ECOLOGICALLY COMPATIBLE LAND USE PLANNING OF ECO-SENSITIVE ZONES USING REMOTE SENSING AND GIS TECHNOLOGIES

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

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in

DISASTER MITIGATION AND MANAGEMENT

By

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CANDIDATE'S DECLARATION

I hereby declare that the work carried out in this dissertation report entitled, "**Ecologically Compatible Land Use Planning Of Eco-Sensitive Zones Using Remote Sensing And GIS Technologies**", is presented on behalf of partial fulfilment of the requirements for the award of degree of "**Master of Technology**" in **Disaster Mitigation and Management** submitted to the Centre of Excellence In Disaster Mitigation And Management(CoEDMM), Indian Institute of Technology, Roorkee, under the supervision of **Dr. Kamal Jain,** Professor, Civil Engineering Department, IIT Roorkee.

I have not submitted the record embodied in this report for the award of any other degree or diploma.

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ABSTRACT

In the present day spatial planning plays a major role in the development of the country. India being a country with a population of around 1.2 billion people, providing them with the necessary required infrastructure and services is a challenging task. Due to increase in frequency of natural disasters the proper land use planning is unavoidable. Since the population is increasing in a rapid rate the need of resources is also increasing at an alarming rate. This has resulted in the over usage of the natural resources resulting in environmental imbalance which can cause natural disaster. There are other environment issues like air and water pollution cause due to urbanization and industrialization.

Preparedness for disaster is critical as it hits when least expected. The frequency of disaster has been increasing these days. Disaster Mitigation can be done by proper land use planning in these regions by taking disaster related parameters into consideration. The Ministry of Environment and Forestry has declared 29 Eco-Sensitive Zones and most of these areas are not easily accessible; thus, making the land use planning of these areas a challenging task. Due to the developments in Remote Sensing technologies we are able to acquire satellite images of these locations and through image processing; most of the analysis can be done. With the help of these technologies land use planning of these areas can be done with a great accuracy by including the disaster related aspects and thus making land suitability maps for these locations.

Meeting the ecological compatibility while making a land use plan becomes challenging because of the conflicting goals and the uses of land. Main challenges faced are during the issues of resource extraction activities, infrastructure for settlement, recreational activities, sustaining the compositional and structural complexity of ecological systems, etc.

Remote Sensing and Geographic Information Systems (GIS), has been playing a major role in the land use planning. With these technologies the assessment of settlement patterns can be done in a faster pace, even of the areas that are not easily accessible. The review of studies have done which has shown the efficiency of remote sensing and GIS technologies, and its efficiency in assessing the land use/ land cover characteristics. This would help in site selection for future development of these regions in more secure manner.

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CHAPTER 1
INTRODUCTION

In the present day spatial planning plays a major role in the development of the country. India, a country with a population of approximately 1.2 billion, providing them with the necessary required infrastructure and services is a challenging task. Due to increase in frequency of natural disasters the proper land use planning is unavoidable. As the population is increasing at a rapid rate the need of resources is also increasing at an alarming rate. This has resulted in the over usage of the natural resources causing an environmental imbalance. There are other environment issues like air and water pollution cause due to urbanization and industrialization.

Ministry of Environment and Forestry (MoEF) has defined 29 sites as Eco-sensitive zones to prevent the ecological damages caused due to development activities. The updated ESZ guidelines published February 9, 2011 assures that these areas act as "shock absorbers" to the protected areas by regulating and managing the development activities. These locations are requires special consideration like the case of Ramsar Sites in India, which are the 26 wetlands. Authorities have asked for the use of the areas surrounding the wetlands in a sustainable manner, thus preventing occurrence of non-eco-friendly activities (Krishnadas, 2013). Meeting the ecological compatibility while making a land use plan becomes challenging because of the conflicting goals and the uses of land. Main challenges faced are during the issues of resource extraction activities, infrastructure for settlement, recreational activities, sustaining the compositional and structural complexity of ecological systems, etc.

Remote Sensing and Geographic Information Systems (GIS), has been playing a major role in the land use planning. With these technologies the assessment of settlement patterns can be done in a faster pace, even of the areas that are not easily accessible. Remote sensing has multiple advantages like the availability of data at regular intervals. This can be observed even in Google Earth as there images of same location at different intervals which helps in analysis like change detection. Remote sensing provides the base data which is the build-up area information and its locations. With high resolution images it is possible to obtain the land use and land cover information which can be further digitized using GIS and analysed. In most cases remote sensing data is used as the base for monitoring and implementation as it is accurate and due to its updates (Sapio, 2008).

GIS has been playing a major role in spatial planning in the last decade, and is being widely used by most of the planning authorities. The physical requirement of data storage is reduced to minimum with the introduction of GIS. Large measure of information can be kept and extricated voluntarily with incredible pace. Various modernized programming modules/instruments consider assessment/sort control; including guide estimation, guide overlay, geographic configuration and information control. In addition to all these GIS can combine and control graphic as well as non-realistic data at the same time (Rojas, 2012).

Even though there are many advantages for both remote sensing and GIS there are many limitations that are faced in Indian scenario. This includes the requirement of trained labours. The number of people who is skilled to use GIS are very few in number. India being a developing country at present is not in a state of invest large amount on hardware of software for Remote Sensing and GIS. Changing information organizations and programming creates issues in blending old information with new. One of the other issues faced is the requirement of capacity environment.

1.1 Need of Study

Due to the overexploitation of the natural resources, the natural equilibrium has been disturbed which has resulted in the loss of life, property and wealth. In order to control this dynamic situation there is a sudden need of innovation in the field of spatial planning to mitigate as well manages the catastrophes cause by the change. Advancement in the field of science and technology has provided with numerous technical resources which put to use can lead to finding the apt solution to these issues. In the field of spatial planning the creation of GIS technology with the support of remote sensing can provide accurate results in research at a shorter duration resulting is solving the above mentioned issues.

1.2 Gaps in present works

Sustainable development has been a major sectors countries are concentrating since the United Nations Conference on Environment and Development (also known as Rio Summit) which was held in Rio de Janeiro from 3 to 14 June 1992 (United Nations Environment Programme, n.d.). But achieving this goals has been a difficult task for the developing countries. Mostly, the sustainable parameters are considered in the case of urban areas. And these goals are set at a city level than at a regional level. This is due to administrative issues and lack of availability of data at uniform interval for the same duration. Inaccessibility of many location in India due to varying geographical features, has limited the study to location which are easily accessible. This results in the lagging of sustainable development activities at remote locations.

1.3 Problem Statement and Objectives

1.3.1 Problem Statement

Ecologically compatible land use planning of eco-sensitive zones using GIS and remote sensing technology.

1.3.2 Objectives

- Assessing the existing ecological parameters and settlements in the site.
- Land suitability analysis to find the location suitable for development and agriculture
- Proposing ecologically compatible land use plan for the site.

1.4 Organization of the Dissertation

- Chapter 1 covers the introduction, need of the study, limitations, aim and objectives of this study. This chapter gives a basic idea on the topic and its relevance in the present day.
- Chapter 2 covers the literature review where study of existing rules, regulations and the issues faced in the field of urbanization and environment management at Indian scenario. Chapter 3 covers two case studies that have been done on related fields and the methodology used.
- Chapter 4 shows a basic description of the study area and its surroundings.
- Chapter 5 provides the methodology used for this study. This chapter shows the workflow followed in this study.
- Chapter 6 has the results of various analysis performed and inference made out of it.
- Finally the chapter 7 covers the final conclusions of this study and its future scope.

CHAPTER 2
LITERATURE REVIEW

This chapter covers various literatures based on the research topic. The main focus is given to the existing scenario in Indian context, along with various policies implemented over the time. A glimpse through statistical data of urban India is also covered. Since the location faces lots of environment threats special importance has been given to environment management.

2.1. Urban Planning and Environment Management

At present the stage has come where environment management is covered while preparing an urban plan. Environment Impact Assessments are usually performed before making decisions in the field of urban planning.

2.1.1. Urbanization in India

A transformation index old rural economy to modern one is termed as urbanization. In urban unit it is a progressive concentration of population (Davis, 1965). Presently the urbanization level of India is considered low. Since the year 1901 to the year 2001, an increase in the number of urban agglomeration/town has been seen from 1827 to 5161. During the last five decades, the population of India has grown 2.5 times, with urban growth of about 5 times. In 2001, there was 3700 town and was occupied by around 300 million people, compared to around 62 million in 1951. This is an increase of about 390% in the last five decades a gradual increasing trend of urbanization is reflected here. The process of urbanisation is at an accelerating stage in India and the expected increase is 533 million (in 2021) from 400 million (in 2011) (Datta, 2006).

Reconstitution of municipal bodies within a stipulated time-frame has been made mandatory by the 74th Constitutional Amendment Act (CAA74), thus ensuring continuity of local representatives. Eighteen functions and responsibilities to local bodies have been listed by the twelfth schedule (Article 243W) of the CAA74.

2.1.2 Stages of Urban Planning

At the time of crises, many critical environmental problems manifests to which urban areas become highly prone. Quantification or "resource potentiality" becomes a prime requirement in order to avoid such situations. At the same time, the availability and consumption of such resources in the urban areas requires a comprehensive Urban Information System (UIS). The development of UIS is vital to cater to the developmental needs of the urban areas which are continuously expanding.

These are the steps followed while making an urban plan:

- Using visual interpretation techniques to prepare thematic maps from satellite data.
- GIS environment allows for the generation of spatial framework which can readily be used for perspective and development plans.
- Urban sprawl analysis as well as urban land use change analysis can be done by integrating thematic maps using various GIS techniques.
- According to the population projection of a particular city and its different growth centers, areas required for urbanization is determined.
- On the basis of the carrying capacity of a particular region, calculation of land requirements for urban development can be done.
- Urban land use suitability analysis projected.
- Performing urban environmental sensitivity analysis very effectively merely on the basis of physical and air quality parameters.
- Setting up various amenities such as educational, recreational, medical etc.based on composite functionality index.

Urban planning stages and base map requirements

Table 2-1: Urban planning stages and base map requirements (Directorate of Town and Country Planning, 2015)

S.No	Planning Stage	Base Map Scale
1	Master Plan/ Land use Plan	1:10,000 & larger
2	Zoning Plan	1:4,000
3	Inner City/Urban Cadestre	1:1,000 to 1:2,000
4	Urban Slum/ Unauthorized Development/Encroachments	1:1,000 to 1:5,000

2.1.3 Environment Management in settlement areas

Environment as well as development is interlinked. Settlement areas can be considered as a system that consists of different sub systems namely infrastructure, ecology, and environment, social, economic, etc., a change in all other sub systems are observed if any of the sub system changed. The socio-economic activities such as agriculture, drugs and pharmaceuticals, civil construction including roads and buildings, industrialization, transportation etc. are developed at a fast pace, which accelerated the process of environmental degradation. Food-grains and other consumer item's requirements increased stupendously with the growing population, leading to further environmental degradation.

The allocation of natural as well as man-made resource to optimum use in a sustainable manner is termed as environment management. The elements of sensible choices are selected from multiple proposals by taking the required aspects in order to make resources utilization in an optimum level in this management process.

2.1.4 Characteristics and features of Environment Management

- Environment management will lead to sustainable development.
- Multi-disciplinary approach is for preparing Environment Management Plans.
- Multiple development view-points have to be integrated.
- The short term is extended by the time scale involved and ranges from local to global are considered.
- Natural and social science, policy making and planning are integrated.

2.1.5 Significance of Environment Management

Environmental management is an approach in which ecology, planning, social development and policy making are involved in an integrated manner. Its main objectives are as follows:

- Prevention of environmental problems and their solutions.
- Establishment of limits.
- Development of research institutions and monitoring systems.
- Warning of threats and identification of opportunities.
- Suggesting measures for conservation of resources.
- Developing strategies for quality improvement.
- Suggesting sustainable development short-term and long-term policies.
- Identify new technologies for future development.

2.1.6 Environmental issues faced by India

Environmental problems of region depend on the economic progress, life-style of the residents and availability of resources. In India, factors responsible for the fast damage the environment are rapid growth of its poverty, urban development, demography, industrial developments, etc.

Environmental problems have emerged as a serious issue and cannot be neglected anymore. Due to rapid urbanization and industrialization there has been increase in air and water pollution which is cause health issue in the people residing in these areas (Mondal, n.d.).

2.1.7 Environmental Planning in India

Since ancient times in a country such as India, all the components of environment have always been considered as life supporting systems and thus their protection and preservation has been a matter of paramount importance. The natural elements such as air, water, trees, vegetation, soil, land, rivers, mountain, animals etc. have been considered as sacred in one form or the other since a long time.

During the earlier time due to abundance of resources and less population, there was no requirement of environmental planning. But now the situation has changed. So there is a required for environmental planning through a rational approach as this situation can result in critical problems in later stages.

Both the government and various NGOs have undertaken several measures for the protection of environment and also for the control of pollution. Some laws were enacted for the protection of environment even before independence. Articles 268, 290, 291, 426, 430, 431 and 432 are related with environment in Indian Penal Code of 1860. Similarly, Article 277 and 278 were related with water pollution and with Air pollution respectively. There was a provision to control pollution in Motor Vehicles Act, 1938. Also, in 1927 Indian Forest Act was passed. Since independence, for the conservation and protection of the environment, serious efforts have been made continuously in the form of legislation. A major step for the protection of environment in India is credited to the acts and laws passed during last 60 years.

Some of the important Acts are as follows:

- Damodar Valley Corporation (Prevention of pollution of water) Regulation act 1984.
- Water Preservation and Control of Pollution Act 1974 and 1977.
- Wild Life Protection Act 1972.
- Environmental Protection Act 1986.
- Radiation Protection Rules 1971.
- Central Motor Vehicles Rules 1989.
- River Board Act 1956.
- Factories Amendment Act 1987.

- Atomic Energy Act 1972.

2.1.8 Total Quality Environmental Management- ISO 14000 Ems Certification
EMS: ISO 14000

In order to provide organizations with the elements of an effective environmental system, the International Environmental Standards are formulated. This environmental system is such that it can be integrated with other management requirements in order to assist various organizations to achieve an environmental management system which is capable of supporting the organizations in the following major areas:

- Environmental Management System
- Environmental Labeling
- Life Cycle Assessment.
- Environmental auditing
- Environmental Performance Evaluation

Effective management of environmental responsibilities, costs, liabilities is undertaken by ISO 14000 which thrives to builds a single global management system. Proper guidelines and document commitment to governmental management system (EMS), costs any company in the following mentioned areas:

- Undertaking proper steps for the reduction of energy consumption as well as material wastage.
- Addressing thousands of environmental regulations in India and also in the countries in which various business transactions take place from time to time.
- Due to environmental aspects being out of compliance, issuing of fines and penalties through various government audits.
- Lack of surety in issues relating to the environmental risk factors leads to loss of confidence in various financial institutions and stockholders.

2.2. Case Study

Research requires assistance from multiple studies done by different researcher to perform the study in a precise manner. Form this research two case studies were referred.

The first case study is that of Pulivendula Taluka in Andhra Pradesh in which land use/ land cover was interpreted and further classified to find the percentage area cover by each land use. This was used as a base study for the research as it dealt with the image classification through visual interpretation techniques and land use analysis.

The second case study was of Tinsukia district in Assam which was of greater advantage in later stages of study as it showed the analysis mechanism of existing land use pattern and coming up with a new proposed land use where the location mostly agricultural land and environment parameters were given the highest importance.

2.2.1. Case Study 1:

Land Use/Land Cover Analysis Using Remote Sensing and GIS, a Case Study on Pulivendula Taluk, Kadapa District, Andhra Pradesh, India (T & G, 2014)

Analyses of Land use / Land cover by using Remote Sensing Data:

The satellite data is interpreted after thorough field check and then map is finalised. After proper interpretation maps are classified based on different land use and land cover classes that includes, Forest land, built-up land, cultivated land, water bodies and uncultivated land.

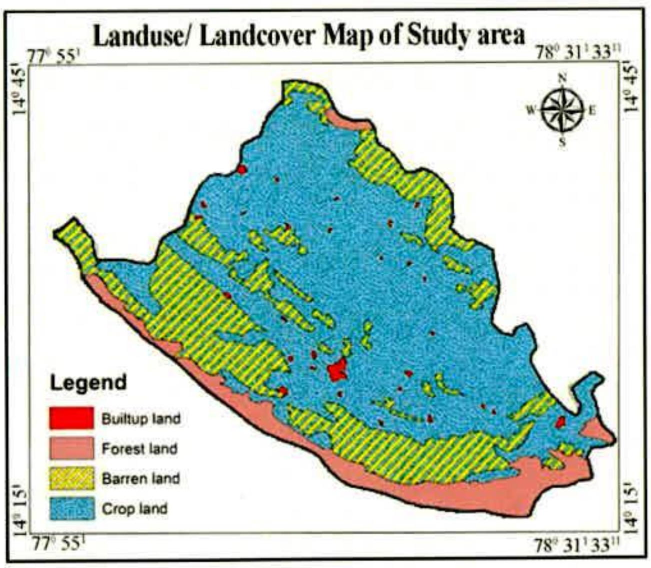


Figure 2-1: Land use/ Landcover map of Pulivendula Taluk

Land use classes of the study area are described below:

Built up land: This health, education and socio-economic facilities come under the category of built up. These are discovered by their dark sapphire tone in the centre and blue colour at the corners. The areas are associated with canals, roads and railway networks. The total extent covered by the settlements is around 13 km² or 0.9 per cent of study area.

Forest Land: It includes of dense canopy of trees. These are recognised by their red to black tone and changing in dimension. These have an irregular shape. In the satellite image the scrubs, bushes and smaller tree forest are identified by yellow one with smooth texture. The total forest area is 162.49 km^2 or 10 per cent of total area.

Barren Land: All the land which is uncultivable. Barren land occupies 419.87 km^2 or 27.88 per cent of study area.

Crop Land: This includes both cultivated and irrigated land. With the help of satellite imagery the agricultural land can be identified by red tone, regular shaped agricultural fields and in association with settlements, water bodies, etc.

Conclusion

The author used Indian Remote Sensing Satellite (IRS), image processing and GIS to identify the land use cover. Satellite images along with topo sheets were used to analyse the land use / land cover changes thus helping in macro and micro level planning of the study area.

2.2.2. Case Study 2

Land Use Diversification Plan for a Cluster of Village Using Geospatial Technology: A Case Study in Tinsukia District of Assam (Das, et al., 2013)

Land is the most valuable natural resource for production of food, fibre, fuel and many other essential goods are required to meet human and animal needs. Agriculture is one of the major occupations in India and it along with it allied activities contributes to around 20 per cent of the country's Gross Domestic Product. The agricultural land accounts to around 54.7 per cent of the total land. Most of these lands are in villages areas. This make the management of the resources harder as it has to be utilised in a sustainable manner. For this purpose land use plans are made for the development as well as for the proper use of the resources. Remote sensing and Geographic Information Systems technologies are widely used for this analysis, assessments and plan preparation.

Study area:

The study area is a cluster of 9 villages of Doomdoma sub division of Tinsukia district covering an area of 2351.26 ha situated on the left bank of river Brahmaputra falling under Dibru watershed of Buri Dihing sub catchment. It is located between 27°38'42" to 27°35'17" N latitude and 95°33'5" to 95°37'5" E longitude. According to the 2001 census report, the village cluster had a population of is 11592.

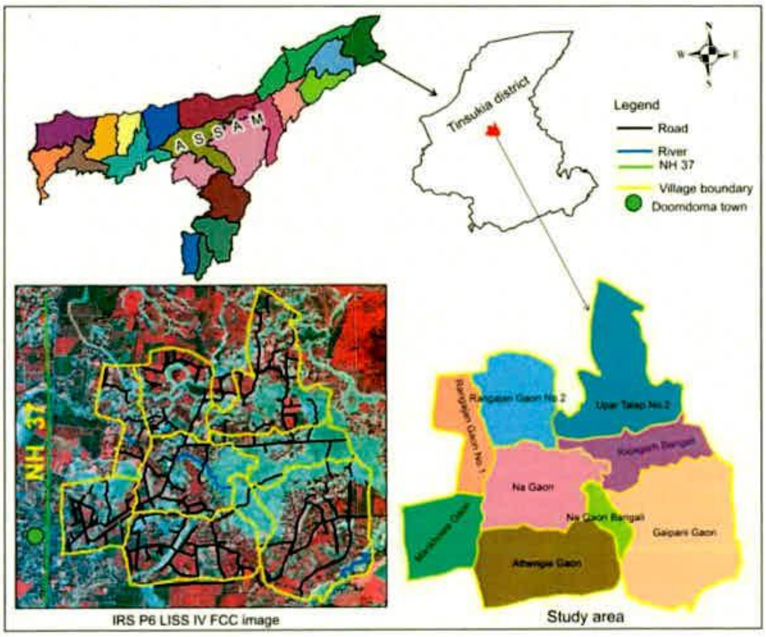


Figure 2-2: Location map of Doomdoma

Satellite Data: IRS P6 LISS IV multispectral, Cartosat I and LISS IV + Cartosat I merged image of year 2011 (January) were used to prepare land use land cover map, land degradation map and physiography map. IRS LISS III images of year 2012 (July and November) were also used to delineate different cropping pattern existing in the study area and to map land degradation.

Methodology:

Topo sheets from Survey of India of scale 1:1, 25,000 were used along with remote sensing and GIS for different analysis. Various elements like tone, texture, shape, size and association were interpreted. Ground truth data was collected for confirming the various map units.

Soil Map: Ground survey was conducted to find the pH value, soil content and organic matter present in the soil. Point layer was generated in ArcMap 9.3 software by entering latitude longitude value of sampling sites recorded in Global Positioning System (GPS) and entered NI value as attribute of the layer. The maps were classified based on NI values.

Ground water prospect map: Ground water prospect map prepared by National Remote Sensing Centre (NRSC) and North Eastern Space Applications Centre (NESAC) was updated with LISS IV + Cartosat I merged image of year 2011 and prepared ground water availability map from physiography map. Slope map was generated by using topomaps.

Accuracy Assessment: The classes identified in the identified in the land cover, soil, physiography and ground water prospects are verified by the using the data collected using GPS and ground survey.

Action Plan: The action plan map was made integrating different agro-physical parameters like land use/land cover, soil, slope, land degradation, soil fertility, ground water availability and rainfall.

Result and Discussion

Land use Land cover: 81 per cent of the total land comes under the agricultural land. Industrial area constitute of 1 per cent. 4 per cent of and comes under the waste land. And less than 1 per cent comes under water bodies and forest plantation. Physiography and ground water availability: Three major physiographic units namely deep alluvial plains (92.91 %), flood pains (1.7%) and paleochannels (4.2%) were identified. The ground water availability in the study area varies from good (93.3%), very good (1.2%) to excellent (4.2%).

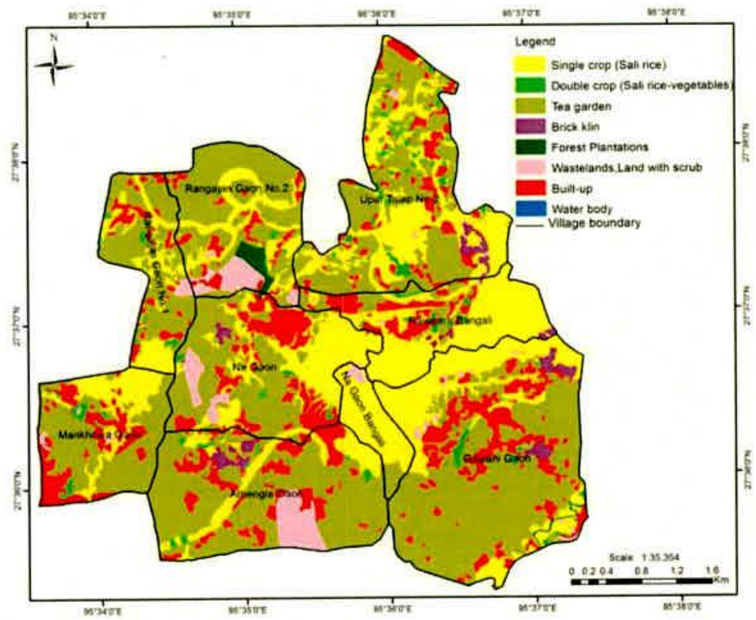


Figure 2-3: Land use/Landcover map of Doomdoma

Suggested Action Plan

The area mostly consists of agricultural land and the soil condition is highly supportive for this purpose. Different types of crops are cultivated throughout the year depending on the season. Due to large amount of rainfall received the cultivation of crops like rice which require good amount of water are not affect.

Air pollution is caused due to brick kiln. Burning of coal results in emission of gases like carbon dioxide (CO_2), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxide (NO_2) and particulate matter into the atmosphere. These gases are highly responsible of global warming and climate change.

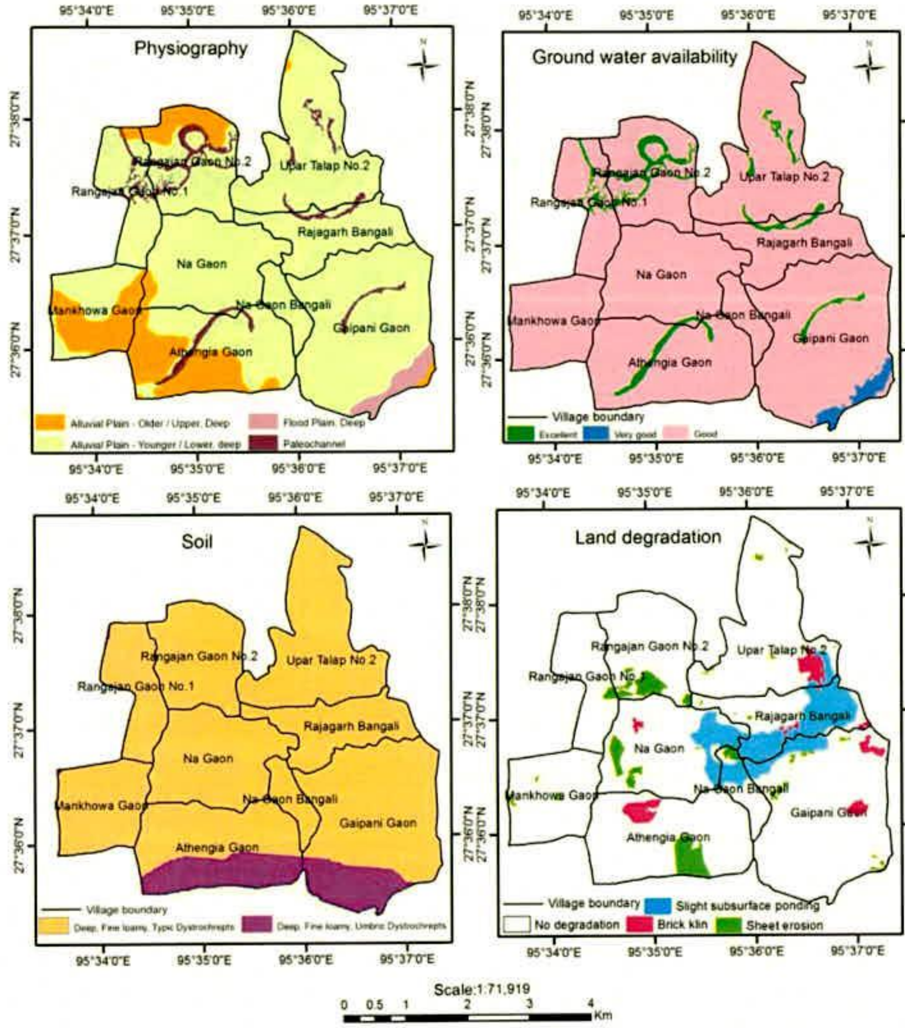


Figure 2-4: Physiography, Ground water availability, Soil and Land degradation map of Doomdoma

Since the land being highly fertile and used for cultivation purpose, the pollution factors has to be controlled. This is done by efficiently using he fuels that is used in the brick kiln which results in the pollutants emission.

There is no suggestion to alternate land use in residential areas and forest plantations. The water from rivers/streams can be used for surface irrigation to paddy fields located nearby.

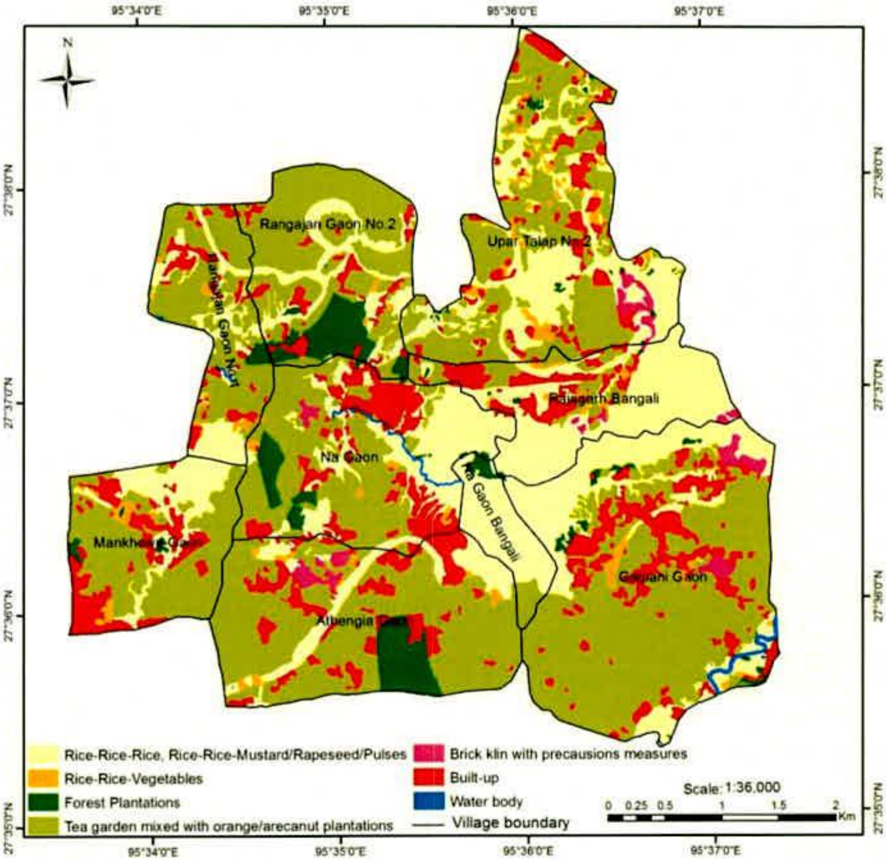


Figure 2-5: Propose land use/landcover of Doomdoma

Conclusion:

Visual interpretation method of the aerial photography data has facilitated the characterization of the study area in terms of land use, physiography, slope, soils and land degradation with lesser economic investment, time and number of workers. Tea gardens are the most dominant land use (50% of TGA) followed by kharif paddy (29%), built up (13.7%) and scrub lands (3.6%). Brick kilns are the only industrial area that covers only 1.3% of the total study area. The recommended land use and interventions as per natural resource inventory will support in land resource management. Since the study area represents major area of upper Assam, the outcome of this study will be applicable for large areas of the state.

CHAPTER 3
WORK PLAN AND METHODOLOGY

The research starts with understanding the existing conditions of the site. This included the village locations, climatic conditions, vegetation cover, agriculture, etc. This is followed by the geographic analysis. This consisted of analysing the slope, hillshade, flow accumulation, etc. Finally analysing the existing land use and applying the model for finding the most suitable locations for development in an ecologically compatible manner.

3.1. Study Area

The site taken for the study is the ESZ along River Bhagirathi from Gaumukh to Uttarkashi. The said ESZ has the entire watershed of about 100 Km stretch of river Bhagirathi from Gaumukh to Uttarakashi covering an area of 4179.59 Km².

The Eco Sensitive Zone is bounded by 31°05'46.54"N latitude and 79°25'11.65"E longitude towards east; 31°27'23.28"N latitude 79°04'32.21"E longitude towards north; 30°51'03.95"N latitude and 78°22'57.78"E longitude towards west and 30°39'08.09" latitude and 78°31'26.41"E longitude towards south.

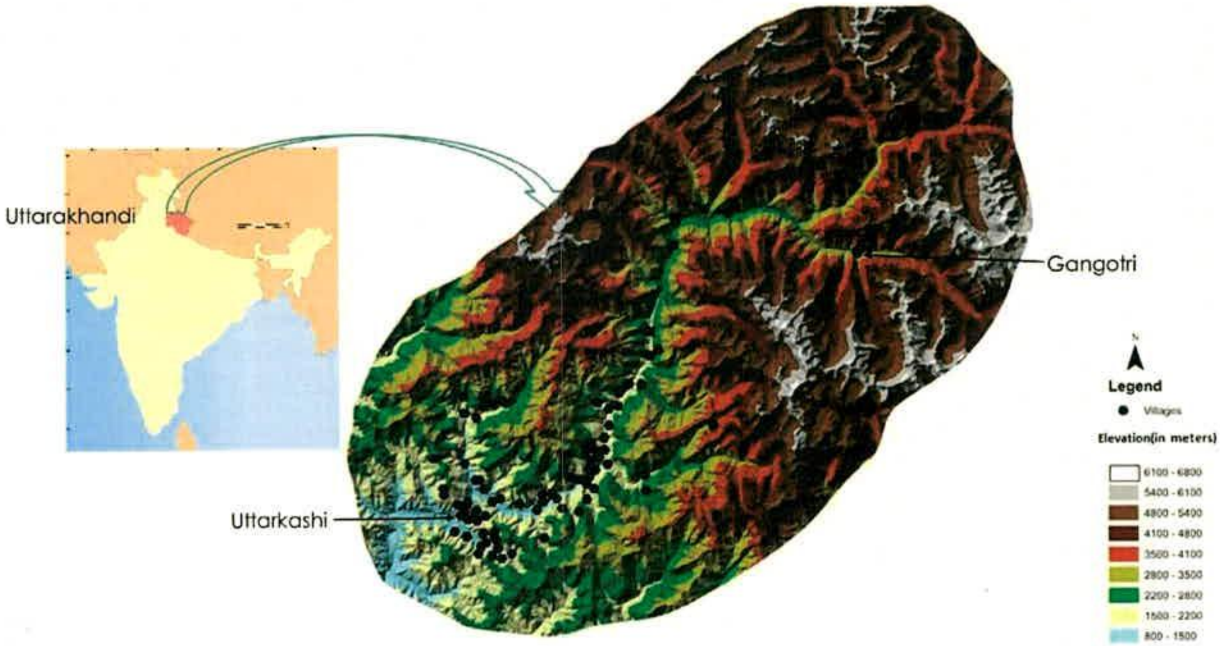


Figure 3-1: Study Area

Figure 3-2: Uttarkashi Terrain with buildings

The average temperature of the ESZ is 18.8°C and rainfall of 1693 mm. During winter temperature drops to below 0°C. Monsoon season in this region occurs during the months of July, August and September (Uttarakhand Tourism Development Board, 2014).

The flora in this region varied depending on the altitude. The areas having altitude 1000-2000 metres are mostly filled with pine forest. Areas with altitude ranging from 2000-3000 metres are mostly covered with rhododendron, oak and deodar. Beyond 3000 metre altitude birch, spruce and fir are mostly found (Uttarkashi District Administration, 2015)

Agriculture is a major field of occupation for the locals. Most of the crops cultivated are Kharif crops and few are rabi. Kharif crops are irrigated by the monsoon and and Rabi crops requires additional irrigation. Cereals cultivated are wheat, paddy, finger millet, maize and barnyard millet. Pulses and oil seed crops includes Pea, black gram, red gram, mustard and lentil. Horticulture crops more than just for sales is also a tourist attraction. These crops include pear, apple, walnut, citrus and plum. Other vegetable cultivated in this region includes vegetable pea, tomato, French bean, cabbage and potato (Uttarkshi District Administration, 2008).

3.1.1. Regional Settings

Regional settings shows the details of major surrounding locations. This helps in understanding the accessibility of the ESZ with other towns. Figure 3-3 shows the major locations and the road network connecting the villages under ESZ with the major cities around it.

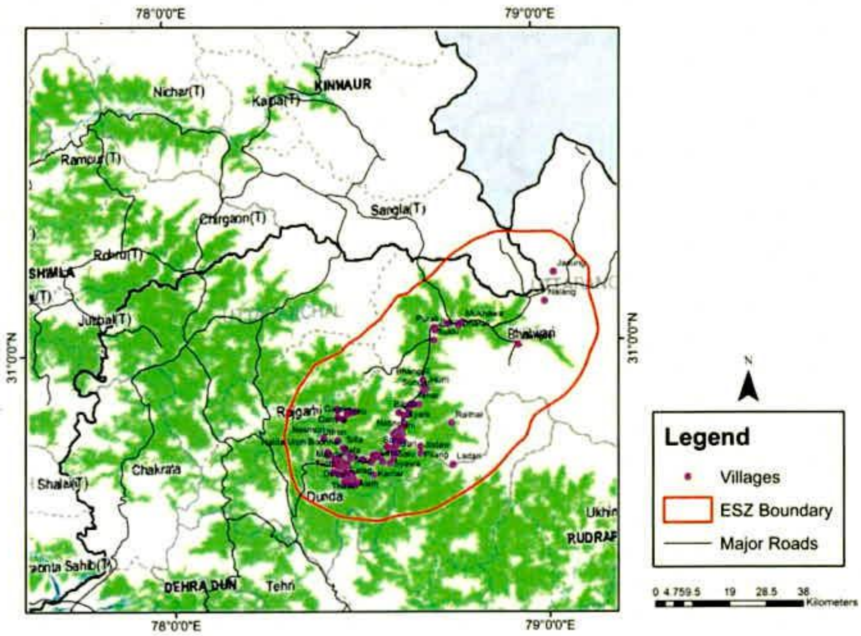


Figure 3-3: Regional Settings

All the villages under ESZ are located in Uttarakhand state. Uttarkashi being the most developed village in the ESZ has accessibility to major surrounding cities like Dehradun and Shimla. Dehradun is 208 Km and Shimla is 294 Km away from Uttarkashi.

3.1.2. Zonal Master Plan for the Eco-sensitive Zone

Zonal Master Plan are prepared when an area is considered as a zone with some unique characteristics. In this study the site is defined as a special zone because of the environment vulnerability and it's prepared by State Government with the support of locals (especially women). State departments involved: Environment, Forest, Urban Development Tourism, Municipal Revenue, Public Works Department, Water Resource, and Pollution Control Board. Restoration of denuded area, this includes the areas affected due to landslides. These areas need to be restored in a safe manner, thus avoiding the risk of future disasters. Conservation of existing water bodies is a main goal in this zonal plan. Especially at present when river Ganga has been highly contaminated, it has to be given special consideration as these are the areas which still have good quality streams. Management of catchment areas has been included due to disaster occurrence as well as for agriculture. Agriculture being a major occupation requirement of water is high. Even though the Rabi crops are comparatively less, the requirement of irrigation is inevitable. The other factors that are taken care by the Zonal Master Plan are watershed management, ground water management and spoil and moisture conservation (Ministry of Environment and Forestry, 2012).

3.1.2.1. Prohibited activities in Eco-sensitive zones

- River Valley Project
- Abstraction of river water for industries
- Mining of minerals and stone quarrying and crushing
- Commercial felling of trees
- Setting up saw mills
- Commercial use of firewood
- Polluting industries
- Sewage and industrial effluents
- Use of plastic bags
- Hazardous waste processing unit

3.1.2.2. Regulated activities in the Eco-sensitive Zone

- Use of water
- Cutting of trees
- Defense installations
- Introduction of exotic species
- Establishment of hotels and resorts
- Erection of electric cables
- Drastic change of agriculture systems
- Noise pollution
- Air pollution
- Discharge of effluents
- Hydro-electric plants
- Solid waste
- Bio-medical waste
- Vehicular traffic

Table 3-1: List of Villages under ESZ

Village Name	Village Name	Village Name	Village Name
Agoda	Gangotri	Kyark	Raithal
Aleth	Gawana	Ladari	Salang
Bagori	Gorshali	Lata	Sald Urph Maja Gaon

Bagyal Gaon	Gyanja	Malla	Salu
Bandrani	Hinna	Mando	Sangrali
Barsu	Hurri	Maneri	Sanj
Bayana	Jadung	Manpur	Sara
Bhancoli	Jakhol	Mastari	Sarag
Bhangeli	Jamak	Mukhawa	Sari
Bhatwari	Jaspur	Nalang	Saura
Bhela Tipri	Jhala	Nalda Urph Bodhhar	Seku
Bhukki	Jodaw	Natin	Silla
Bonga	Jokani	Naugaon	Silyan
Bongari	Joshiyara	Nesmor	Siror
Dandalka	Kamar	Netala	Sukki
Dansra	Kanath	Nirakot	Sungar
Dhanpur	Kankrari	Ongee	Syawa
Dharali	Kishanpur	Pahi	Tehar
Dhwari	Kotiyal Gaon	Pala Mardi	Thalan
Didsari	Kumalti	Pata	Tiloth
Dovah	Kunjan	Pilang	Uttarkashi
Gajoli	Kuroli	Purali	Uttron

3.2. Methodology

For the purpose of ecologically compatible land use planning multiple GIS functions has been carried out. The functions carried out are integration using the model builder tool in order to come to the final results.

3.2.1. Model Builder

Model builder is an application in ArcGIS which is used for creating a model for a particular function. These models can be reedited even at later stage of analysis which makes it suitable for modifications if required thus making the work faster and results more accurate. (ESRI, n.d.)

To create a model a toolbox needs to be created first. After creating a toolbox in a specific folder connection a model can be created within the toolbox. A model looks like a workflow diagram through which various geo-processing tools are connected. The output of a particular function can be used as the input for the next. By using this method the multiple analysis can be one at the same time. While using GIS during some analysis the files might get heavy and display of the output might take a long time and can even result in crashing of the system. But while using model builder we have an option for displaying only the required.

Model builder is generally used when we require a large number of parameter to come results or when multiple steps are required to come to a result. In real time application we use for analysis like land suitability, hydrology, etc. In addition to all these advantage it helps the user get a visual relationship between different parameters and makes it easier to explain to a third person on how the analysis is performed thus making this one the most advanced tools in the field of GIS.

3.2.2. Land use Suitability Analysis

The suitability of proposed land use depends on land quality and the requirement of rural development, were the analysis based on the relationship between the resource requirements of rural development, were analysed based on the relationship between the resource requirement of the suggested land use and present resource conditions. After assessment of the suitability of each suggested land use they were integrated into comprehensive land suitability for agriculture. Land suitability analysis will be conducted on ArcGIS 10.1 using restriction model where the buffers are created along different parameters to create a union which helps in finding the suitable land.

Land development strategies and policy analysis: The land development strategies and policies are proposed and analysed as per requirement of rural development and land suitability, and the final results were presented.

3.2.3. Reclassify

Reclassification is the process used to reclassify raster data to required number of classes. Reclassification can be used when there are different parameters with different units and needs to be considered together like in the case of weighted overlay. In this study slope, road network buffer, hillshade, Euclidean distance and relative relief are reclassified. Reclassify tool is available in Spatial Analyst toolbox.

3.2.4. Weighted Overlay

This is a method that combines all the parameters used in a study to get a result. Each parameter can be given different percentage weightage depending on the importance. The evaluation scale can be decided as per requirement. In this study final evaluation will be don't at a scale of 5. It will be set as '1 to 5 by 1', meaning the range is from 1 to 5 and the smallest value would be one. Even the each parameters classes can be given different values depending on the evaluation scale. At some situation when a specific area can be used for any purpose because of a parameter. The evaluation scale for that particular class in the parameter can be defined as 'Restricted'. This helps in achieving more accurate results.

3.2.5. Land Suitability and Most Suitable Locations

Land suitability and most suitable locations are the outcome of weighted overlay. The direct out of weighted overlay is the land suitability. Further conditional evaluation with highest suitability value is performed to extract the most suitable areas. These areas can be single sells too. Thus a majority filter is performed to extract the areas. Further the raster output is converted to polygons to get the most suitable locations and for further analysis.

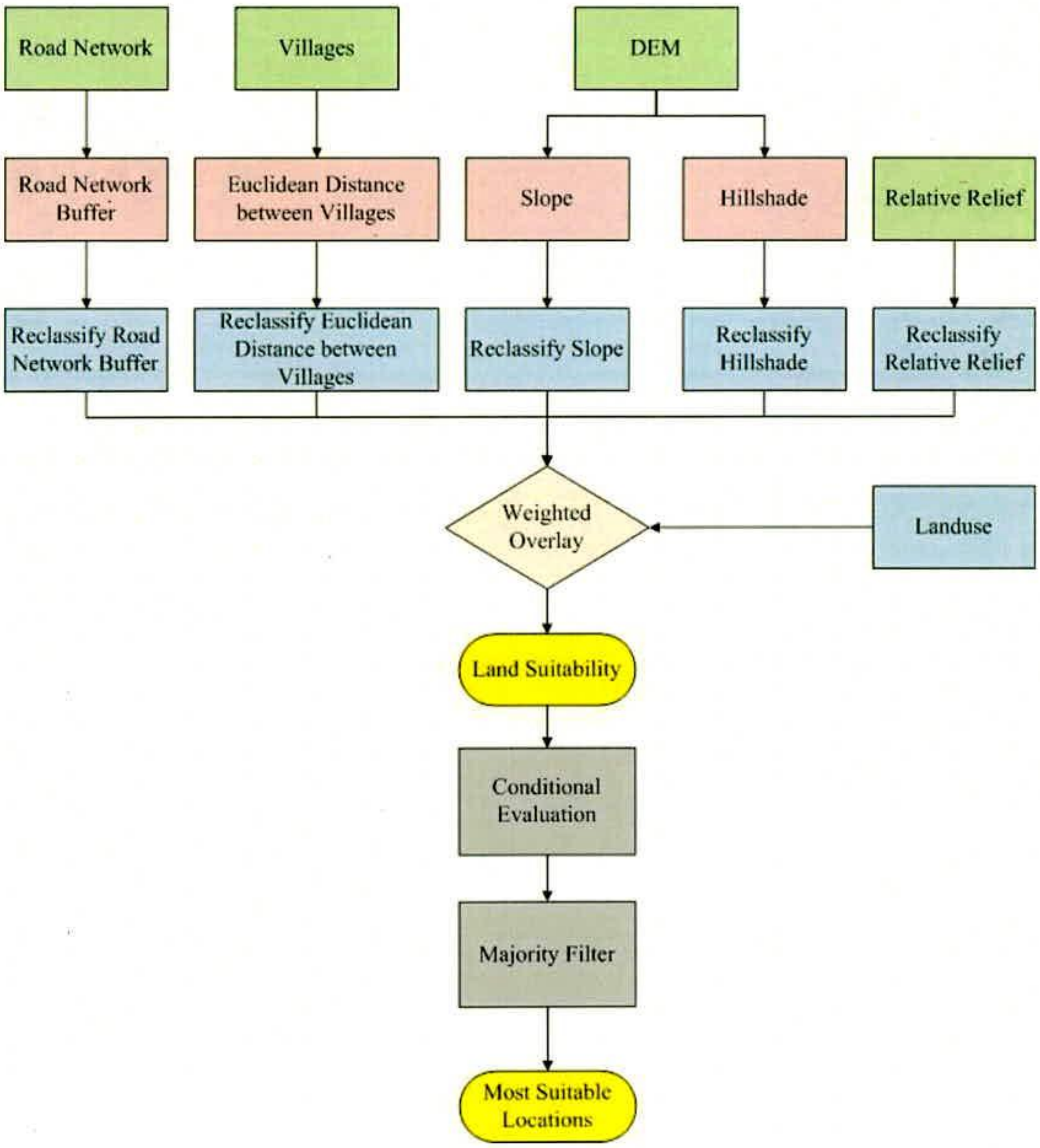


Figure 3-4: Land Suitability and Most Suitable Locations

With this method first the Land Suitability analysis of the site is done and further the most suitable locations for development are found.

CHAPTER 4

RESULTS AND DISCUSSIONS

Once the study area is analysed and model is created, the outcomes of multiple parameters are studied. This is done in order to convert each parameter into same units thus a combined result can be obtained. This is required to find the land suitability and locating the sites that are most suitable for development. This chapters shows the methods used to analyse the data, its results and inferences.

4.1. Locating the villages and defining the ESZ boundary

Before using the model builder multiple layers need to be created and analysis needs to be performed. The first task is the marking of boundary and locating the villages that comes under ESZ. In this study there are 88 villages. These locations are marked by first locating the villages using the Google Earth with the latitude and longitude given by the MoEF. These are then saved as Keyhole Mark-up Language (KML). (KML) is an XML-based mark-up language designed to annotate and overlay visualizations on various two-dimensional, Web-based online maps or three-dimensional Earth browsers. (Rouse, n.d.)

Since the entire village kml files are different and this has to be converted to shapefile as a single one. This is done by using the Expert GPS software which converts and combines as a single shapefile.

The boundary of ESZ created by using polygon feature. A new shapefile (polygon feature) is created by using ArcCatalog inside the folder connection. Type of shapefile is chosen and title is given to the shapefile. The next step includes the defining the coordinate system for the location. In case of this location the coordinated defined as Projected Coordinate System > UTM > WGS 1984 > Northern Hemisphere > WGS 1984 UTM Zone 44N.

4.2. Digital Elevation Model (DEM) and DEM Masking

A Digital Elevation Model is the representation of continuous elevation values over a topographic surface by a regular array of z-values, referenced to a common datum (ESRI, n.d.). The Digital Elevation Model for the study area is given in Figure 4-1.

Figure 4-1: Digital Elevation Model

The DEM used for this study is of 30 meter resolution and is obtained from asterdem. In case of this study four DEMs were required in order to cover the complete area. Later these were combined and masked using ArcGIS masking tool with reference to the boundary created.

Masking is used for extracting the required part of raster file with the reference of a feature class. Masking tool is found in the ArcToolbox under Spatial Analyst Tools > Extraction > Extract by Mask. Once this process is done the output is

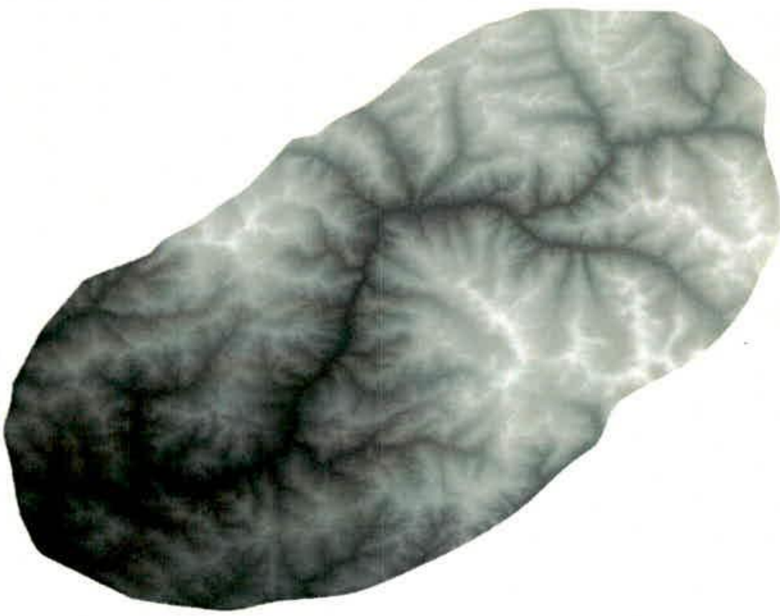


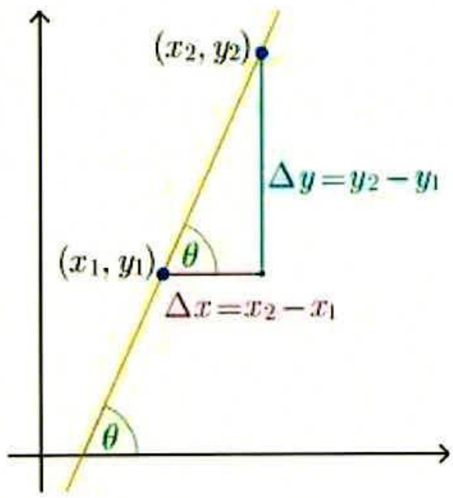
Figure 4-2: Digital Elevation Model after Masking with site boundary

This masked DEM is going to be used multiple analysis like slope, elevation, TIN model, flow accumulation, hillshade, etc.

Due to the lack of accuracy in the coordinates of obtained ASTERDEM, the DEM has to be projected again using ArcGIS. This is done with help of Projection and Transformation tools in Data Management toolbox.

4.3. Slope Analysis

The slope or gradient of a line is a number that describes both the direction and the steepness of the line. The Slope tool calculates the maximum change in value from that cell to its neighbours. Basically, the maximum change in elevation by the distance between the cell and its eight neighbours finds the steepest downhill descent from the cell. The tool fits a plane to the z-values of a 3 x 3 cell neighbourhood around the processing or center cell. The direction the plane faces is the aspect for the processing cell. The lower the slope value means flatter terrain and vice versa. The cell location with a NoData z-value, the z-value of the center cell will be assigned to the location. (ESRI, n.d.)



$$m = \frac{\Delta y}{\Delta x} = \frac{\text{vertical change}}{\text{horizontal change}} = \frac{\text{rise}}{\text{run}}.$$

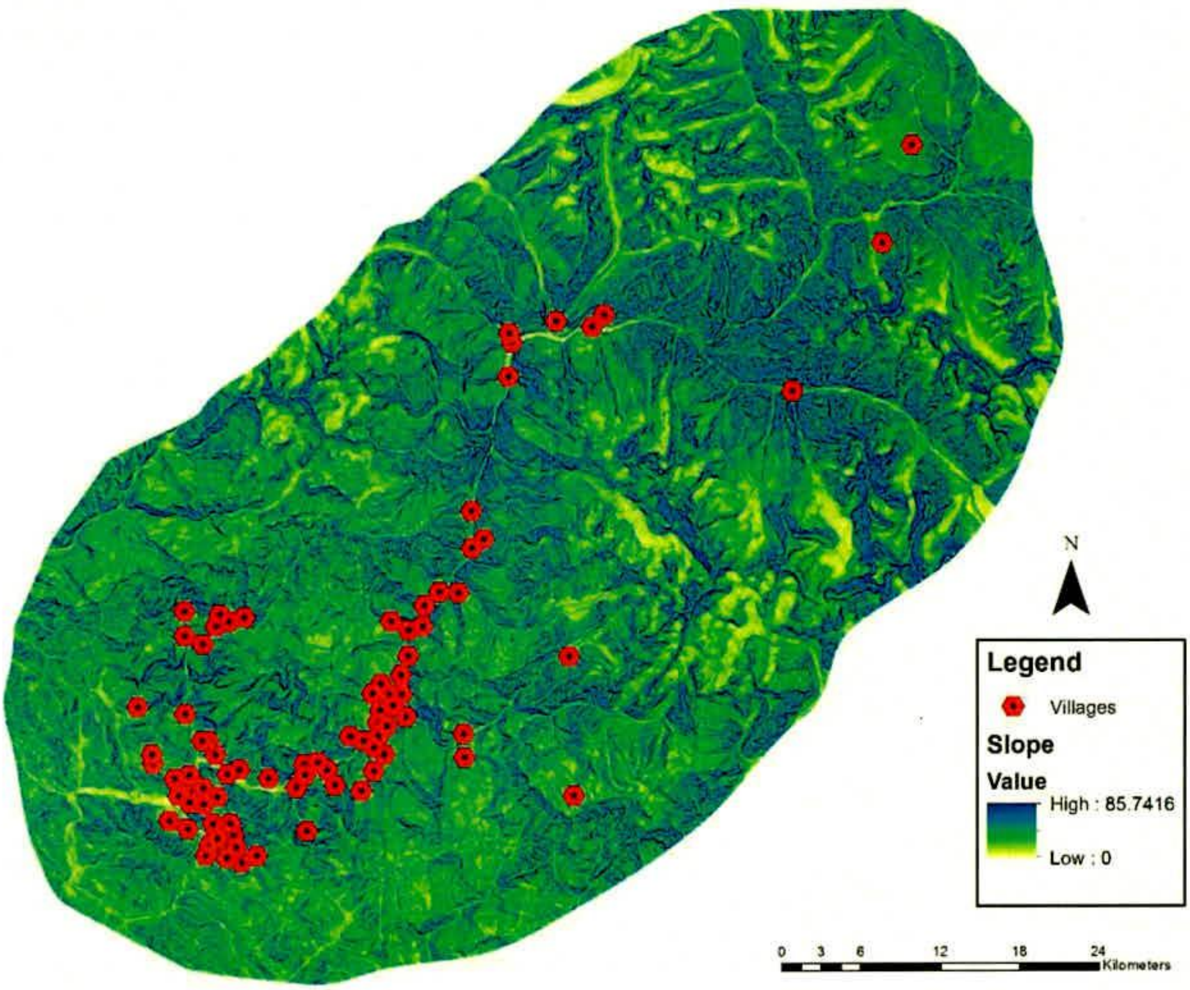


Figure 4--3: Slope of ESZ

Analysis and Inferences

- Input raster: DEM of site.
- Output raster: Slope in destination folder location.
- Output measurement: It is in either degree or percent.
- Z-factor: It is the elevation of the site.
- In this site the minimum slope is 0° and maximum of 85.74°.
- The location with slope more than 30° can't be used for any development activity.

4.4. Aspect Map

Aspect map shows the direction and steepness of slope for a terrain. Aspect tool is under spatial analyst and is created using DEM. The areas that have steeper slopes are shown brighter. The aspect map is classified on the basis of direction of slope in degrees (0-360°).

North: 0-22.5

North-east: 22.5-67.5

East: 67.5-112.5

South-east: 112.5-157.5

South: 157.5-202.5

South-west: 202.5-247.5

West: 247.5-292.5

North-west: 292.5-337.5

North: 337.5-359.5

Whichever locations are flat is assigned (-1).

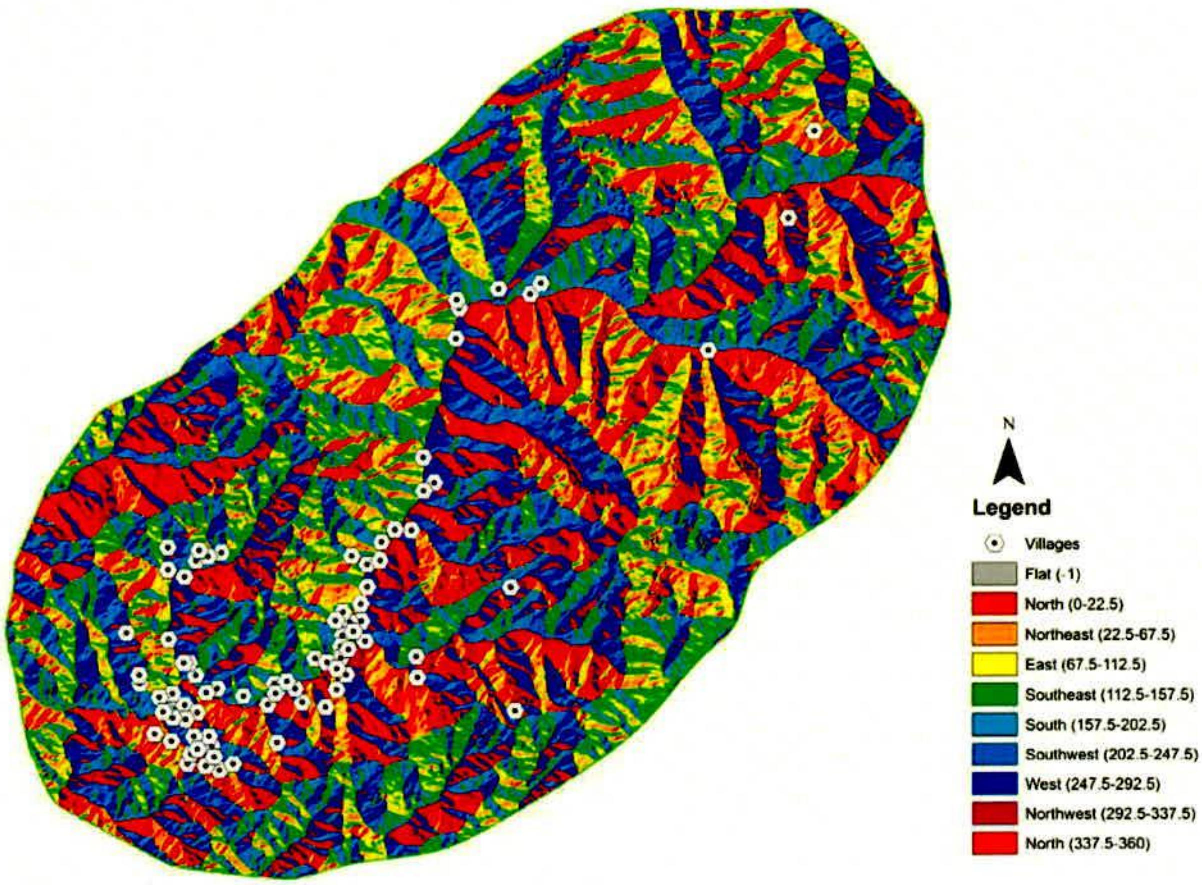


Figure 4-4: Aspect map of ESZ

Analysis and Inferences

- Input raster: DEM of site.

- Output raster: Aspect in the destination folder.
- This map represents the direction of slope. As seen in the aspect map most of the slopes are towards Northwest, South and west.

4.5. Elevation Map

Triangulated Irregular Network (TIN) model is a digital data structure used in GIS for representation of a surface. TIN model is generated using DEM. Advantage of TIN over DEM is that points of TIN are distribute variably by using an algorithm that decides which points are more accurate for terrain representation.

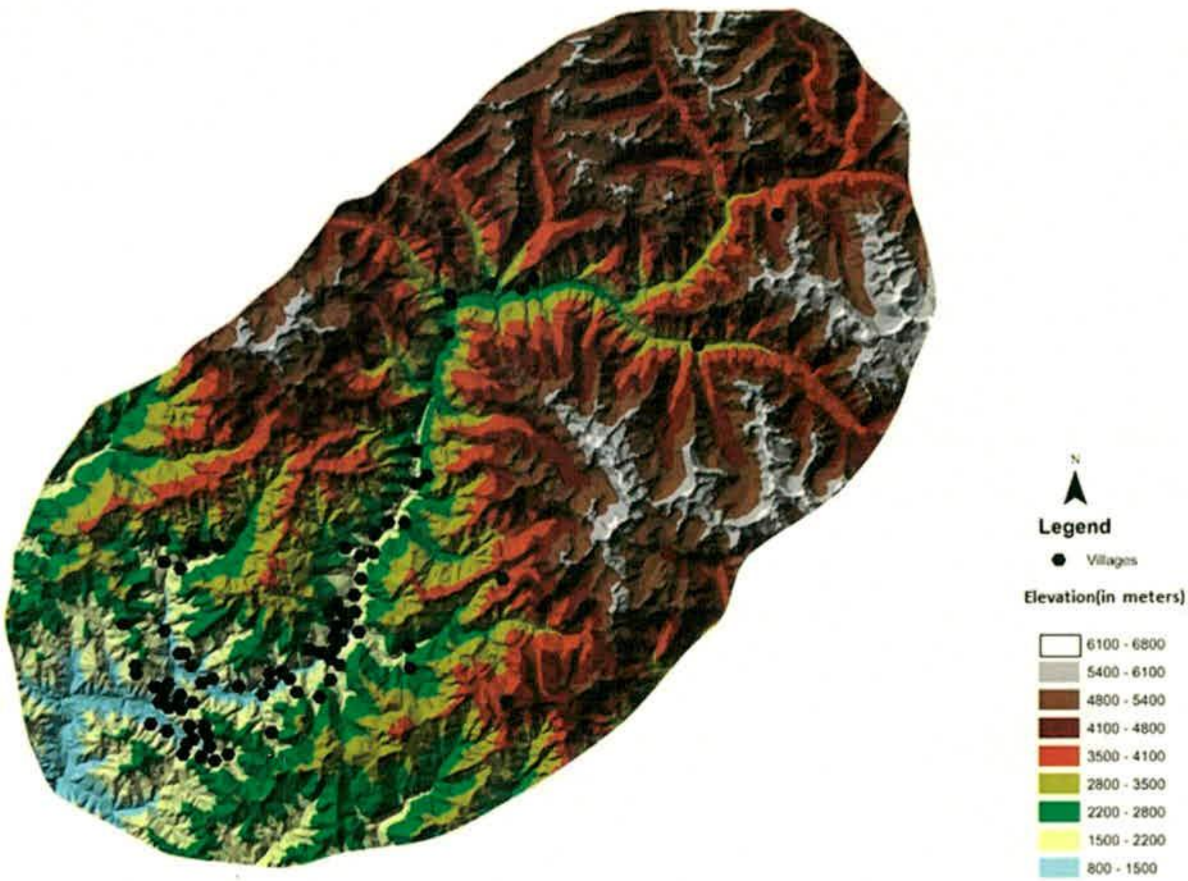


Figure 4-5: Elevation Map of ESZ

Analysis and Inferences

- Elevation of the site is found using TIN model.
- Output TIN: TIN model is the destined folder.
- Coordinate System: Imported from the DEM.
- Input Feature Class: DEM of the site.

- In this location it can be noted that the elevation is increasing from southwest to northeast ranging from 800-6800 meters above mean sea level. The areas with lower elevation are more suitable for development.

4.6. Contour Map

Contours are lines that connect the points of same values. The contour model is used for study of elevation, temperature, precipitation, pollution, etc. In this study contour map is used for the analysing the elevation details. This helps in finding the areas that have less steep slopes and can be developed. Contour map over the TIN elevation model will help is visualizing the terrains in a better manner.

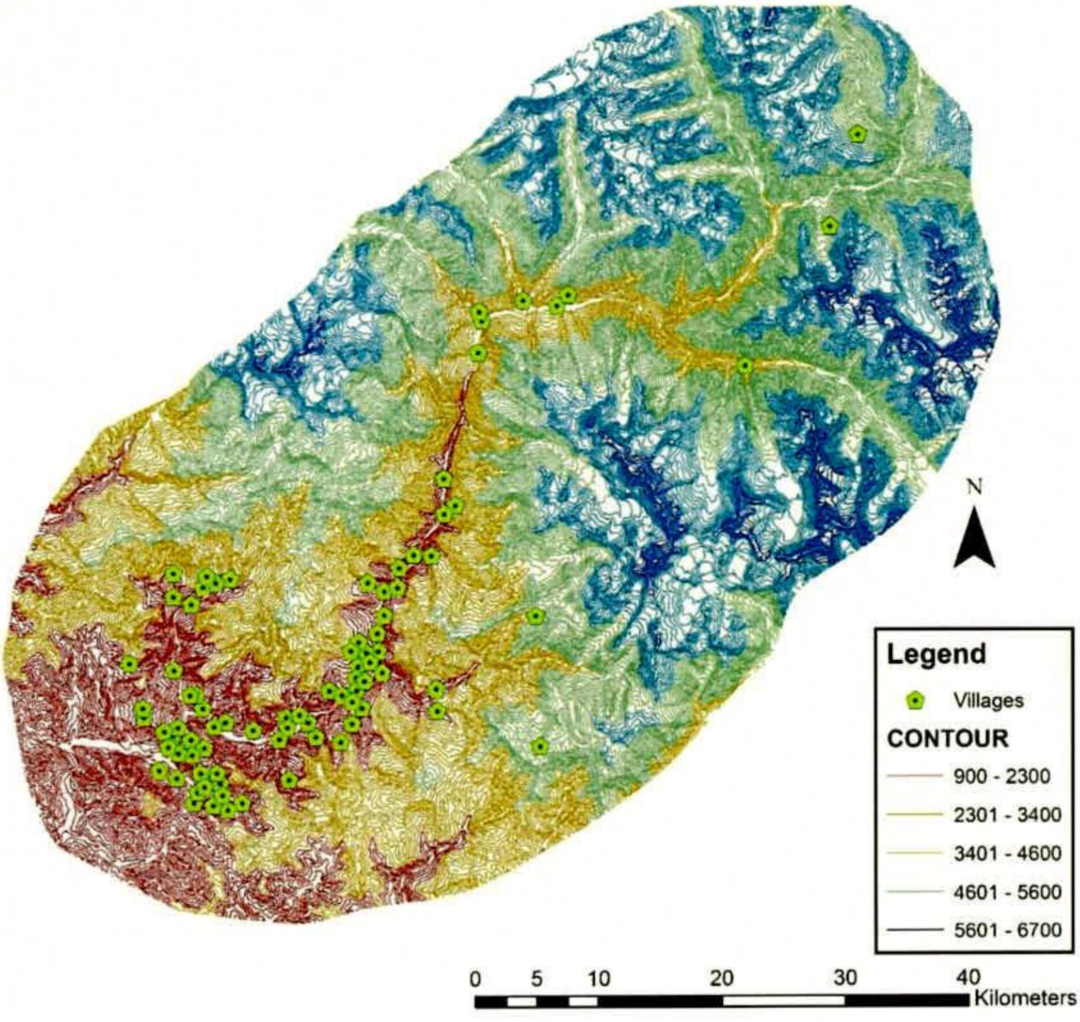


Figure 4-6: Contour Map of ESZ

Analysis and Inferences

- Input raster: DEM of site.

- Output polyline features: Contour file in the destination folder.
- Contour interval: In this study it is 100 meters.
- Z-factor: Elevation of the site

4.7. Sun Path

With the help of SunEarthTools the azimuth and elevation of the site is available so that the Hillshade of the location can be created. Azimuth and elevation of 1 June 2014 and 1 December 2015 is used.

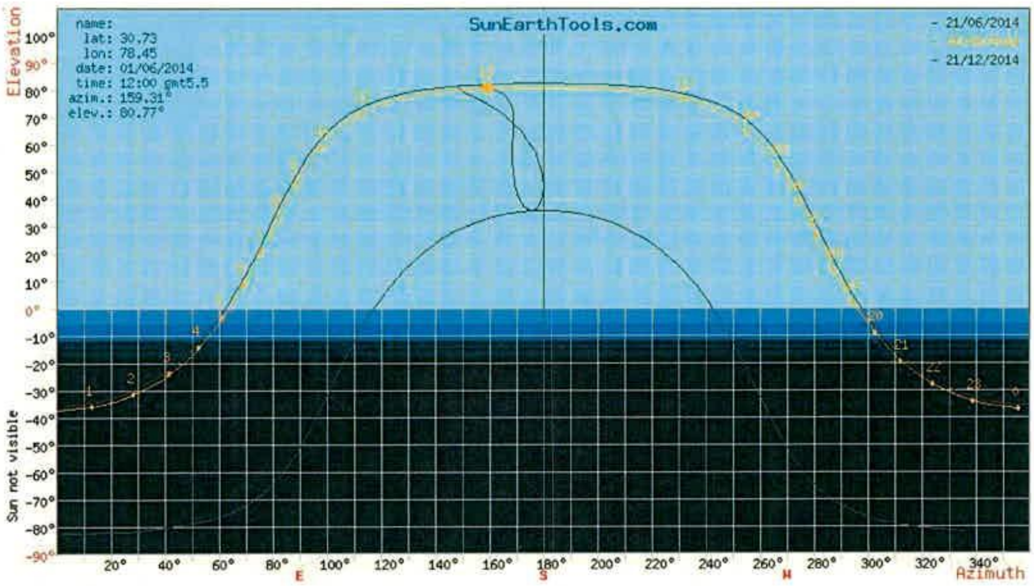


Figure 4-7: Sun path on 1 Jun 2014

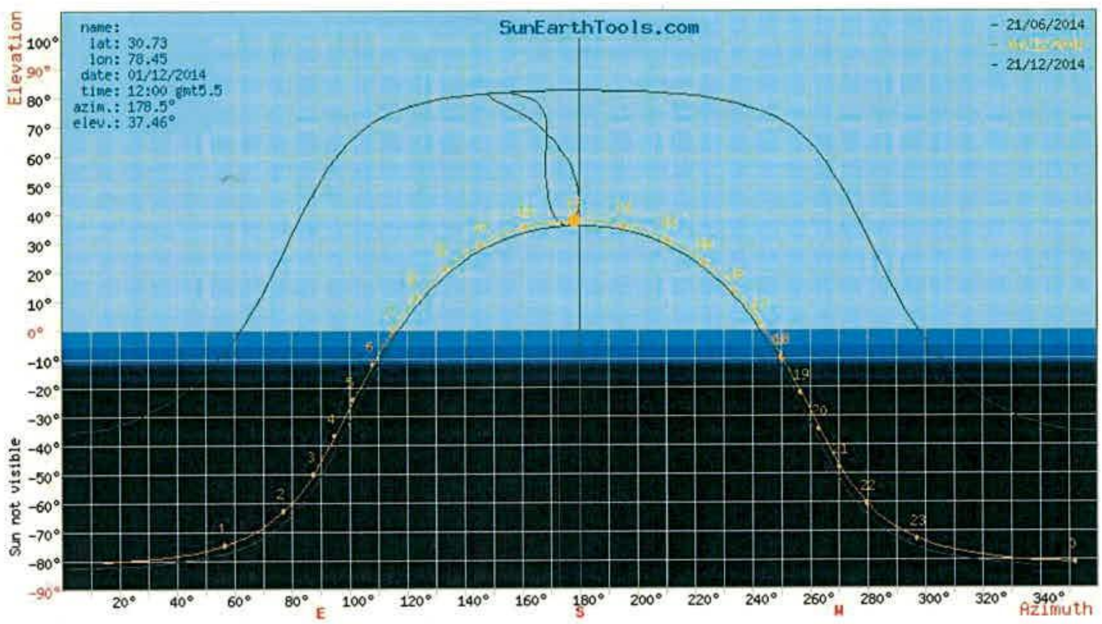


Figure 4-4-8: Sun path on 1 Dec 2014

4.8. Sun Position, Twilight, and Daylight

Sun position shows the elevation, azimuth, latitude and longitude of the site. Twilight shows timing of sunrise and sunset. Daylight shows the duration for which the sunlight was in the location.

Table 4-1: Sun Position, Twilight, and Daylight on 1 Jun 2014

sun position	Elevation	Azimuth	latitude	longitude
01/06/2014 12:00 | GMT5.5	80.77°	159.31°	30.73° N	78.45° E
twilight	Sunrise	Sunset	Azimuth Sunrise	Azimuth Sunset
twilight -0.833°	05:14:01	19:14:14	63.59°	296.5°
Civil twilight -6°	04:46:43	19:41:31	59.94°	300.16°
Nautical twilight -12°	04:13:38	20:14:40	55.1°	305.01°
Astronomical twilight -18°	03:38:20	20:50:03	49.34°	310.79°
daylight	hh:mm:ss	diff. dd+1	diff. dd-1	Noon
01/06/2014	14:00:13	00:00:46	-00:00:48	12:14:07

Table 4-2: Sun Position, Twilight, and Daylight on 1 Dec 2014

sun position	Elevation	Azimuth	latitude	longitude
01/12/2014 12:00 | GMT5.5	37.46°	178.5°	30.73° N	78.45° E
twilight	Sunrise	Sunset	Azimuth Sunrise	Azimuth Sunset
twilight -0.833°	06:55:40	17:14:25	115°	244.91°
Civil twilight -6°	06:29:27	17:40:36	111.78°	248.12°
Nautical twilight -12°	05:59:42	18:10:20	108.33°	251.57°
Astronomical twilight -18°	05:30:32	18:39:30	105.08°	254.81°
daylight	hh:mm:ss	diff. dd+1	diff. dd-1	Noon
01/12/2014	10:18:45	-00:00:52	00:00:52	12:05:02

4.9. Hillshade

Hillshade is a 3D grayscale model of a surface by taking sun's relative position to account. It shows the areas that receives sun light and that comes under the shade at a particular time. For this function the azimuth and altitude of location is required.

The inputs for this function are the following:

- Input DEM
- Azimuth
- Altitude
- Scaling
- Z Factor
- Pixel Size Power
- Pixel Size Factor
- Altitude is the angle of elevation of sun (0-90°) and azimuth is the relation position of sun along the horizon (0-360°). Z-factor is the elevation of the location.
- The Hillshade tool comes under spatial analyst toolbox in ArcGIS.

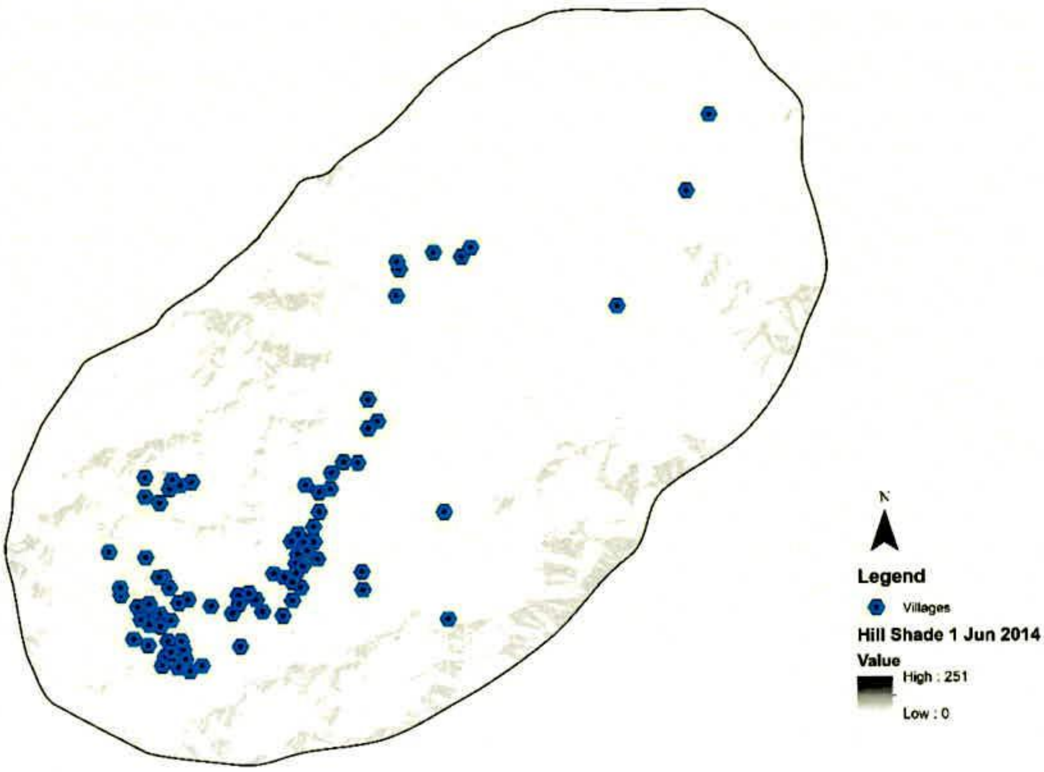


Figure 4-9: Hillshade on 1 Jun 2014

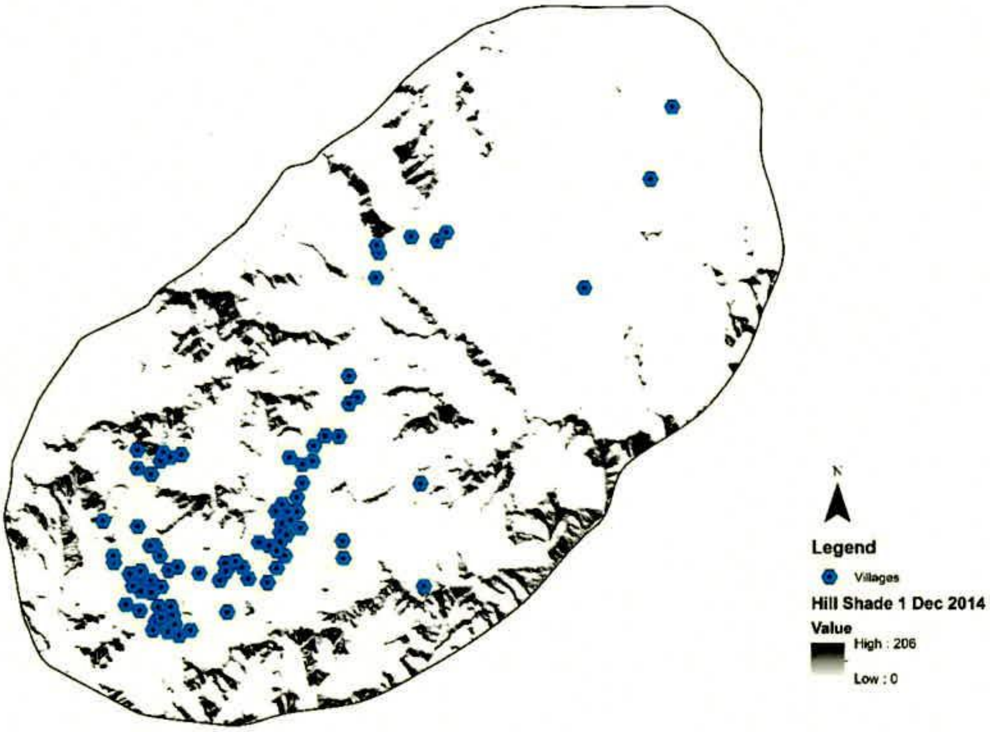


Figure 4-10: Hillshade on 1 Dec 2014

4.10. Hillshade with Elevation Map

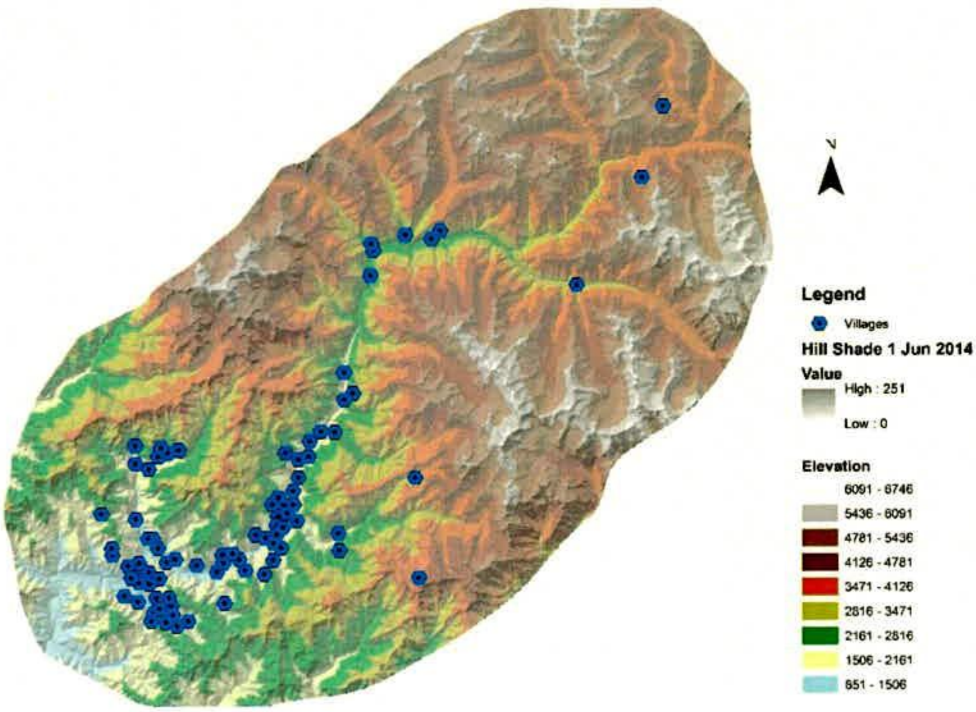


Figure 4-11: Hillshade with Elevation 1 Jun 2014

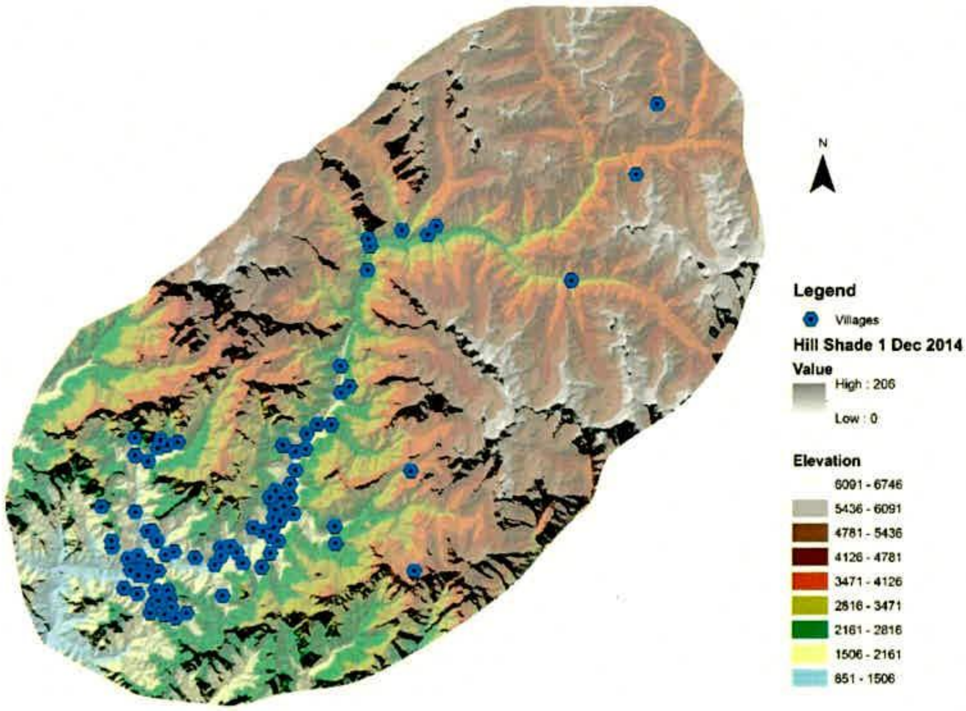


Figure 4-12: Hillshade with Elevation 1 Dec 2014

Analysis and Inferences

The location which receives maximum sun light can more suitable for agricultural activities. This areas mostly cultivates Kharif crops but still has a good amount of Rabi crops cultivation too, thus making hillshade an inevitable factor for this study.

4.11. Relative Relief

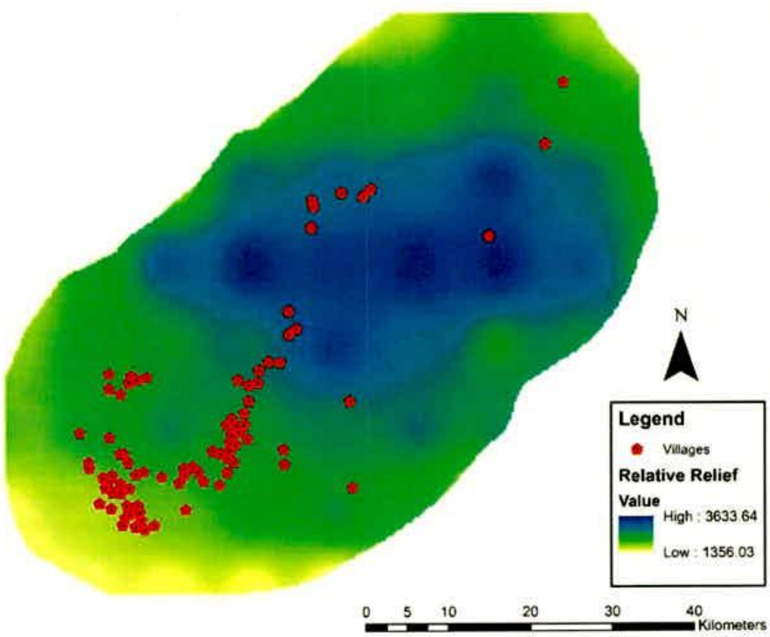


Figure 4-13: Relative Relief Map of ESZ

Analysis and Inferences

- Relative relief shows the change is height between two points.
- It is crated with the help of DEM.
- A fishnet is created around the site. The zonal statistics is created my matching the centre of the fishnet and the z-value of DEM at that point.
- Finally relative relief is created by using Inverse Distance Weighted (IDW) function under Interpolation tool in Spatial Analyst toolbox.
- The areas shown is blue are of higher relative relief thus making it not suitable for an kind of development.

4.12. Stream Order

Stream order shows the hierarchy of tributaries. This used for creating the basins and the flow accumulation in the site.

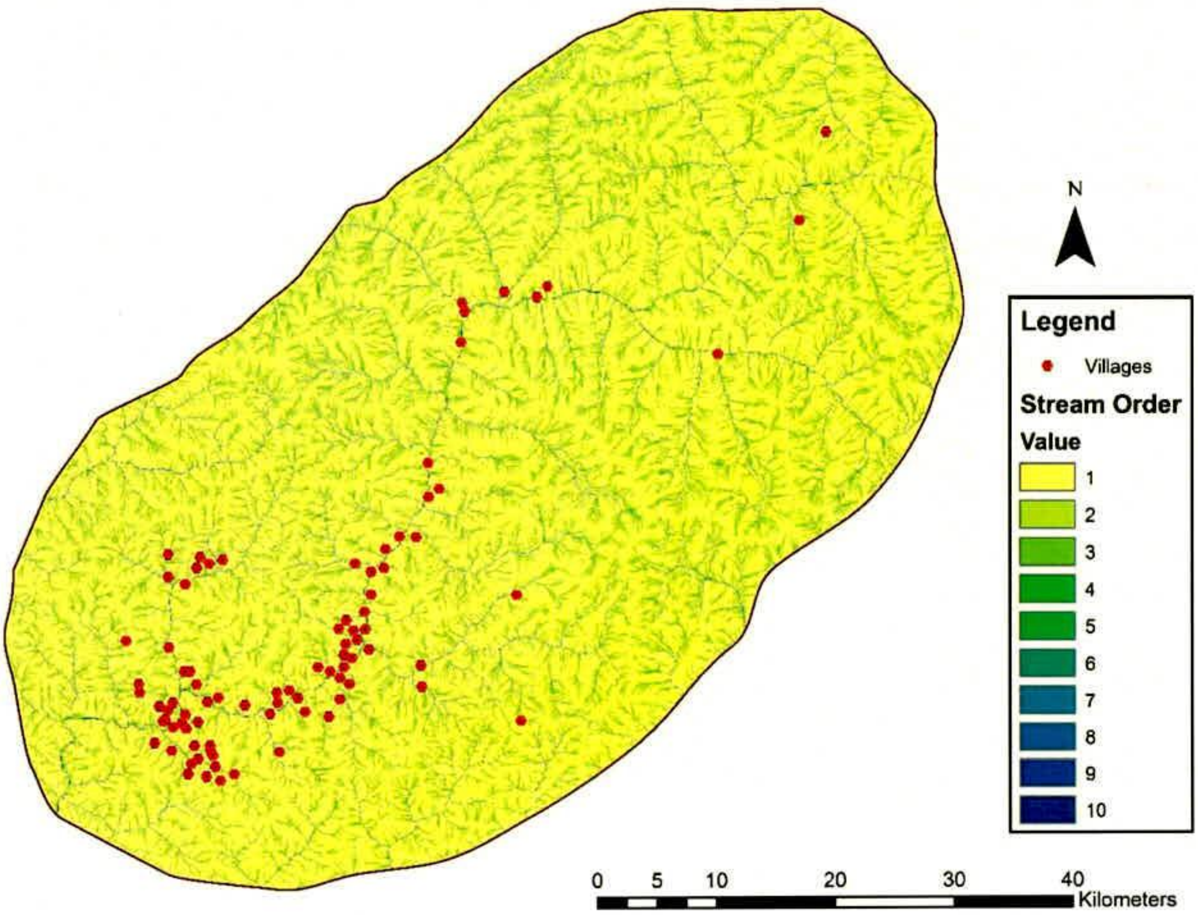


Figure 4-14: Stream Order Map of ESZ

Analysis and Inferences

- Input stream raster: DEM of site.
- Input flow direction raster: Input the flow direction raster created using hydrology tools
- Output raster: Stream order in the destination folder.
- Method of stream ordering: STRAHLER.
- This is further use in finding flow accumulations and in locating the major streams.

4.13. Flow Accumulation

Flow accumulation map shows the areas that will accumulate water. In ArcGIS a raster file is created of accumulated flow into each cell. Flow direction is used as the input for flow accumulation raster. Flow accumulation comes under hydrology tool which is under spatial analyst toolbox.

Usage:

- Cell with high flow accumulation can be used to identify stream channel.
- Cell with flow accumulation of zero can be used to identify ridges.

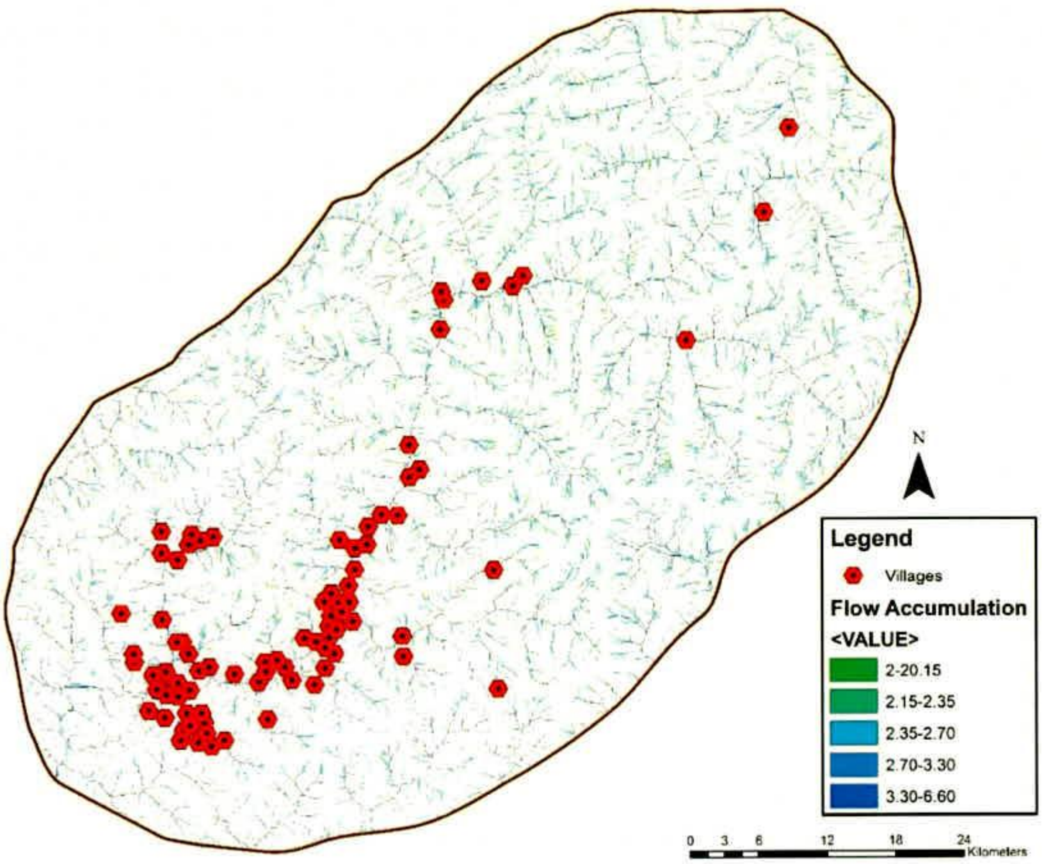


Figure 4-15: Flow Accumulation Map of ESZ

Analysis and Inferences

- Flow accumulation is generated with the help of flow direction feature in hydrology tool in spatial analyst toolbox.
- The major setback in his tool is that values to flow accumulation can go to large extent. So to visualise first raster calculator needs to be used. By applying the log function the range can be reduced.
- There is a chance that at the accusation at the end points might not really occur. Thus is conditional function is used to remove that.
- In this site after applying all these functions the range is from 2-6.60.
- It can be understood that most of the villages are located near the areas of higher accumulation, increasing the risk of flood during rains.

4.14. Basins

This tool creates a raster that delineates all the drainage basins. The drainage basins are delineating ridge lines between basins. For creating the basins, the flow direction is used as the input. Even if the basin is in one cell, all the cells in a raster will belong to a basin.

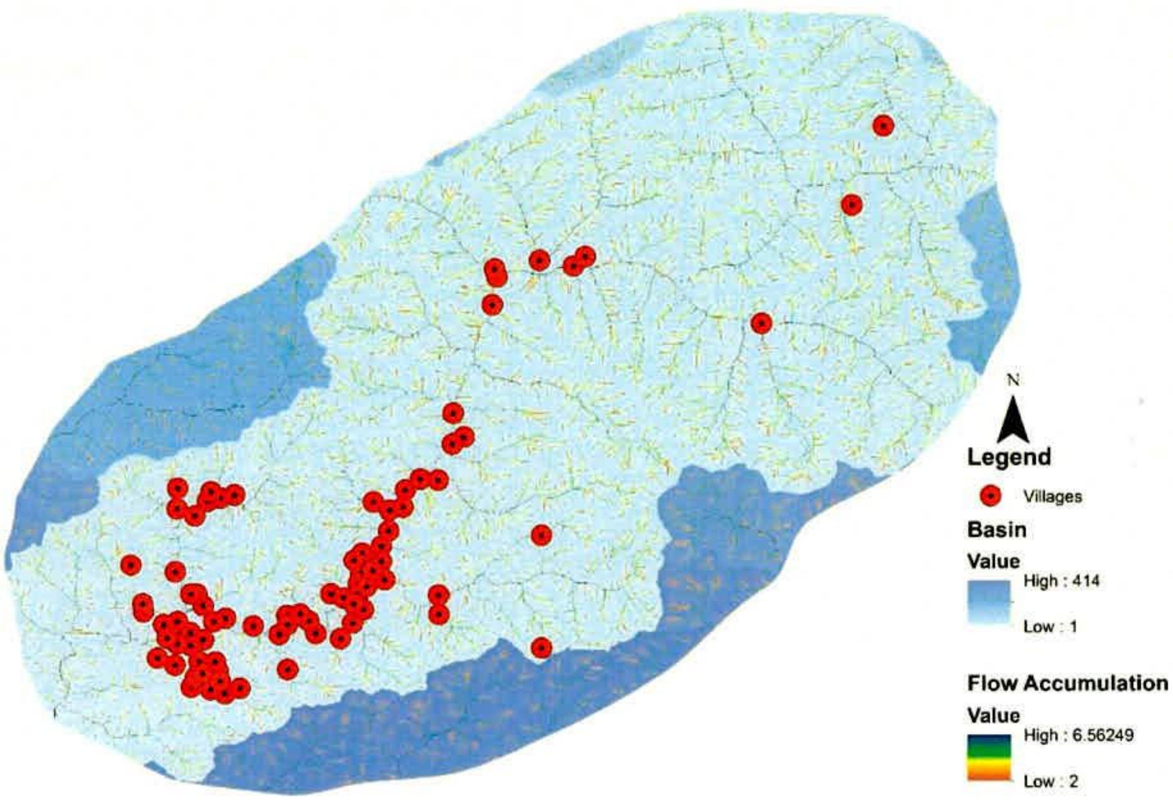


Figure 4-16: Flow Accumulation and Basin Map of ESZ

Analysis and Inferences

- Basin tools shows multiple basins created by the waterbody.
- Basins are created with the help of flow accumulation.
- Basin creation can be done with Basin tool which is under Hydrology tools in Spatial Analyst.
- Basin are divided as raster, but can be converted to polygons using data management tools.
- This has a major role is agriculture and disaster mitigation and management.

4.15. Land use Map

Land use map is required to understand for what purpose different areas put into use. Land use map is a polygon feature. It is created using the cut polygon tool in ArcGIS. Since the area being large, in this study land use map is prepared at a macro level.

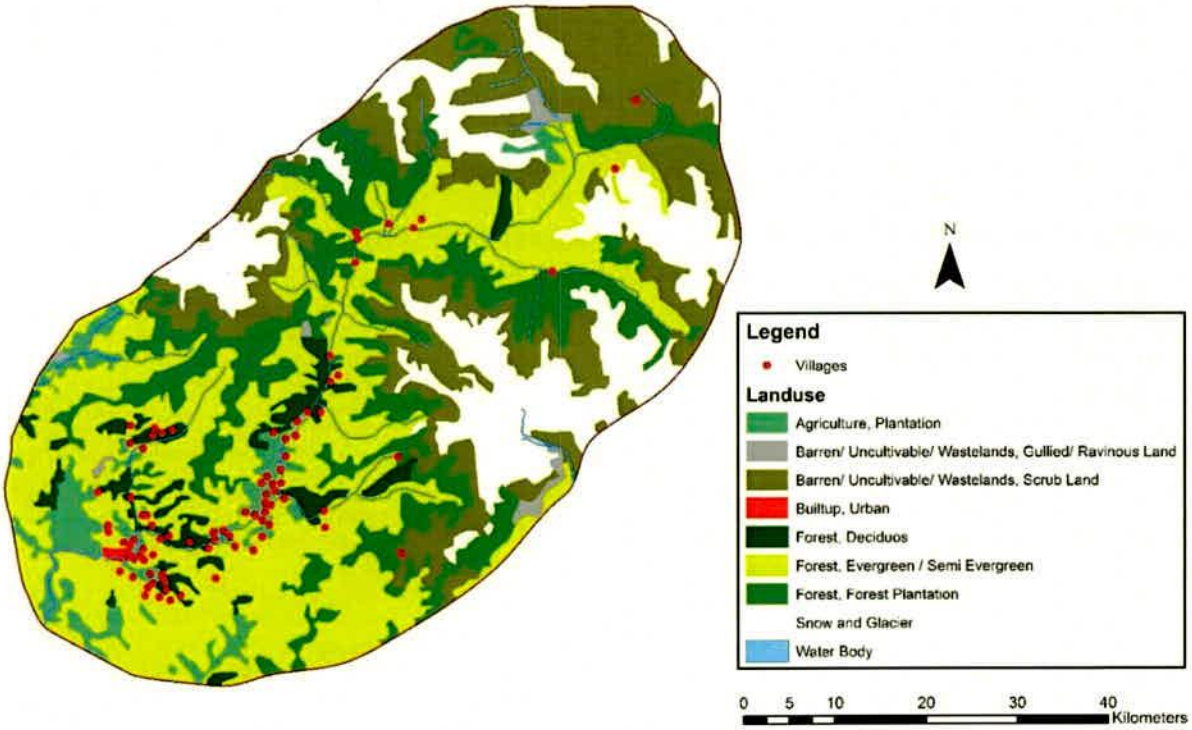


Figure 4-17: Land use Map of ESZ

Analysis and Inferences

- Land use map has a major role is finding locations suitable for development. Especially because the area being highly vulnerable to disasters.
- It can be noticed that most of the area come under forest, glaciers and wastelands.

- Even though there are 88 villages under the ESZ, comparing it with total area the major built-up area is negligible.
- As per the MoEF guidelines forest area can't be used for any kind of development, thus limiting the developers in finding a proper location for development.
- Wastelands are the major areas that can be used for development purpose. But since most of this area being at higher altitude and near to glaciers, the available area for development gets limited.

4.16. Major Road Networks

Road network are created using polyline feature. For this study since the area being large only the major road are mapped. Further buffers will be created in order to do the proximity analysis to find the locations that are suitable for development.

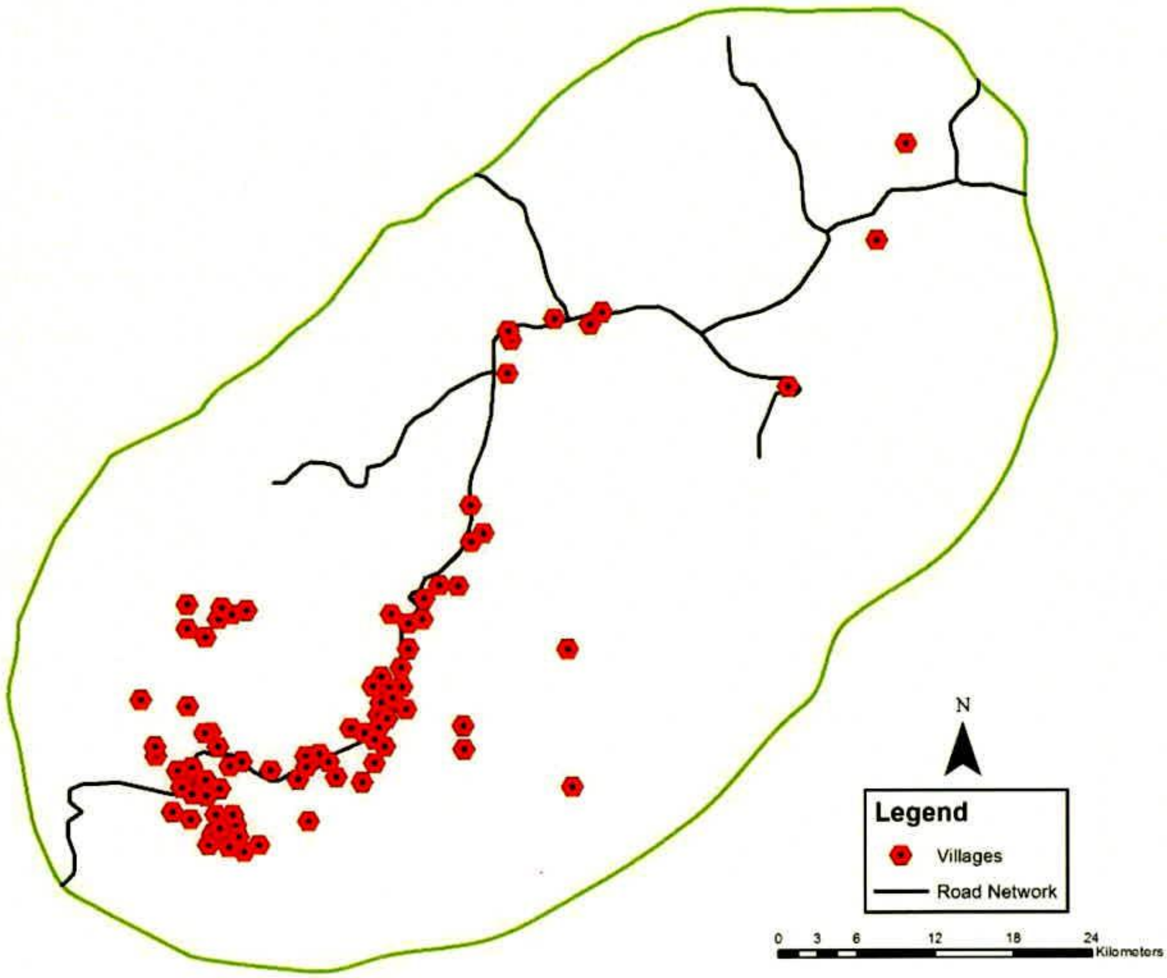


Figure 4-18: Major Road Network Map of ESZ

Analysis and Inferences

- Accessibility is a major parameter to be considered in case of selecting a site.
- Road network near development site help in logistics of materials required for infrastructure and development.
- In ESZ location due to increase in disaster frequencies the road network near location helps in evacuation and providing relief and medical support.
- Road network is created as a polyline feature.
- Only major road networks are considered as the planning is done at a macro level.
- It can visualised that the road networks has been constructed in such way that most villages can access it.

4.17. Road Network Buffer

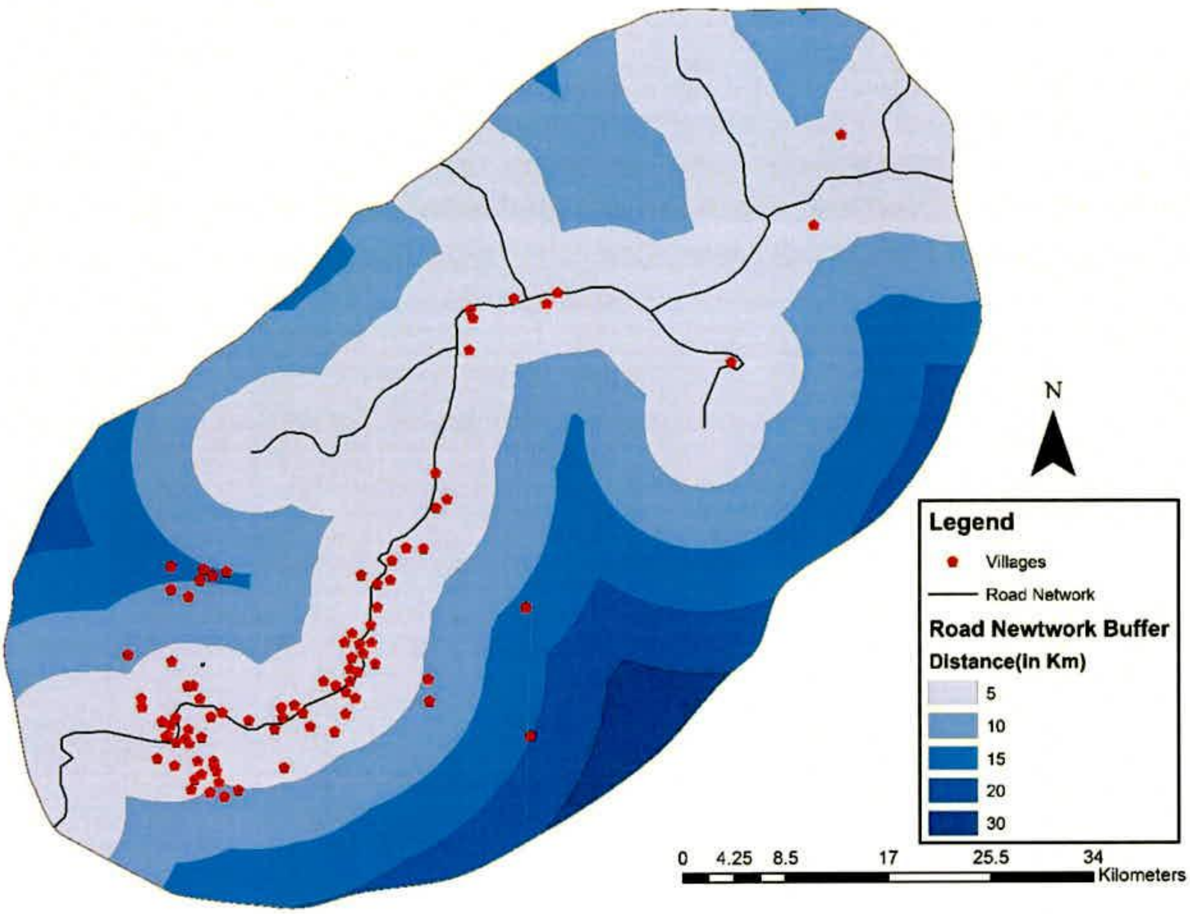


Figure 4-19: Road Network Buffer Map of ESZ

Analysis and Inferences

- Road network buffer is required for the land suitability analysis.
- In this study buffer is created at 5, 10, 15, 20, 30 kilometres.
- During development location near to the major roads are better.
- It can be seen that most of the existing villages under ESZ comes under the buffer under 5 kilometres buffer.

4.18. Wastelands

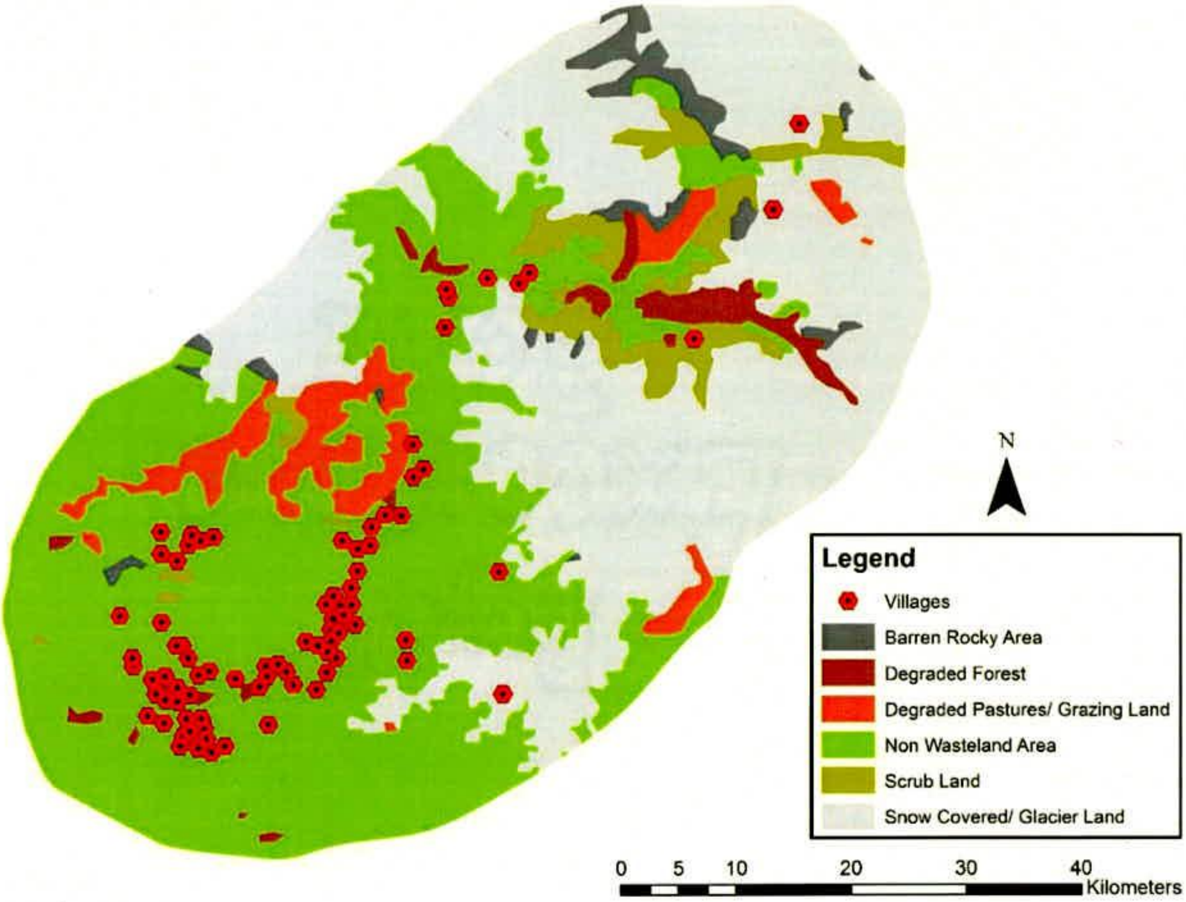


Figure 4-20: Wasteland Map of ESZ

Analysis and Inferences

- Wastelands are the areas that can be used for development purpose.
- Glacier areas can't be used for the purpose of development.
- Degraded forest areas can't be totally used for development as it can be used for afforestation.

- Scrub lands are the most suitable for the development purpose. The area covered is large but due to the steep slope all the areas can't be used for development.

4.19. Euclidean Distance between villages

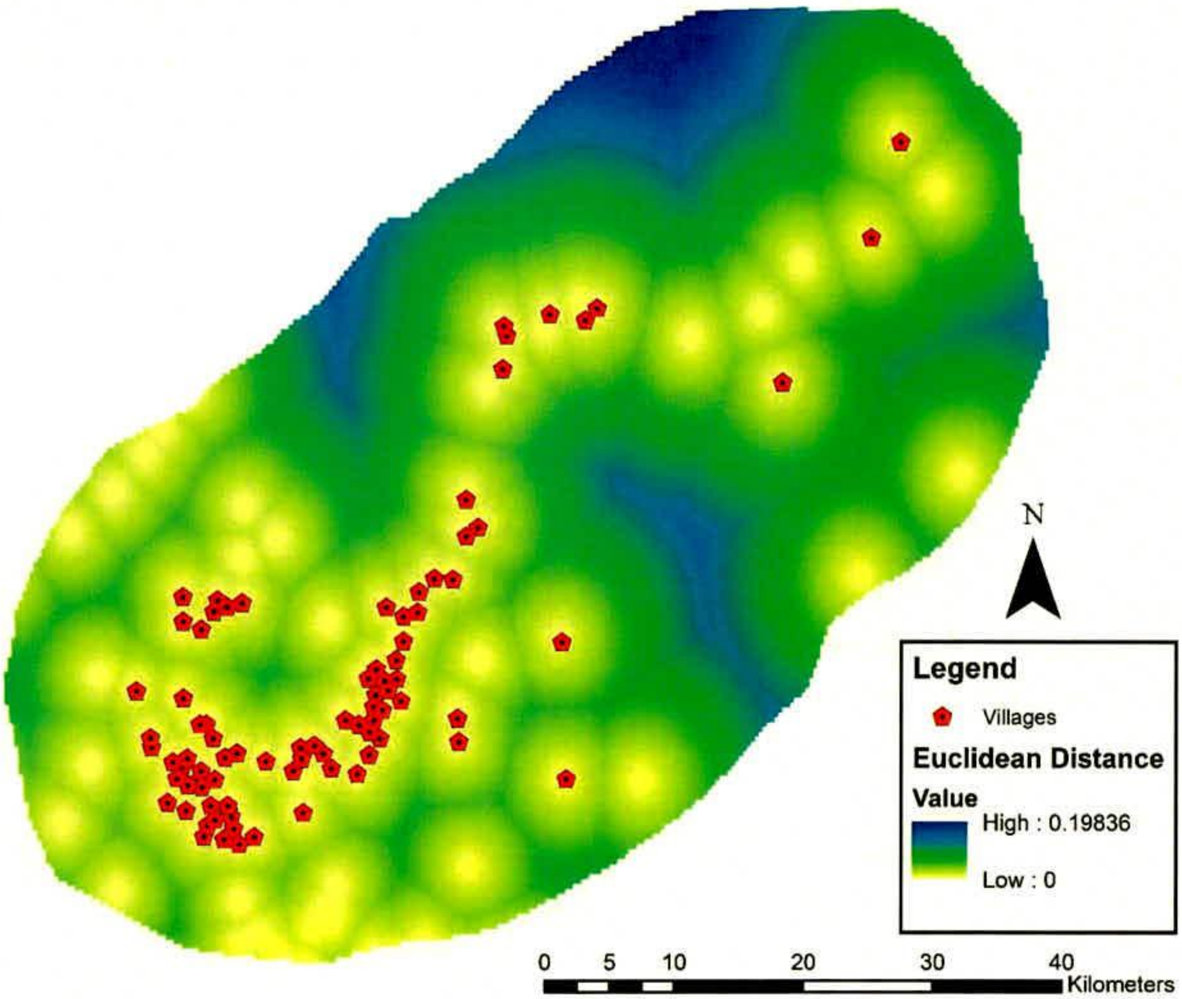


Figure 4-21: Euclidean Distance Map of ESZ

Analysis and Inferences

- Euclidean distance is the distance between two points in a Euclidean space.
- In this site all the villages even the ones not included in ESZ is considered.
- This has a major role as finding villages near in the surrounding would be of use while developing an area.

4.20. Reclassified Slopes

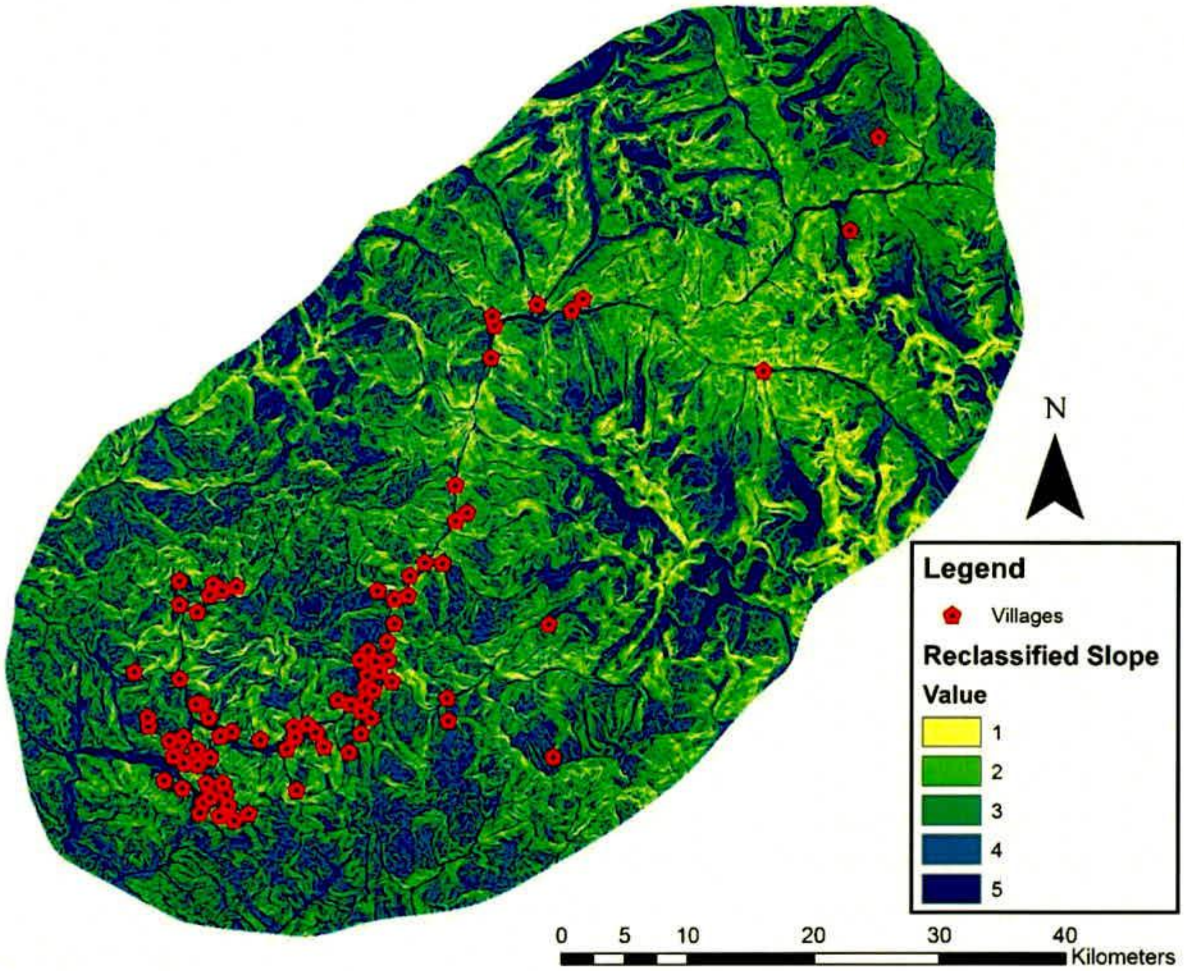


Figure 4-22: Reclassified Slope Map

Analysis and Inferences

- Slope map generated has to be reclassified for the purpose of land suitability analysis.
- Reclassification is done to 5 classes.
- Classified under equal intervals, the higher degree of slope mean lower value in reclassification and vice versa.
- Most of the villages under ESZ come under slope with lower degrees.
- For the purpose of infrastructure development any slope more than 30° can't be used.
- The area being vulnerable to cloud burst and flooding, construction of building at locations with higher degree of slope can increase the risk of landslide.

4.21. Reclassified Hillshade

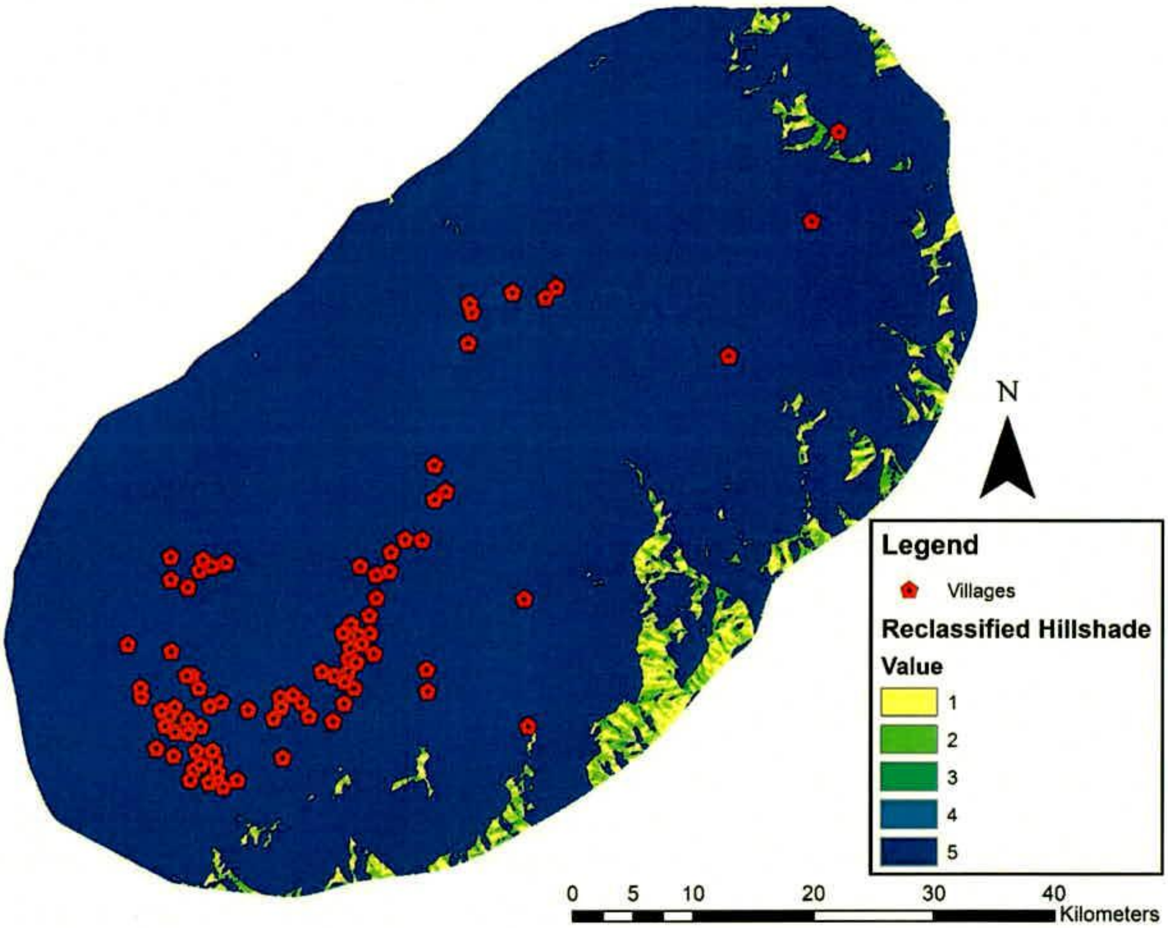


Figure 4-23: Reclassified Hillshade Map

Analysis and Inferences

- Hillshade is reclassified in 5 classes.
- Highest assigned value is 5 and lowest in 1.
- Areas receiving more sunlight is given highest value and the ones that remains under shade is assigned lower values through classification.

4.22. Reclassification of Relative Relief

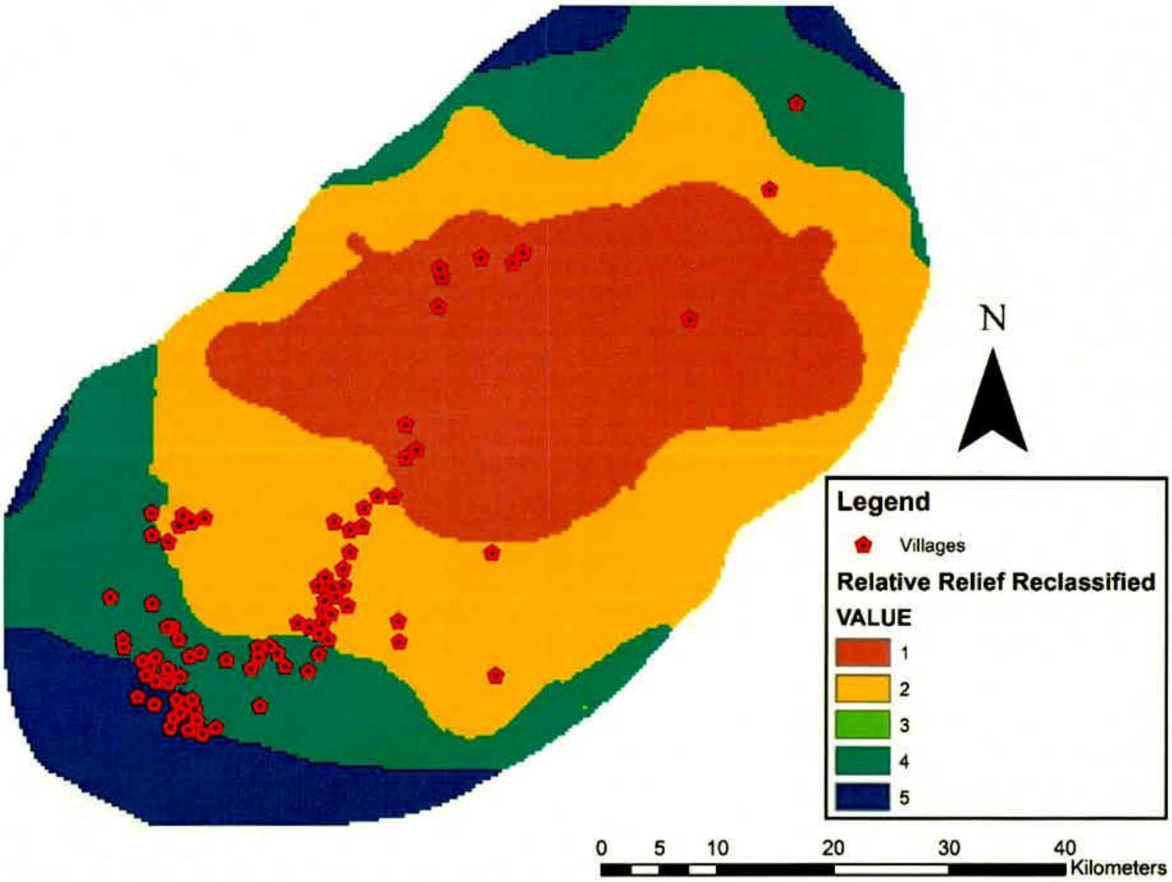


Figure 4-24: Reclassified Relative Relief Map

Analysis and Inferences

- Relative relief shows the change is height between two points.
- It is reclassified into 5 classes, 1-5(5 being higher).
- Areas with higher relative relief are reclassified to lower values and vice versa.

4.23. Reclassification of Euclidean Distance

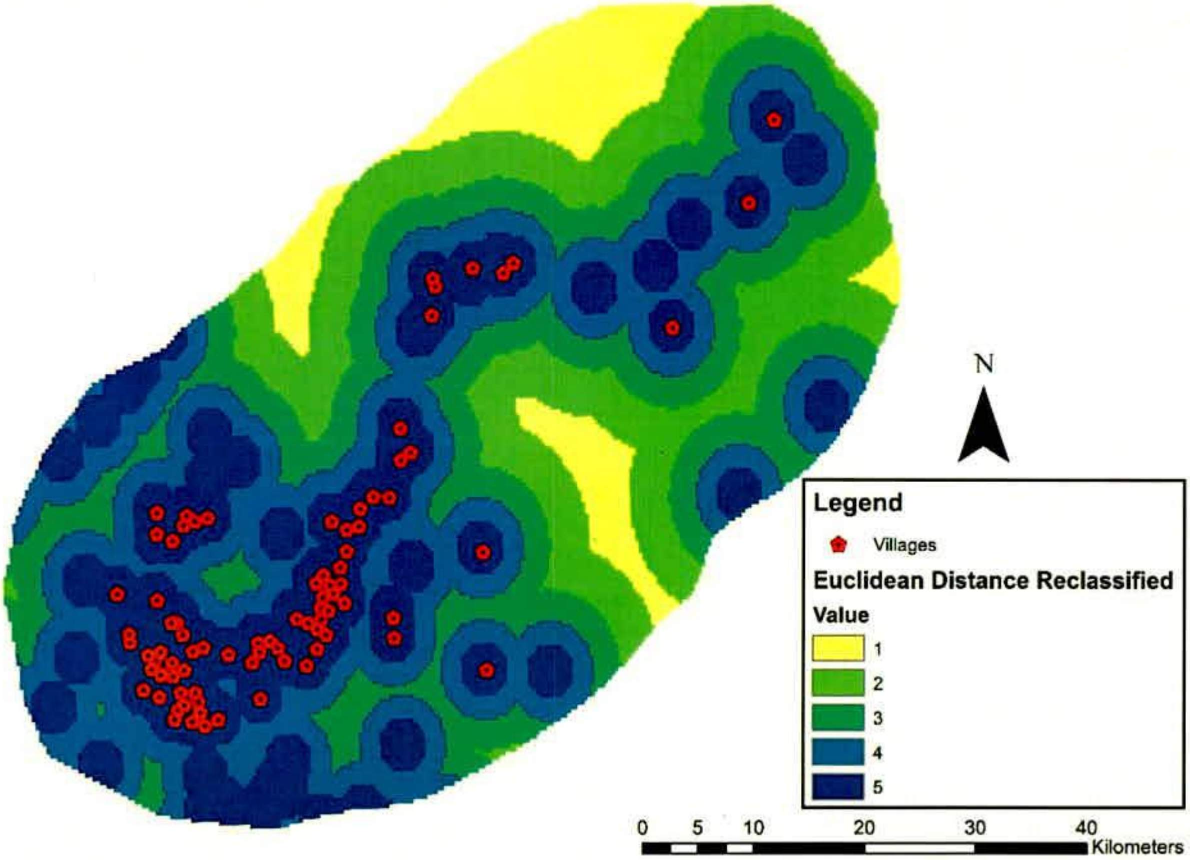


Figure 4-25: Reclassified Euclidean Distance Map

Analysis and Inferences

- Euclidean distance is reclassified in 5 classes, 1-5(5 being higher).
- More the villages closer, more suitable for development.
- Reclassification is done into 5 classes, 1-5(5 being higher).
- If the villages are closer higher values are given and if away lower the value.

4.24. Road Network Buffer Reclassified

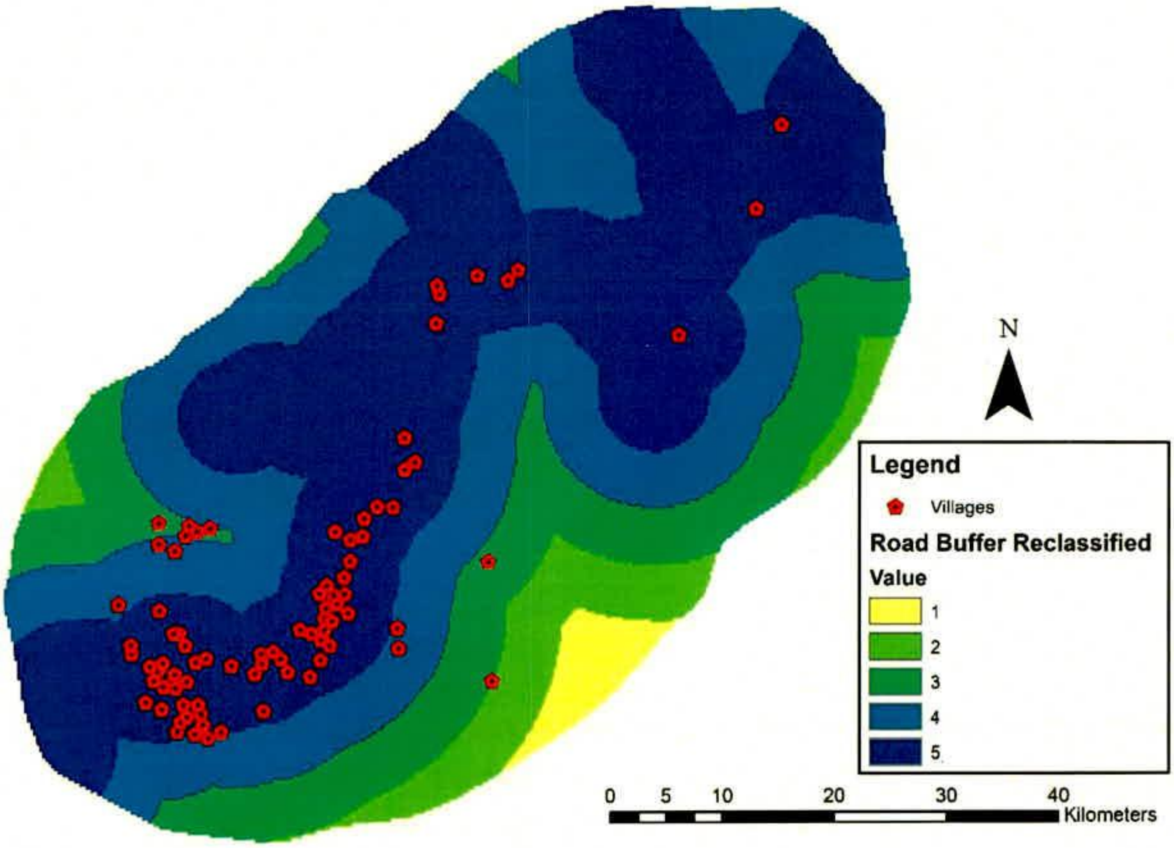


Figure 4-26: Reclassified Road Network Buffer Map

Analysis and Inferences

- Road network buffers are reclassified into 5 classes, 1-5(5 being higher).
- Any major road nearby would steer the development.
- Presently the major road networks can be easily accessed by most of the villages.

4.25. Land Suitability Analysis

Land suitability analysis is performed to find locations that are suitable for development. Model Builder in ArcGIS is used for this analysis. A model is created with the model builder and is run to get the suitable location for development. The model created is shown in Figure 4-27.

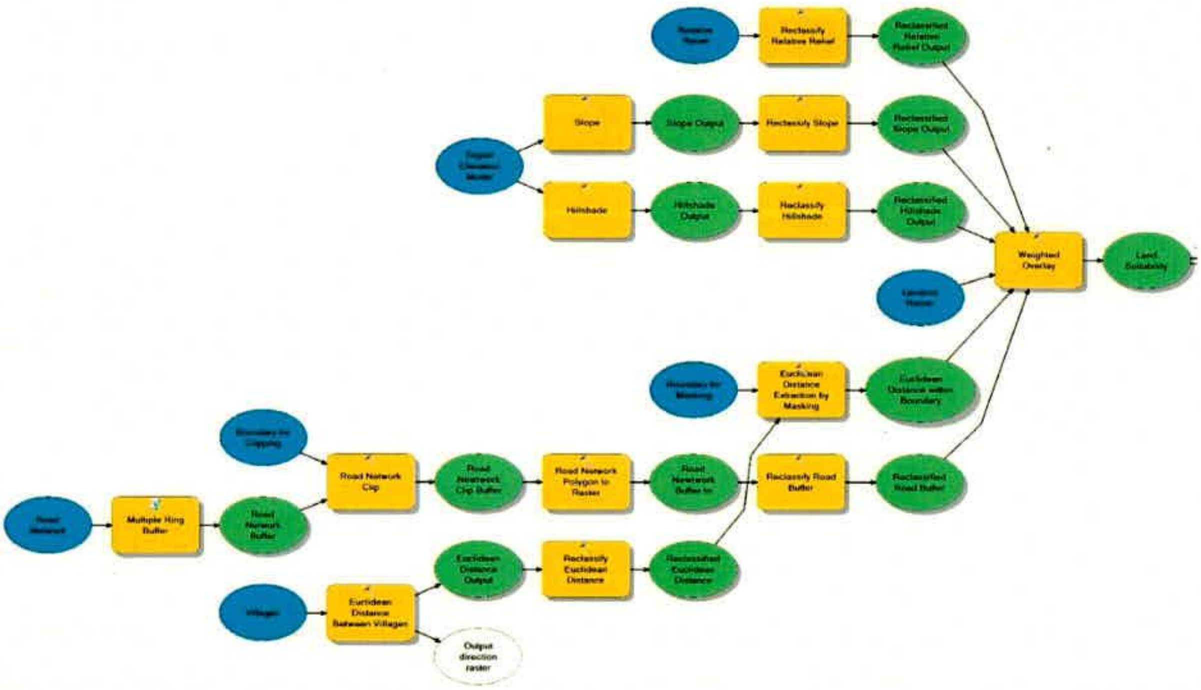


Figure 4-27: Land Suitability Analysis Model in Model Builder

As seen in the model six parameters are used for the land suitability analysis.

- Relative Relief is added as an input and then reclassified into five classes to obtain the Reclassified Relative Relief Output.
- DEM is used to generate the slope. The slope generated is further used as the input for reclassifying the slope into five classes to obtain Reclassified Slope Output.
- DEM is used to generate the hillshade. The hillshade generated is further used as the input for reclassifying the hillshade into five classes to obtain Reclassified Hillshade Output.
- Land use map which is a vector is converted to raster and is added directly.
- Village locations are added to find the Euclidean distance. The Euclidean Distance Output is the reclassified into five classes. Since the Euclidean distance map extends beyond the boundary of site, Extract by Mask tool is used to extract the raster data that comes within the boundary.

- Road Network shapefile is added and then multiple ring buffers are created around it. This being a vector data is the clipped in order extract the data within the boundary. Then these polygons are converted to raster using Conversion Tools. Further the raster is reclassified in five classes.

Once the Land use raster along with five other reclassified parameters are added Weighted Overlay is done. In this all the six parameters are linked to it then percentage values are defined to each parameter depending on the importance. While summing up all he percentage value it should come to 100%. The Evaluation Scale is set '1 to 5 by 5', meaning land suitability will range from 1 to 5 starting with 1 and increasing towards 5. Further within each parameters classes are given ranked from 1-5(on the basis of Evaluation Scale). There is an additional option 'Restricted'. If this value is chosen in any parameter, whatever maybe the rank for other parameters the value will remain 0. In this study if the slope is more than 30° the site can't be used for development, so it will be defined Restricted. In the case of land use as per the Zonal Plan of ESZ no development can take place in forest locations. Thus even it will be defined Restricted. Finally it is save to a specific folder and then the model is run. The output is shown below:

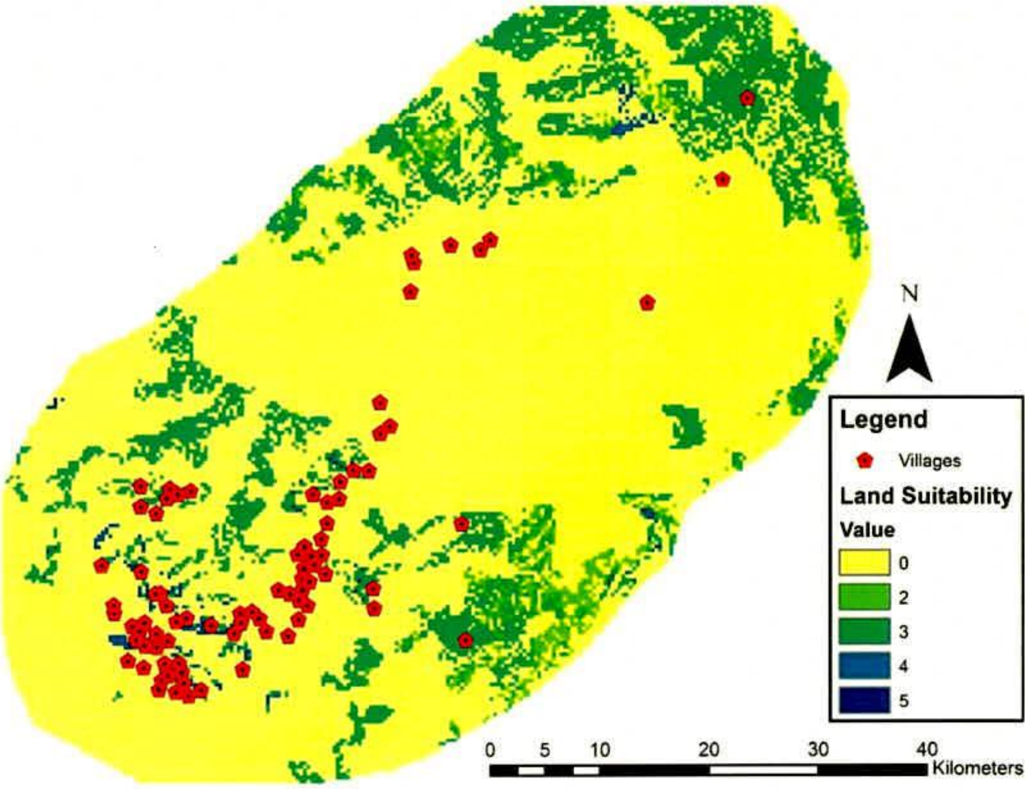


Figure 4-28: Land Suitability Map of ESZ

Analysis and Inferences

- The dark blue locations are most suitable for development.
- The yellow locations are not suitable for development.
- Locations with Land Suitability value 3 and 4 can also be considered for minor developments without too much infrastructure or for agriculture.
- Location with Land Suitability vale 2 has low suitability thus can be vulnerable to disasters.

4.26. Most Suitable Locations for Development

Many of the patches are showing high suitability, but finding the most suitable locations is very important. For this Model Builder is further used. In this case Land Suitability Analysis acts as the input. Model used is in Figure 4-29.

Figure 4-29: Most Suitable Location for Development in Model Builder

- Land suitability is used as input for this process.
- To find the most suitable location we need to use the Condition tool. In the tool we add the condition that 'Value = 4'(values is 4 since the values in Land Suitability raster attribute table starts with 0, thus Value in attribute table to value in Land Suitability scale will be like 0=0, 1=2, 2=3,3=4, 4=5. This is because the value 1 is not there is Land Suitability scale).
- Majority Filter in Spatial Analyst toolbox is used to find location that has large number of cells with same Value. Number of neighbours to be used was set to eight. So only of five out of eight has same values have same value centre cell the centre cell value will be retained. This would give a raster output showing the most suitable areas.
- For further analysis we need this raster to be converted to a vector. Thus using conversion tools raster is converted to polygon. This will help is finding the area of different sites, perimeter and for applying further conditions.

The most suitable location map is shown in Figure 4-30.

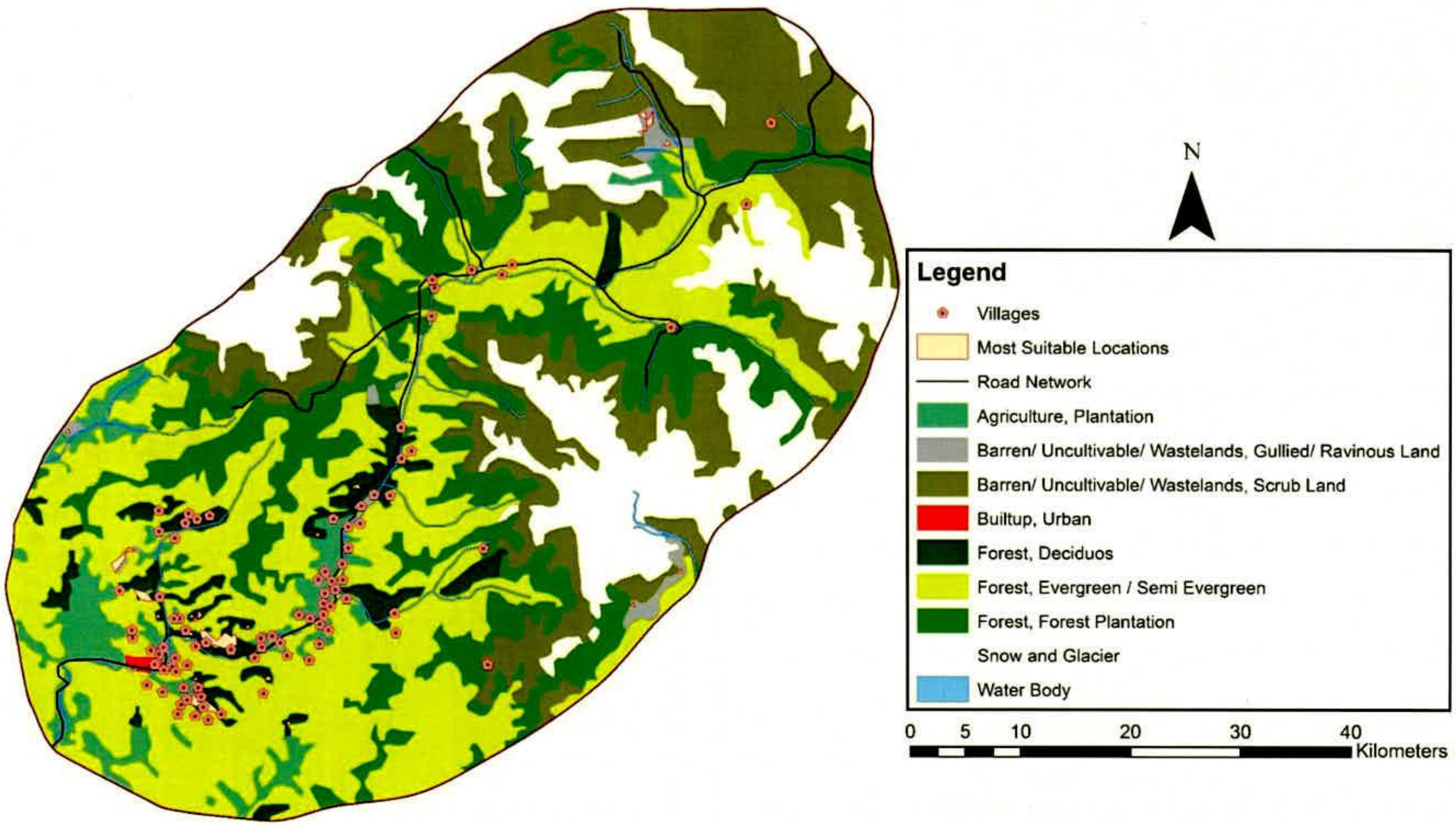


Figure 4-30: Most Suitable Locations for Development

4.27. Magnified View of Most Suitable Locations

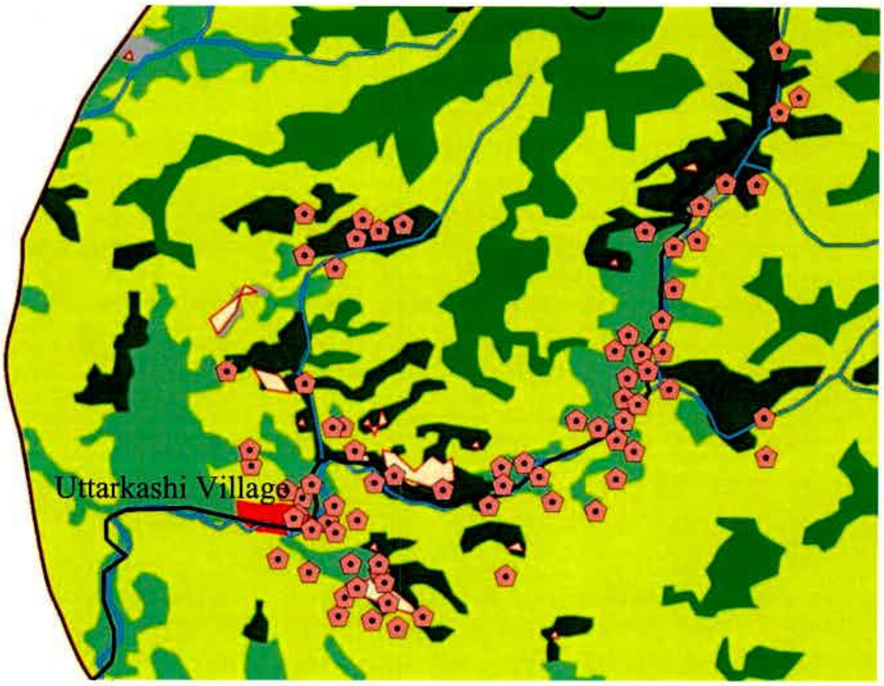


Figure 4-31: Most Suitable Locations for Development near Uttarkashi Village

Figure 4-32: Most Suitable Locations for Development near Gangotri Village

Analysis and Inferences

Most suitable locations are mostly location near the Uttarkashi Village and few near Gangotri village. Due to the elevation factors and accessibility issues has reulsted in more areas near Uttarkashi than at Gangotri.

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

The study showed the process of land use planning can be done with the help of Remote Sensing and GIS. This type planning process is applicable when the areas are not easily accessible.

Model Builder in ArcGIS was of great use in the case of comparing data of different parameters and combining the result to come to a result which was land suitability. While analysing the land use map it is seen that a major part of the site comes under the forest land. As per the zonal plan of the ESZ none of the ecological parameters can be disturbed, which prevents these area from having any kind of developments. The restricting these site for development areas site selection can be done with Model Builder. In addition to this the conditional evaluation tool helped in extracting the required data. The biggest advantage is that the models created can be further used for other locations too by changing the input data. The final result of the study showed the most suitable locations for development. Even the other tools like Spatial Analyst, Conversion Tools, and Data Management Tools are of high use when data has to be fed in a specific format for a specific process. Like in the case of Weighted Overlay when all the data has to be in raster format and has to be reclassified into equal number of classes. Remote Sensing data used was the DEM of 30 meter resolution which was used for multiple analysis like slope, hillshade, flow accumulation, relative relief, etc.

This type of modelling has high scope in future especially due to increase in frequencies of disaster. Using Model Builder many of the analysis can be performed very fast and it provides people with visual understanding on inter relation between the parameter, importance given to each parameter and method in which the whole process is carried out.

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