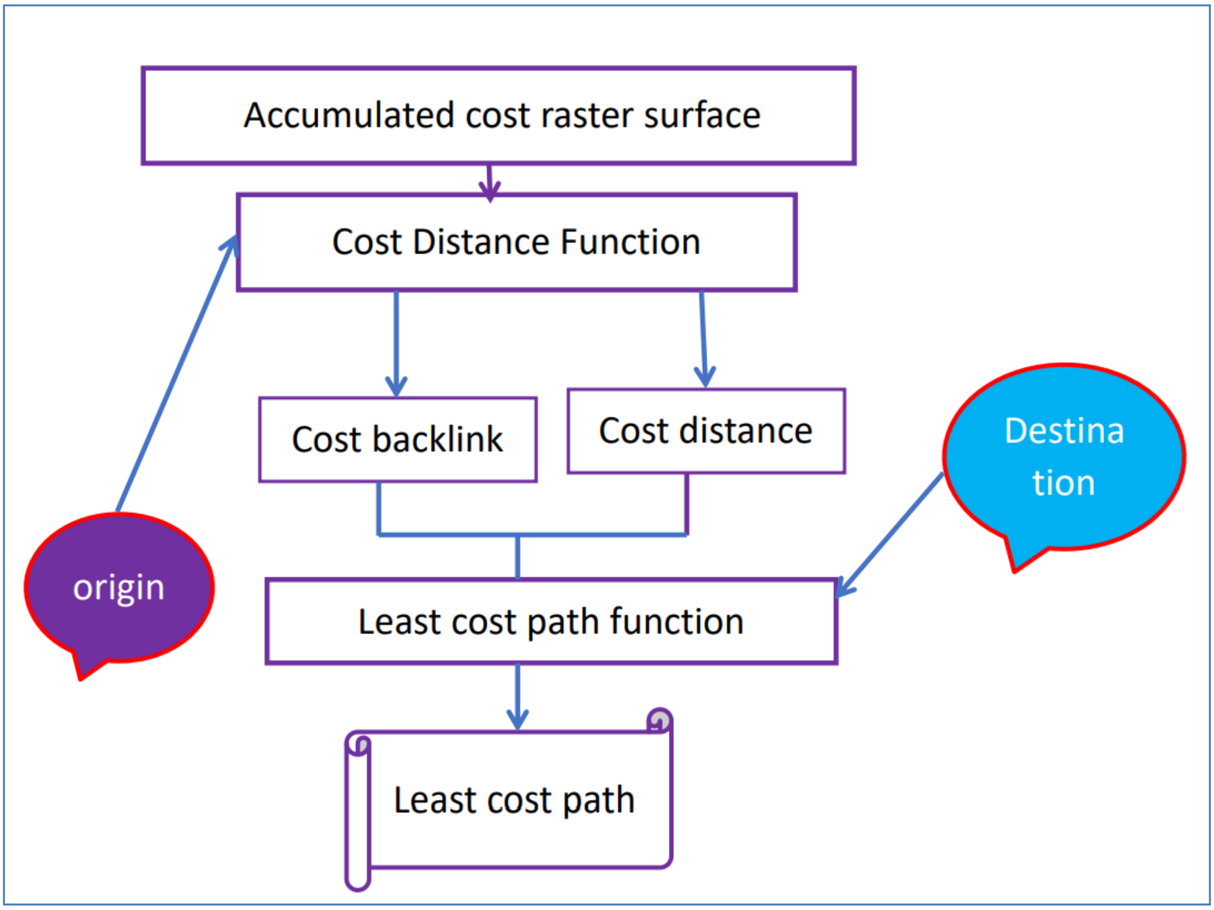


Figure 4-14: Methodological flowchart of the least-cost path analysis using GIS

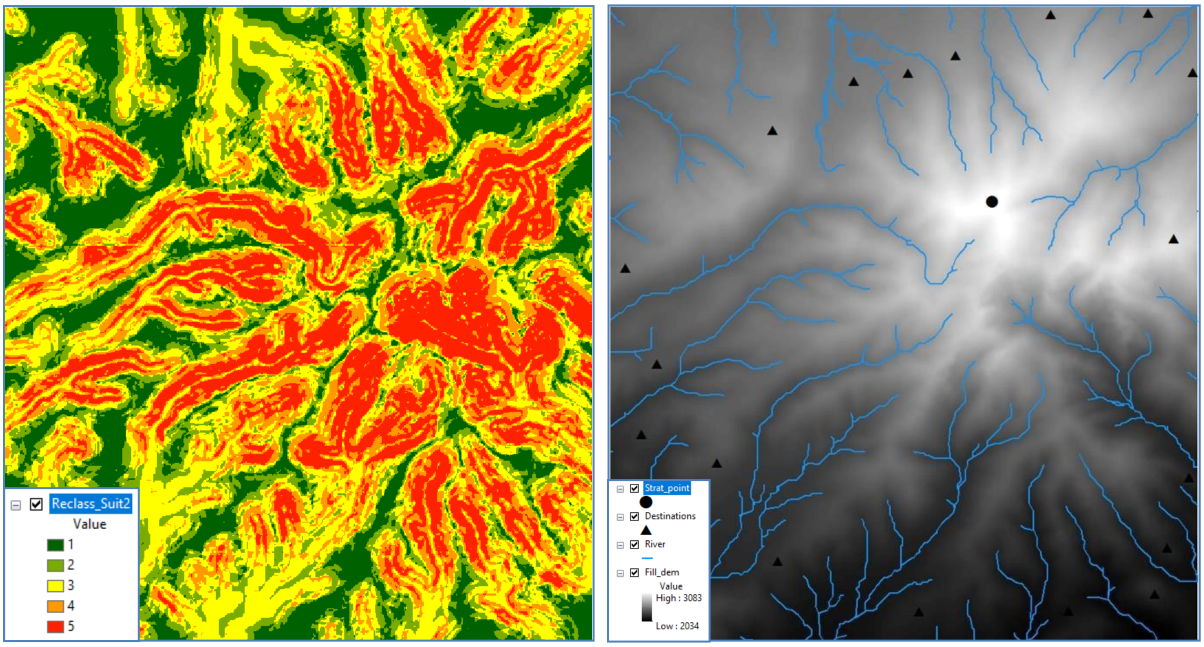


Figure 4-15: Raster calculation with reclassification and point-of-interests

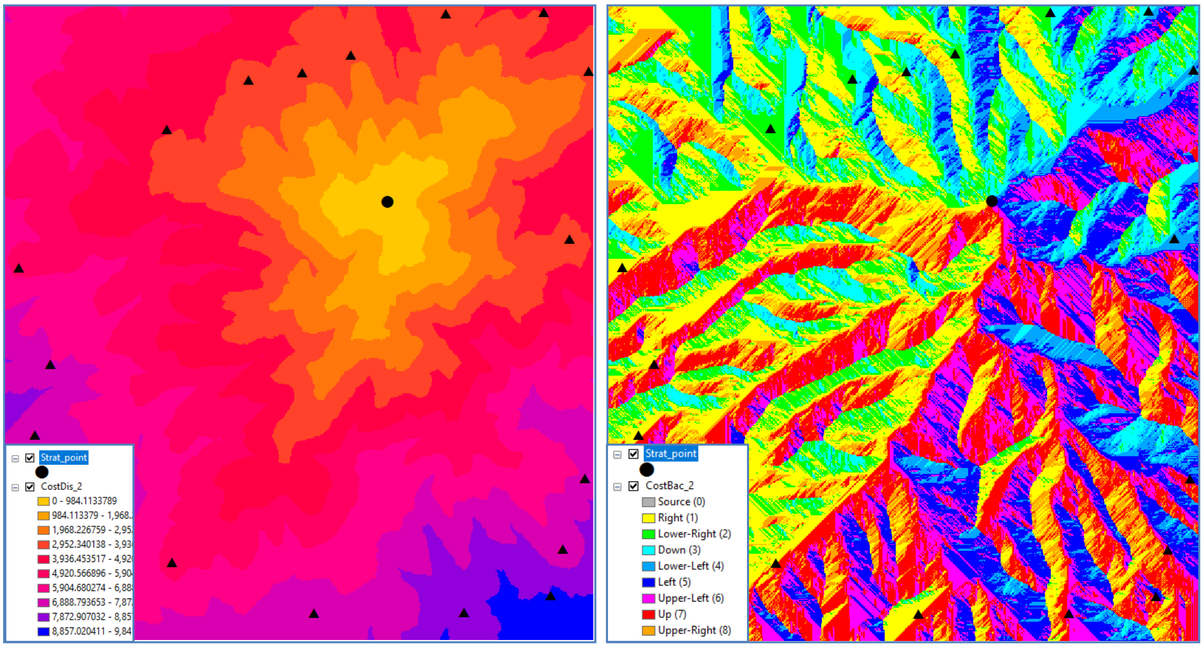


Figure 4-16: Cost distance raster and cost back link raster from the origin

4.10.1. Cost Distance Raster

Using the cost raster and the source, the cost weighted distance function produces an output raster in which each cell is assign a value that identifies least accumulative cost distance over a cost surface to the identified source locations. Every cell in the cost weighted raster was assigned a value representing the sum of minimum travel cost that would be incurred by traveling back to the nearest source.

4.10.2. Backlink Raster

In an attempt to create the cost weighted distance raster, another program is prompt which the backlink raster is this also makes use of cost raster and source raster. The back-link raster contains values of 0 through 8, telling you the direction to travel from every cell in the cost distance raster along accumulative cost path back to the source point. The algorithm is; each cell is assigned a value representing the direction of the nearest, cheapest cell.

4.10.3. The Results of LCPA

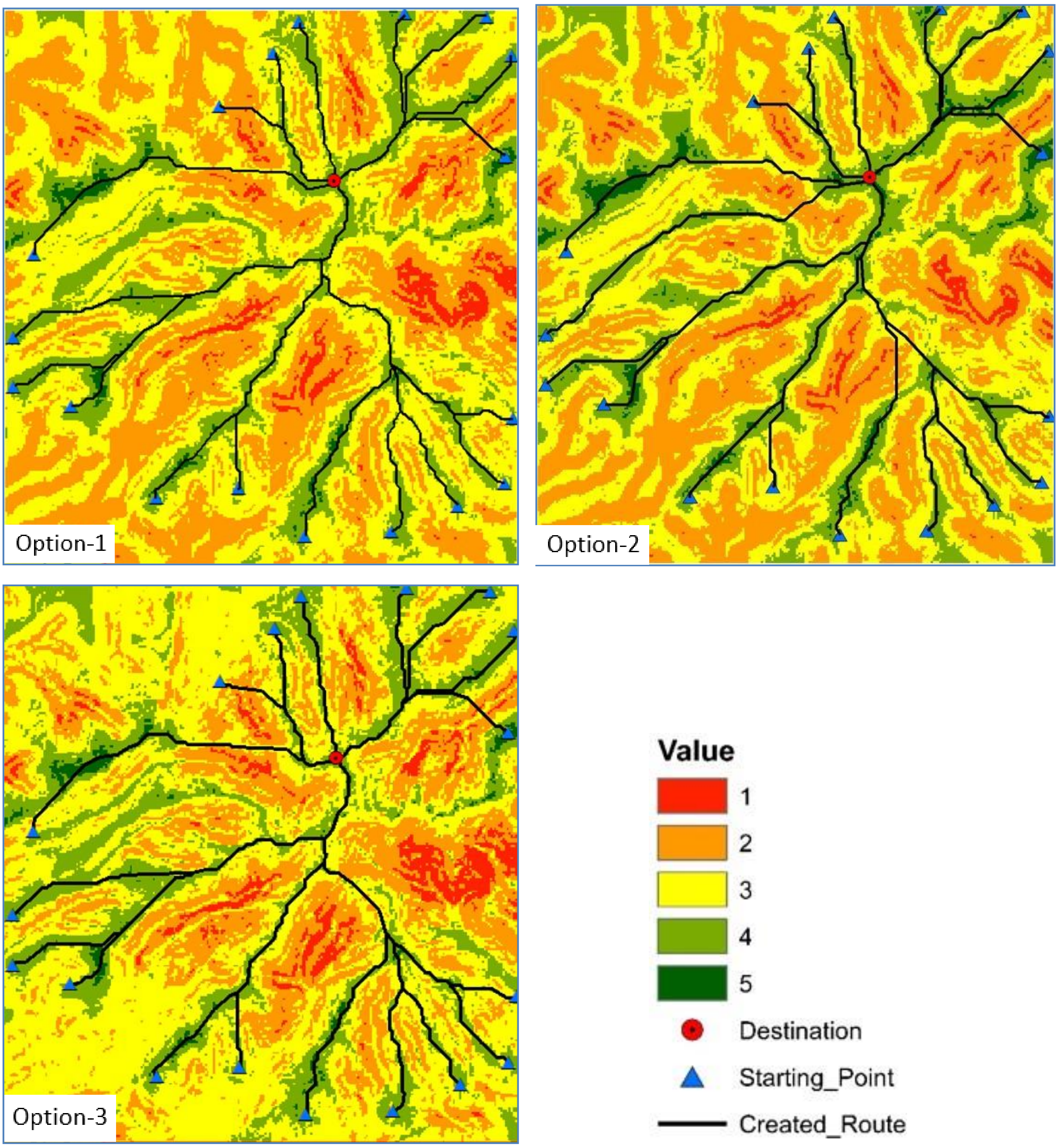


Figure 4-17: The three-scenario trail alignment

The inputs of this step are Destination raster, Cost distance raster and Backlink raster, after generating all these inputs, cost path tool of the spatial analyst extension is used to generate the three (options) shortest paths which will have the least cost. The methodology flowchart is shown in figure above. Raster Calculator Spatial Analysis Tool was used to find the optimum location for hiking trails alignment planning by overlaying several input layers as criteria.

4.10.4. Optimum Hiking Paths

Apparently, all the three scenarios are suitable for Erer mountain hiking trails. Of course, scenario-1 is influenced by all input layers equally, scenario-2 is influenced by the existing trails and scenario-3 is influenced by the slope. Scenario-3 is chosen as it produces the optimal hiking trails compared to the remaining two scenarios.

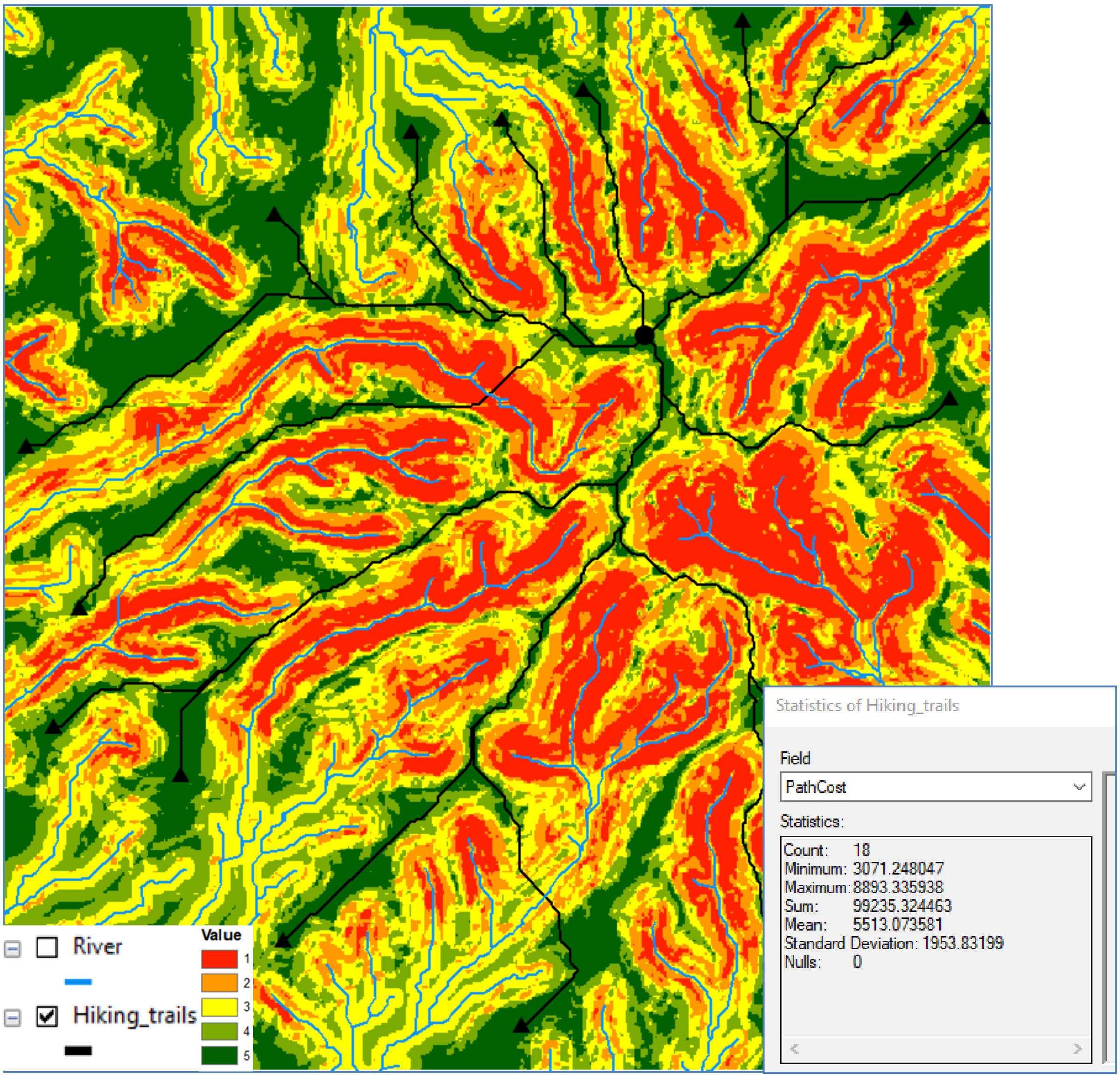


Figure 4-18: Scenario-3 trail alignment

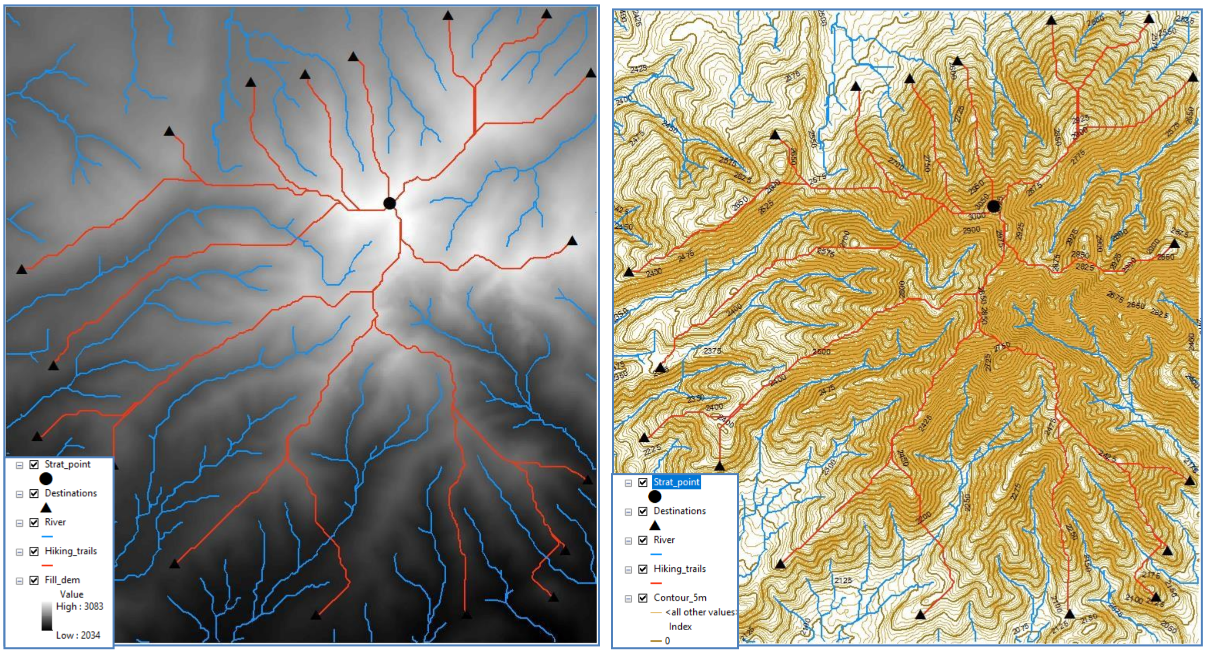


Figure 4-19: Scenario-3 trail alignment overlaid with other layers

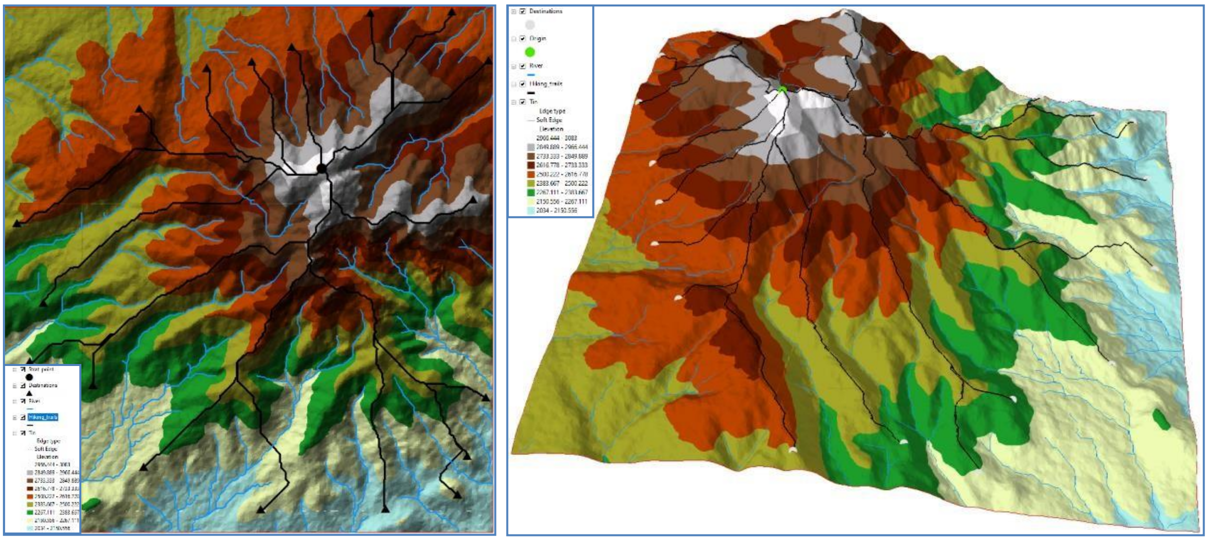


Figure 4-20: Scenario-3 trail alignment overlaid on TIN

The alignments obtained appear to be irregular polyline starting from the start points passing through different features considering cost along its shortest possible path.

Out of the three optimal hiking trails route alignments, the shortest and most economic route was found to be 99.24KM.

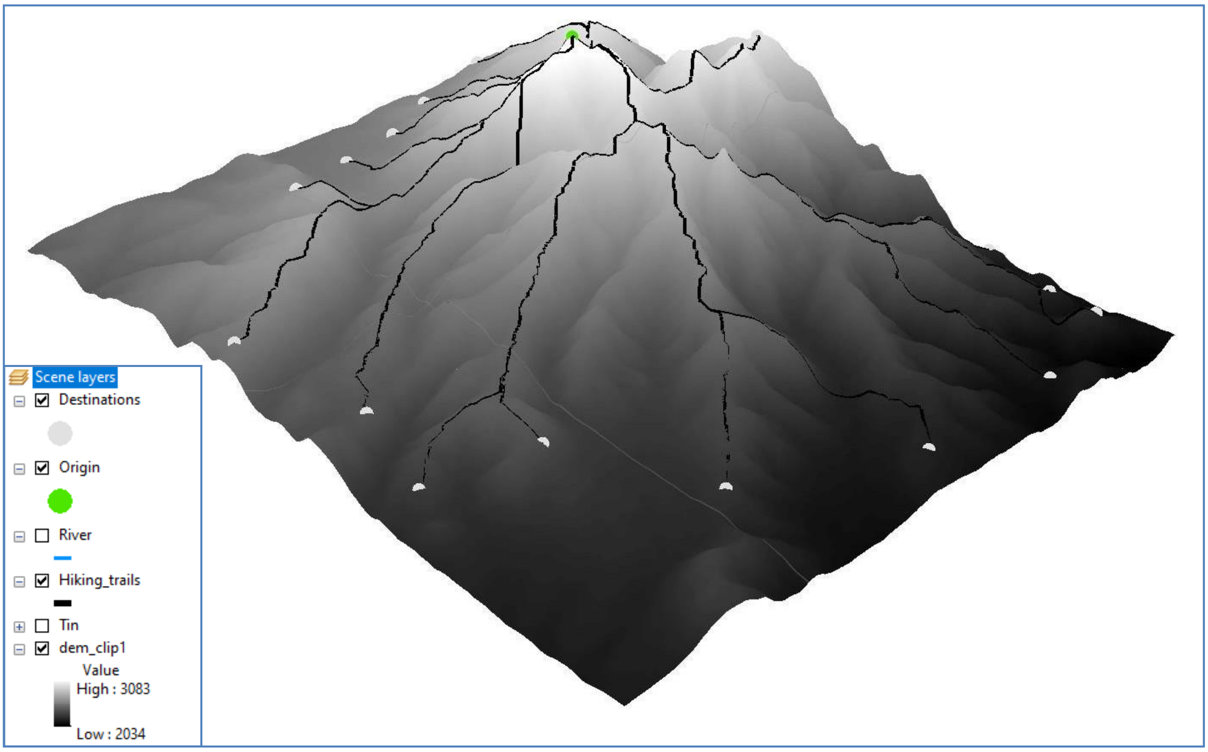


Figure 4-21: Scenario-3 trail alignment overlaid on DEM

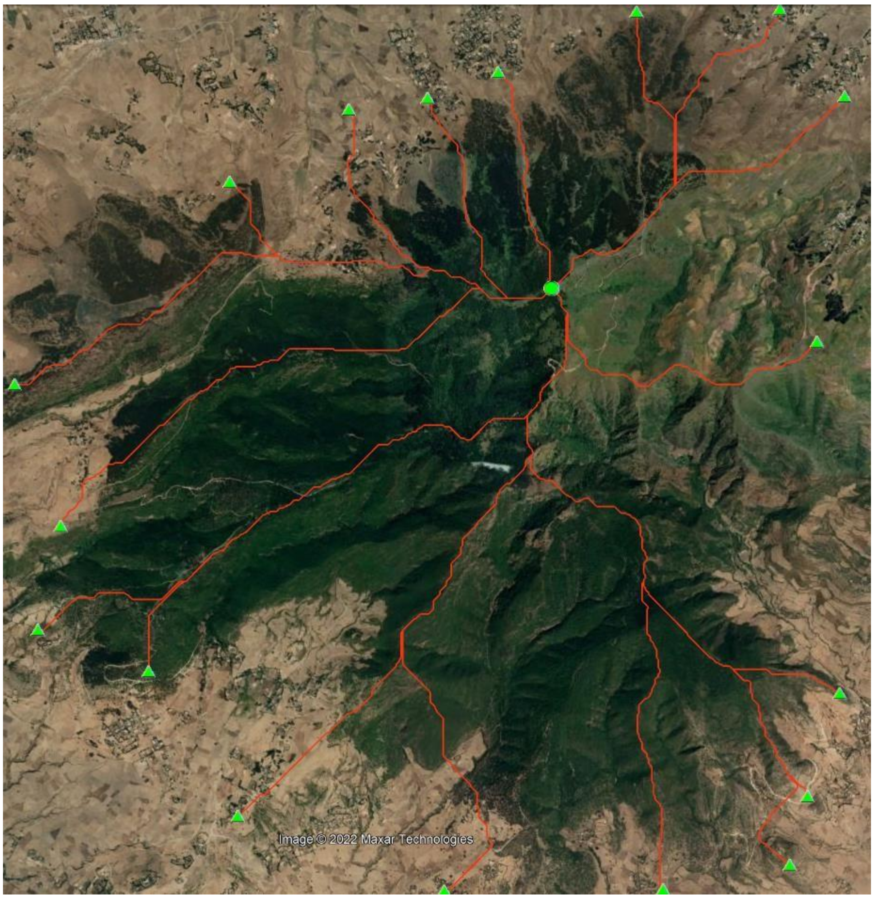


Figure 4-22: Scenario-3 trail alignment overlaid on Google Earth

4.11. Impacts of The Hiking Trails

The Environmental Impact assessment should focus on identifying key features of the environment that should either be featured on or protected from the trail. It is also important to note the type of environment on and around the proposed trail route in order to determine whether placement of the trail in that location is appropriate and sustainable. This study focuses on the following three central questions:

- How are the trails cast-off by residents and how can impact the existing landscape and forest?
- What is the ecotourism contribution of the spending associated with trail-based recreation?
- What is the health, social, and environmental benefits derived from trail landscapes and their use?

Erer Mountain Hiking Trails can also generate positive impacts as it can serve as a supportive force for peace, foster pride in cultural traditions and help avoid urban relocation by creating local jobs. As often happens when different cultures meet, socio-cultural impacts are shared. The social and cultural impacts of Erer Mountain Hiking Trails can result in changes to patterns of behaviour, lifestyle and the quality of life of the inhabitants or local people. Like all business ventures, tourism can have an impact on communities and may be positive or negative, and sometimes both (Van Der Merwe, 2008).

4.11.1. The Positive Impacts

Increase in local economy: Different construction materials and equipment will be required during the construction phase. Local suppliers of Bishoftu markets will get an opportunity to supply construction materials like cement, steel, bar, gravel, sand etc. which definitely benefits the local market. It will help to increase the economy of the local people. Currently, there are more than 5 numbers of shops, groceries and food stalls in kuriftu very nearer. There is probability of increase in number of such shops. Besides, canteens and cafeteria will also come into existence near to construction sites to serve the construction workforce. Once earned money when utilized in sustainable manners will impact long term. The envisaged direct impact will be long-term, site specific medium and hence will be significant.

Employment opportunity: During the construction phase of the Erer mountain Hiking Trails, large number of manpower whether skilled, semiskilled or unskilled will get employment. The local people preferring such work need not to go out seeking the job opportunities. Different manpower from different professionals is required for the construction of the project, thus the employment opportunity will be high. The owned skill will help the persons to get jobs of similar nature in other places it will hence get long term benefit. It will increase of local economy when will be used in sustainable and in proper works will improve the economy in long-term. The envisaged direct impact will be long-term, site specific medium and hence will be significant. Similarly, street vendor business will be proliferating ranging from clothes seller to tea install, and other necessary items occasionally. Flow of the tourists will add the business of the vendors which increase the probability of increasing the vendor business.

Health Benefits: Recreational trail use is a form of exercise. The physical activity associated with trail-based recreation can reduce the probability of adverse health outcomes, in turn reducing average health care costs. The monetary value of these health benefits is calculated using the estimates of trips taken to trails by residents of each county, local health statistics, and models of health risk reductions. Exposure to nature through trail use is also associated with mental health benefits. Although not monetized, mental health improvements, as well as the beneficial effects on physical health and productivity they support, are important benefits of trails recreation in Bishoftu/Ethiopia.

4.11.2. The Negative Impacts

Ecological impacts: Deforestation and clearance of trees to prepare a hiking trail and intensified or unsustainable use of land. Damaged Forest and greenery areas as a result of hiking trail; We need to plant more trees and prevent them from contributing to environmental damage control. For this reason, the best reforestation practices recommend is immediate planting once a forest is cut or destroyed. New forests help prevent soil erosion or desertification and they are important to protect fields from winds.

Environmental Pollution: Plastic water bottles and various food packages that tourists carry with them and when they come for entertainment to this Erer mountain hiking area, it will have a negative impact on that pollution of environment. Littering and ineffective garbage and sewage disposal are major environmental concerns. Therefore, planning for and manage waste disposal. Design trail facilities so that they encourage the proper disposal of all waste. Trash receptacles and recycling containers should not be provided at trailheads or along a trail unless the group managing the trail has the resources to monitor and empty the containers as required. Once these receptacles are full, the extra waste will blow or be distributed by animals throughout the trail environment.

In addition, there is no existing rest rooms/ toilets on the Erer mountain hiking site. As it has been known, tourists and local visitors that will come to the Erer mountain for hiking. But there is no existing restroom/toilet, to defecate. This will practice will increase air and water pollution. Thus, providing adequate and appropriate toilets (compost toilets) at trail access points, that are regularly and effectively supplied and maintained, is the best way to minimize the negative impacts of this proposed hiking trails and enhance the human well-being.

Socio-cultural impact: On the social and cultural side, tourists may disrupt traditions, influence the indigenous communities by lifestyles, and attract service providers from outside the Erer mountains to become permanent residents in mountain resorts. These negative impacts have to be counterbalanced against positive influences, including economic benefits. In order to mitigate this negative impact, it is important to using the local tour guides for introduce the culture and traditions of the local communities to the tourists.

Overall, ecotourism industry generates substantial economic benefits to the host countries. Especially in developing countries, one of the primary motivations for a region to promote itself as a tourism destination is the expected economic improvement. As with other impacts, this massive economic development brings along both positive and negative consequences. There are many hidden costs to tourism, which can have unfavorable economic effects on the host community. Often rich countries are better able to profit from tourism than poor ones. Whereas the least developed regions have the most urgent need for income, employment and general rise of the standard of living by means of tourism, they are least able to realize these benefits. Among the reasons for this are large-scale transfer of tourism revenues out of the host country and exclusion of local businesses and products. Still, dependency situations, i.e., when a local area or community depends on one activity, e.g., tourism, this can lead to rather disadvantageous consequences. Many countries, especially developing countries with little ability to explore other resources, have embraced tourism as a way to boost the economy (Natasha A. Lynn, 2000). Quality of life improvements also attract business activity to the city that then results in additional economic activity. Improves environment, encourages awareness and appreciation by the community of natural assets and the environment and other resources on which tourism relies, and promotes cultural understanding.

Indeed, Mountain hiking worldwide represents the dilemma of conservation and development that is currently being debated in the context of sustainable development. Ecotourism and other sustainable tourism strategies have gone a long way towards minimizing the negative environmental and socio-cultural impact and ensuring that the economic benefits of mountain tourism can contribute to environmental protection and the sustainable use of natural resources.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Geospatial Technologies

Suitability modelling and its inherent GIS technology applications represent a powerful tool for ecological planning in general, and mountain hiking trails route alignment planning in particular. It provides users with a broad range of tools which significantly enhances the effectiveness of analysing and presenting spatial data. The method demonstrated allows information from different sources to be connected and used in the analyses. Although this capability represents the main power of the method for deliberate planning, there are other benefits as well as limits to the model. While the suitability model is prepared for Erer Mountain Ecotourism Park development its potential use in other similar application areas is discussed here as well.

In general, in this study, GIS as a tool for hiking trails route location and alignment was applied in order to obtain different route alternatives that would pass through the most suitable areas. The GIS model applied in obtaining cost path were quite successful in avoiding sensitive areas, important water feature, areas with higher slops, therefore the objective of this study is satisfied within the selected criteria.

5.2. The Benefits of Suitability Modelling

The suitability modelling as demonstrated represents an example of the potential of GIS applications. The emphasis has turned from descriptive query searches of existing databases to prescriptive analysis of mapped data. The dominant feature of the spatial analysis is that digital maps are conceptualized as a set of maps with a common registration, allowing one to look down and across the stack of digital maps. The spatial relationships of the data can be summarized or mathematically manipulated. Due to their digital method, these maps create a wealth of quantitative as well as qualitative processing possible. The ability to analyse and then summarize large amounts of geo-information in the way it is needed makes this technology a very sophisticated tool for more informed decision-making in environmental planning.

Another benefit is the involvement of the concept analytical hierarchical analysis in the suitability modeling method. This method enables the inclusion of values of various priorities issues and thus weight the final summary model towards chosen criteria. Weighting modifications affect the combining of the produced suitability layer into an overall suitability map. Through this approach different suitability scenarios can be created and various alternatives of possible optimal locations can be compared.

Moreover, ESRI has already issued Model Builder, which is a user-friendly technology for building spatial models. Flow diagrams created with Model Builder let users save models and rerun them using different input data. Users can also rerun their models using different function parameters, thus enabling them to calibrate their models or examine how they perform using different sets of values. This study also serves as a template for a future inclusion into ArcGIS Model Builder.

5.3. The Limits to Suitability Modeling

A suitability model is a generalized statement, or abstraction, of important considerations in a real-world situation. In spite of its various benefits, suitability modeling has its limitations. Significant limitations concern the accuracy and precision of the input data given the spatial resolutions of satellite imagery. Accuracy is the degree to which information on a map or in a digital database matches true or accepted values. Accuracy is an issue pertaining to the quality of data and the number of errors contained in a dataset or map. Precision refers to the level of measurement and exactness of description in a GIS database. Precise locational data may measure position to a fraction of a unit. It is important to realize, however, that precise data, no matter how carefully measured, may be inaccurate. Both accuracy and precision pose important issues affecting the quality of performed suitability analysis.

The criteria that were used in this suitability modeling process need to be taken into consideration as well. Not every relevant piece of information can be included in the model and not all information is relevant to either the hiking trails planning purpose or the given study area. Although the model of Erer Mountain Ecotourism Park contains the major criteria expressive of local conditions and determine the suitability of hiking trails alignment, it only provides a base-line. There are still many important areas to which the model can be extended, such as vegetation, soil, sensitive wildlife, and other stakeholder values.

If this method is to become part of an effective and informed decision-making policy in environmental planning such as ecotourism park development, the people that are making the decisions need to be aware of its limitations. GIS is a tool as is any other tool; it can be used either appropriately or inappropriately. Although based on a great deal of scientific data and rigorous GIS modeling, the final assignment of suitability values involves a large amount of subjective judgment. Thus, if an area appears best suitable area on the final map, it does not necessarily mean it can be automatically developed. The results of the suitability modeling have to be validated and checked in the real world.

Environmental planning including ecotourism park development is considered to be a very useful tool in many disciplines, including environmental planning, as it enhances the effectivity of land development and lowers the economic, environmental, and social effects that are associated with it. Although the conditions in mountain trails alignment planning and other GIS application areas may be different, the basic criteria, which serve as the inputs for environmental planning, are the same.

5.4. Possible Use in Other Application Areas

The potential of suitability modeling or GIS application in mountain trails alignment planning can be seen at the beginning of the planning process. After appropriate modifications that would express the nature of local conditions, it could serve as a standard baseline for the surveys and analysis in actual future Erer Mountain Ecotourism Park development. It could also be used to define effectively the assignment of an urban plan. Furthermore, Ecological organizations, regional tourism sectors and other stakeholders might find it very helpful for their institutional objective such as ecotourism plan scenarios. It might help to deal with issues in areas that have been neglected in the past, such as recreation, transportation, and the like. Considering the character of available data and the method itself, it might be most suitable at the level of large land development unit. However, it can only be successful if all stakeholders accept advantages of using GIS and if the method is incorporated into the regional planning methodology.

5.5. Recommendations

This study aimed at demonstrating the possible uses of geospatial technologies such as Geographic Information Systems, especially suitability modeling, for the purpose of thoughtful environmental planning. A brief overview of the basic application of GIS technology were created, with an emphasis to the raster analysis and spatial modeling. Some specific natural characteristics of the Erer Mountain were described. A large quantity of information and spatial data about the study area was gathered and analyzed from the environmental planning perspective. However, the major aim of this work was to further develop the standard GIS method, which would, using advanced GIS cell-based analysis, produce a suitability model for the area under study that would assist both planners and decision-makers in identifying the general geographical areas that have optimal location or high development suitability to determine optimal location for hiking trails.

The proper application of GIS technology does not consist of the mere collection of spatial information and the construction of endless databases but must be followed by detailed analysis and thoughtful problem solving. Thus, different analyses considering both natural and socio-economic land characteristics of Erer Mountain were performed in this study and the analysis process culminated in identify optimal locations for trails alignment planning, or places which are valuable from the ecological planning point of view. The analysis procedures were briefly described and some land characteristics that stem from the specific local conditions of the studied geographic area were explained as well. The benefits of the method, mentioning possible weighting modifications and future extensions, as well as its limits with respect to the quality and subjective character of the results presented were discussed. Finally, the potential use of suitability modeling in Erer Mountain Ecotourism Park development in general and hiking trails in particular was outlined.

Although suitability modeling represents an efficient technical tool for deliberate environmental planning, it requires a certain level or type of system set-up in the ecotourism application. If the GIS suitability analysis is to be performed at the most sophisticated level, a large amount of quality spatial data has to be included in the analysis process and thus, the data must be easily accessible. All the spatial information and data sets about the area under the study in this study were collected from online open sources and GIS internet data ports. There is still a lack of specific data and their collection in the field is difficult, time consuming and costly. It is clear that the system of the data availability and exchange has to be updated, to take advantage of the potential that GIS suitability modeling offers for sophisticated environmental planning including ecotourism park development.

In general, this study provided a preliminary analysis for a proposed Erer mountain hiking trail alignment planning. The purpose of the study was to determine and compare trail alignment using ecological criteria such as watershed, slope, point-of-interest, LULC, existing trails, soil type to determine the most suitable trail alignment in order to minimize environmental, social and economic impacts. The results show the least-cost path from origin (starting point) to destinations by way of the most cost-effective route in GIS environment. It can be concluded that geographic information system short path analysis is proved to be well suited in optimum hiking trails route location in a short period of time which is economical, it also provides ability to the planner to provide several alternatives and compare such alternatives.

The overall intention of the study was to develop a methodology for a preliminary mountain hiking trail alignment analysis from environmental planning perspectives. It is critical to take into consideration various data attributes when determining least-cost path trail alignment. The result has the potential to be used by trail designers, natural resource managers, park managers or anyone involved in ecotourism park development as a preliminary and cost-effective analysis to determine suitable and sustainable trail alignments. Thus, this analysis has the potential to be used for various trail planning applications in similar context in other parts of the country.

Ecotourism has gained increasing popularity as a sustainable alternative to other developments, particularly in developing countries like Ethiopia. GIS has been widely used as a cost-effective spatial decision support tool to select the best locations for hiking trails alignment and planning. Certainly, GIS has the potential to provide wealth of spatial information with simple but reliable method to combine several layers to select the most suitable sites for any development in general.

In this study, several factors and constraints were selected as criteria to analyse the suitable location for hiking trails alignment planning, including slope, watershed, contour line, point-of-interest, point of destinations, existing trails, and LULC. Apparently, the study suggests that the appropriateness of the developed method to identify and select the optimum location for mountain hiking trails alignment or planning should be validated against any reliable reference or by filed visit using such as GPS technologies. Although the suitability map was developed for Erer Mountain, the developed method has a potential to be applied to other ecotouristic activities at minor modification. Similarly, the method illustrated in this study may be applicable to other developments with the similar background and local context. While mountain hiking trails have relatively little impact on the environment compared to others, the study recommend all appropriate mitigations that were discussed in chapter two under EIA section to be practiced and respected. Of course, there are a number of ways in which future study could strengthen the validity of the findings pertaining to Erer Mountain hiking trails alignment planning.

Overall, better amalgamation of GIS-based ecological and environmental planning is required to move on the path of sustainable development. A framework that makes ecological and environmental planning mandatory for any developmental projects including ecotourism park will be a huge step towards sustainable development.

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