

ADDIS ABABA UNIVERSITY SCHOOL OF GRADUATE STUDY



**LAND DEGRADATION MAPPING AND EROSION
ESTIMATE IN GADO SUBWATERSHED USING REMOTE SENSING
AND GEOGRAPHICAL INFORMATION SYSTEM**

By

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DECLARATION

I the undersigned declare that my thesis being entitled in the original work has not been presented for a degree in any university. Source of relevant materials taken from books and articles have been duly acknowledged.

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ADDIS ABABA UNIVERSITY School of GRADUATE STUDY
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Acrimony

A (Equation)= Soil loss ton/ha-year

AAU = Addis Ababa University

a.s.l = above sea level

CSE = Conservation Strategy of Ethiopia

EIAR = Ethiopian Institute of Agriculture Research

EMR = Electromagnetic Radiation

Ha = hectare

IFOV = Instant Field of View

JICA = Japan International Agency

K- Factor = Soil erodibility

MERET = Managing Environmental Resource to Enable Transition to More Sustainable
Livelihood

MoA = Ministry of Agriculture

MoARD = Ministry of Agriculture and Rural Development

MoME = Ministry of Mine and Energy

MoWR = Ministry of Water Resources

NSCS = National Soil Conservation Strategy

PPNSCSE = Project Proposal for A National Soil Conservation Strategy for Ethiopia

OM = Organic Matter

RRC = Relief and Rehabilitation Commission

RUSLE = Revised Universal Soil Loss Equation

R_factor = Rainfall erosivity

LS = Slope length factor

S = Slope

S and WC = Soil and Water Conservation

SE = South East

SWCS = Soil and Water Conservation Service

SRCP = Soil Conservation Research Project

SRTM = Shuttle Radar Topographic Mission

SWD = Subwatershed

USLE = Universal Soil Loss Equation

WBISPP = Woody Biomass Inventory and Strategic Planning Project

WFP = World Food Program (WFP)

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Abstract

Land degradation is exhibited in different forms of which soil erosion is dominantly affecting the livelihood of many people who are dependent on natural resources in particular on agriculture. In this respect, a land degradation study was conducted in Gado subwatershed, which covers 500 km². The site is located in North Shewa Zone, Amhara region of longitude 39° 28' 31E - 39° 44' 24 E and latitude 9° 41' 3N - 9° 54' 49 N. Satellite images, thematic maps and relevant data were acquired, organized, analyzed and produced information for decision making. Supervised classification was undertaken on Enhanced Thematic Mapper (ETM+) and land use/land cover of the area was developed. Land use/land cover map revealed, degraded land (150 km²), plantation (18.60 km²), scrub land (62 km²), cultivated land (180.4 km²), grassland (8.7 km²), and marginal lands (91.8 km²). Land classification contingency matrix developed and evaluated for the accuracy to be more than 85%, and histogram of the classification was also evaluated. Land degradation map of the study area was extracted from the land use map. It was also attempted to estimate depth of streams/gullies in the subwatershed by analyzing contour lines and it revealed that depth of channel increases as elevation decreases, and the relationship is polynomial. Rate of soil erosion was estimated using Universal Soil Loss Equation (USLE) and the maximum erosion rate identified for the subwatershed was more than 171 t/ha/year with average rate of 22 t/ha/year. Erosion rate was related to drainage network. On areas of high concentration of streams similarly high erosion rate was noticed. Erosion rate identified was beyond soil formation rate of 2 t/ha/year. Abay Basin Master Plan Study stated North shewa zone erosion rate between 51-100 ton/ha/year and classified under area that cannot tolerate further soil loss which the subwatershed is also located. The subwatershed is under severe threat and the community livelihood as a consequence.

Key words: Degradation, Erosion, Remote sensing and GIS, Sub-watershed, USLE.

Chapter I

1. Introduction

1.1 Background and Justification

Land degradation can be generalized as the physical, biological, and chemical property of one or more of land resources such as water, vegetation, soil, rock, air, climate, and relief productivity declines and become less worth to grow crop in the agricultural context (UN/FAO). Indication of land degradation can be manifested in sanitization, soil erosion, acidification, deforestation, overgrazing, soil compaction, crusting and leaching. Areas that support many people with food grain, fiber, forest and forest products, and fodder become less productive and turn to bare land sometimes. This, in turn affects populations of living organisms that forms a system and human being in particular. Of all land degradation forms, soil erosion plays a significant role.

Soil erosion, soil salinity and related problems have faced man ever since he first settled and started to cultivate the land some 7000 years ago(Kebede Tato and Hans H.,1992). Moreover, Jacks, G.V. and Whyte, R.O. (1939) related erosion process very old (geological erosion/ denudation) and universal phenomenon that carved the earth in to its present shape through thousands of years. They also mentioned denudation early and important process of soil formation where by the original rock material is continuously broken down and sorted out by wind and water until it becomes suitable for colonization by plants. Similarly, Kebede Tato and Hans H. (1992) revealed soil erosion should be investigated as geo-ecological process controlled by different natural actors (geomorphological, pedagogical, climatically) and agro-technical, economical and political factors and appraised holistically.

Soil erosion is one of the major factors causing severe land degradation problem in Ethiopia, which in turn is threatening the agricultural productivity and the very survival of the overwhelming majority of the rural population. The rate of soil loss, depletion of soil organic matter and nutrients as a result is so high and much faster than they can be replaced. The Ethiopian Highland Reclamation Study (FAO, 1986) estimated that water erosion moves nearly 1.9 billion tons of fertile soil from the highlands annually. This amount is found to be equivalent to an average soil loss of 130 tons per hectare per year from cultivated lands. The same study indicates that about 50% of the highlands have been significantly eroded and 25 percent seriously eroded. The study area is also a partly affected by this process.

Identifying the degree of erosion and map the erosion distribution is important to examine the scope of damage and to envisage the consequence. Undertaking such activity is important for mitigation action before the situation gets worst. There are efforts to investigate erosion related studies in many areas while comparing with existing situation is interesting to see changes. In this respect, in the first chapter which is an introduction part specifies background and justification of the study, its importance, general and specific objectives were pointed out (chapter 1). Chapter two mainly focuses on literature review that discusses important technical terms on remote sensing, GIS, and degradation and conservation. Moreover, it summarizes past experience on soil conservation activities at national level in particular.

Chapter three focuses on describing the location of the study area, Gado subwatershed, enclosed kebeles, geology, topography, soils, land use and rainfall. The method and materials used in this study are in chapter four. This chapter indicates the primary and secondary data sets used. List of materials and softwares used are also indicated. Data analyses and interpretation aspect that includes image processing and image enhancement for which visual interpretation could be improved are in the same chapter. The different enhancement tools such as Histogram equalizer, Band combination and Normalized Difference Vegetation Index (NDVI) are illustrated for which land features could be identified during classification. In addition, the different steps that Digital Elevation Model (DEM) should be followed in delineation of watershed are also briefly described. The method and material section also discusses furthermore the Universal Soil Loss Equation (USLE) Model besides defining the five important parameters which the model built upon.

Result and discussion are given on the fifth chapter, where the different erosion types such as sheet and rill erosions are discussed, degraded lands mapped in particular bare lands, streams and gullies are shown. Furthermore, stream/gully average depths are estimated by analyzing contour lines using QuantumGIS.

The Universal Soil Loss Equation (USLE), which predicts the long-term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices (Wischmeier and Smith 1978) was applied to estimate erosion rate (chapter 5). Soil erosion rate of the subwatershed was identified by overlaying the above parameters. The result reveals erosion rate up to 170 ton/hactare/year. Conclusion and recommendations are given in the last chapter, (chapter 6), that draws the lessons extracted from the study and actions required to avert the danger of soil erosion.

Remote sensing and Geographic Information system are valuable tools in assessing changes (land use and land cover, degree of land degradation and extent, orientation and direction) of resource in space. The computer based

technology enables modeling what would happen next under different scenarios, the wide area coverage further enables to understand the relationships that exist in a system.

1.2. Statement of the Problem

Gado Catchment is characterized by rugged topography of irregular and steep terrains, which makes agricultural practices, human and livestock mobility difficult in the area. The amount of annual rainfall is 1120 mm, which is relatively high and intensive to cause severe soil erosion problem. Moreover, shallow soil depth is indicated in some studies in Ethiopian highlands. The steepness and irregularity of the topography, high population pressure, high and intensive rainfall combined with the poor and century old cultural practices caused severe soil erosion and seriously damaged the productivity and sustainability of the agricultural lands with far reaching consequences of food insecurity and vicious poverty problems.

In order to reverse this interweaving environmental, economic and social problems of the area, the government launched massive land rehabilitation and soil and water conservation measures. Implemented a wide range of techniques including soil bunds, stone bands, Fanya juu terraces, cutoff drains, waterways, check dams and micro basins during the last two to three decades. In this process of massive land rehabilitated including farmlands, degraded forest or grazing lands and lands affected by gullies were treated. Similarly, huge size of degraded hillsides were closed from livestock and human interference and were treated with various soil and water conservation(SWC) interventions to enhance the rate of natural regeneration, establishment of planted vegetation and intensification of the overall biomass production.

Implementation of various soil and water conservation strategies was complemented with extensive vegetative measures, where various multipurpose plant species were planted on conservation structures, in degraded hillsides in the form of hedges or dispersed agro-forestry. As a result, considerable size of cultivated lands were protected from soil erosion. Their productivity enhanced, the enrichment plantation of the degraded hillsides with multipurpose species boosted the amount of biomass production from the closed areas which availed a great opportunity of accessing fuelwood, construction material and livestock feed. The huge biomass created is used either for generating income or for meeting the domestic needs of the community.

Despite the fact that the massive land rehabilitation measures proved to be valuable for sustainable management of the environment and improvement of the livelihoods of the inhabitants, the coverage and extent of the achievements are still below the requirements indicating the need to meet the ultimate objectives. Furthermore, the ongoing soil and water conservation efforts were not adequately supported by regular maintenance works and as a result, structures were damaged(Chris R., Ian S. and Camilla T.,1996). Breakage, partial removal and destruction of conservation structures werecommon in the proposed watershed and this indicated the limitation of

the efforts. Moreover, farmers have their own reasons that require an investigation, which RS and GIS might address through analysis.

In view of this, it is intended to investigate degree of the land degradation in the subwatershed. Furthermore, changes in land use and land cover of the last three decades were heighlited in the Gado watershed. Assessment of soil erosion situation in the area is also made.

1.3 Objective

1.3.1 General objective

The general objective of the study is to evaluate the soil erosion hazard and extent of the problem mainly using Remote Sensing and Geographical Information System and applying USLE Model.

1.3.2. Specific Objectives

The specific objectives of the study include

- To estimate soil loss in the watershed,
- To map degraded lands of the subwatershed,
- To suggest appropriate mitigative measures, and
- To undertaken appropriate action accordingly.

The result of the study will reveal the degree of erosion in the subwatershed and its distribution. Areas that are under severe hazard will be clearly displayed and accordingly appropriate action should be undertaken before the situation gets worst.

Chapter II

2 Literature review

2.1. Remote Sensing

Remote Sensing has been defined in many forms while the basic objective and methods are similar. The commonly used definitions are as follows.

Remote Sensing is a science or art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation (Lillesand and Kiefer, 1994).

Remote sensing is the acquisition of data and derivative information about objects or materials (targets) located at the Earth's surface or in its atmosphere using sensors mounted on platforms located at distance from the targets to make measurements (usually multispectral) of interactions between the targets and electromagnetic radiation (Saud Amer, 2008).

The remotely collected data can be in many forms including variation in force of distributions, acoustic wave distribution, and electromagnetic energy distribution. Sensors acquire data on various feature of earth emitted or reflected electromagnetic energy. Most common sensing systems operate in one or several of the visible, infrared, microwave portions of the spectrum. The source of energy could be by the sensor own (active sensor) or solar (passive).

2.1.1. Spectral Reflectance

Energy reflected, absorbed and transmitted varies for different earth features depending on their material type and condition. These differences permit us to differentiate one object from others. However, objects that respond similar in a certain portion of electromagnetic radiation might differ in other portion of the wavelength that objects can be discriminated.

A graph of spectral reflectance curves of an object as a function of wavelength is called a spectral reflectance curve. The configuration of spectral reflectance curves provides insight characteristics of an object and has a strong influence on the choice of wavelength region(s) in which remote sensing data are acquired for a particular application. Hence, the spectral reflectance curve of deciduous and coniferous forests differ. Healthy vegetation shows considerable increase from green band to infrared while water bodies decline. The difference in water content and organic content could affect the reflectance of soil.

Differentiating objects with the above indicated ways doesn't mean identification of objects is simple. This could be for the reason that objects with variation in moisture content alone respond differently to electromagnetic radiation and species divergence within the same category lead to range of values than specific value of reflectance. Availability of sufficient energy to illuminate the object and atmospheric effect will have considerable importance to the changes as well. Hence, texture, tone, shape, pattern, shadow, size, association are some of the techniques used in visual classification. Therefore, different mechanisms should be in use for the purpose of objects identification. The information obtained through a number of processes will be organized in GIS environment for decision making.

2.1.2 Digital Image Processing

2.1.2.1 Digital Image

Sensors on board record electromagnetic radiation reflected or emitted by the surface of earth. Sensors generate electric signals that represent energy variation (brightness) and record in digital number ranging 0-255 for which 0 is black and 255 white while the rest represented by gray scale. Digital Image is composed of 2 dimensional array of discrete picture elements (pixel) representing the average brightness or radiance measured.

2.1.2.2 Digital Image Processing

It is a very broad subject that often involves complex mathematical procedures to manipulate and interpretate digital image with the aid of computer. The computer inserts the data into equation or series of equations and stores the results of the computation for each pixel that may be displayed or recorded into picture format or could be manipulated further representing certain features of earth.

2.1.2.3. Geometric Correction

Sources of geometric distortion ranges from variation in altitude of sensor, attitude and velocity of sensor platform, earth curvature, atmospheric refraction, relief displacement and non-linearity in the sweep of a sensor and Instant Field of View (IFOV). Therefore, the intent of geometric correction is compensate for distortions through applying formulas derived by modeling the source of distortion mathematically or analyzing well-distributed ground control points.

2.1.2.4 Radiometric Correction

Radiance measured by any given system over a given object is influenced by such factors as changes in scene illumination, atmospheric condition, viewing geometry and instrument response characteristics. Hence, solar illumination angle is normalized by calibrating pixel brightness assuming the sun at zenith on each date of sensing for seasonal variation. Moreover, earth-sun distance correction is also applied. Therefore, image noise that caused unwanted disturbance on image data need correction before processing.

2.2 Geographical Information System

It is a system of hardware, software, data, people, organizational arrangements for collecting, storing, analyzing, and disseminating information about an area of the earth. GIS is looked upon as a tool to assist in decision making and management of attributes that needs to be analyzed spatially. It integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes, and planning strategies.

2.3 Land Degradation and Conservation

Soil Conservation Research Project (SRCP, 1996) of Ethiopia indicated that the rate of soil loss in extreme cases reaches up to 300 ton/hectare/year with an average of 70 ton ha⁻¹ yr⁻¹. The amount is beyond tolerable soil loss rate. The project also estimated soil loss of about 1.5 billion ton each year. Furthermore, some studies mentioned the highlands of Ethiopia are considered to be amongst the most degraded lands in Africa.

The Woody Biomass Inventory and Strategic Planning Project (WBISPP, 2000) indicated Amhara Region soil erosion rate of less than 12.5 tons/ha/year while 18% suffers a soil loss of 12.5-200 t/ha/ year.

Soil and Water Conservation involves the development of systems for the management and utilization of land, water and vegetation resources that are sustained in the long run, that are economic and productive. The system takes into account of wide variation in reliefs, soils, climate and traditional and use practices. Moreover, it makes, integrated, comprehensive plans for the control of soil and water movement from top to the bottom of a slope (MoA, 1984).

The slope range of SWD reaches to 310 percent that indicates the degree of damage as slope increases. Hence, one of the options in reducing erosion is modifying slope by construction of terraces. Terraces at certain vertical interval are constructed by cut and fill of the landscape and the structure is supported with stone of certain thickness that could withstand the tangential force of soil that is being raised. The structure usually will have reversed slope 1:3 (vertical to horizontal) to withstand the pressure of soil mass built up. Hence, as soil height increases the thickness of stone for supporting the terrace will increase and declines accordingly. Normally, the upper out most thickness of the terrace will be 40- 50 centimeter thick and the

size of the stone big, thicker than 25 cm, while smaller sizes stone and soil is placed in between bigger stones to reduce water flow in stone faced terrace (Lakew Desta, Volli., F.P.C., Asrat Wondmu, and Yitayew Abebe, 2005).

2.3.1 Soil erosion

Soil erosion is the removal of soil by water /or wind. In the United States each hectare is losing soil and producing an average annual sediment loss about 3 ton/acre (31 t/ha) which is about 0.02 inch loss per acre (0.5cm/ha), while some areas lose more than this (Raymond, W., Miller R., et al, 1997). They also indicated croplands that are source of nearly 50% of the sediment and erosion. Furthermore, it was described that about 545 kg top soil was lost in eastern Washington for every 27 kg of wheat is produced. Similarly, in Ethiopia on cultivated lands alone 130 t/ha/year (FAO, 1986) is lost and hence, its effect on agriculture productivity would be by far greater than that of US.

Natural or geologic soil erosion rate of 2.5 cm of soil every 300 years is suggested equivalent to soil formation rate and hence no negative effect on soil (Raymond W., Miller R., et al, 1997). They indicated soil erosion rate can be increased terribly by human activities, such as intensive cultivating. Further, the cost of cleaning sediment from rivers and harbors each year is about 15 times more than the cost of holding the soil on the land from where it eroded. Reduction of water storage capacity also has an impact on the area of land, which would have been irrigated and the income that it could be generated as well. Therefore, soil erosion off-site cost is tremendous and attention should be given to its control before causing hazard.

2.3.2 Major causes of soil erosion

The removal of natural forests for the expansion of arable land, for fuelwood, charcoal and construction materials, overgrazing, intensive cultivation and poor cultural and land management practices have been stated as the major cause of soil erosion (MoA, 1989). Level of soil erosion and severity of land degradation is aggravated by the agricultural activities expanding to marginal lands that are not suitable for cultivation. Moreover, the increase in population pressure also caused more deforestation as a means of income generation through the sale of fuelwood and charcoal to cope with the low level of income and unemployment in the rural areas. All these conditions led to exploitative use of the land (i.e. using the land beyond its capacity with the result of low agricultural productivity and income, leading to poverty in the rural areas).

2.3.2.1 Causes of water erosion

Raindrops striking bare soil is separating particles and causing the finer particles to move with the flowing water as suspended sediments. Erosion transforms sheet into rills, gullies, and eroded land that often has reduced productivity.

Soil erosion normally occurs in a limited time of the year when a land is bare and 2 or 3 of the rainy periods before it is covered by crops. The man accelerated denudation is what is known as soil erosion. When erosion becomes a national problem it affects all classes and interests adversely, causes a progressive lowering of the general standard of living (MoA, 1989; Jacks and Whyte, 1939).

The first scientific investigations of soil erosion were those carried by German soil scientist Wollny between 1877-1895 on small plots to measure the effect of vegetation and surface mulch on interception of rainfall and other related researches (Kebede Tato and Hans H., 1992). Furthermore, attempts were made to estimate World distribution of erosion by Fredric Fournier (Richard J.C., 1969). It was estimated world-wide in range between 0-30 ton/ha/year. He forwarded the relationship that exists between sediment yield and basin size.

Estimation of soil loss in terms of volume such as tones/hectare/year is important, but sometimes it may be meaningless to others. Hence, losses can be estimated in monetary terms that could sound better. Costs could be categorized direct or indirect. The US government spending about \$1 billion a year but, 6 billion tones of top soils is still being lost annually in US. Off-site damage caused by erosion is estimated at some where \$ 3 and \$6 billion a year. Australia is known for soil and water conservation last forty years. Australia cost about 90 million tones of soil annually and average cost to every Australian farmers of land degradation is estimated Aus \$3600 a year. In spite of the expenditure of considerable money, time and effort the situation appears to have worsened, not improved (Kebede Tato and Hans H., 1992).

These figures indicate the situation in other countries worst. If this is a fact, it will be worth to question the reason may well be that our policies and strategies and the general approach to soil conservation have been faulty.

Soil erosion is one of the major factors causing severe land degradation problem in Ethiopia, which in turn is threatening the agricultural productivity and the very survival of the overwhelming majority of the rural population. The rate of soil loss, depletion of soil organic matter and nutrients as a result is so high and much faster than they can be replaced. The Ethiopian Highland Reclamation Study (FAO, 1986) estimated that water erosion moves nearly 1.9 billion tons of fertile soil from highlands annually.

Figure 1 is a typical form of stream erosion in the study area. Streams channel expand and change flow direction damaging lands near by which mostly are cultivated lands. In general, the Ethiopian highlands accommodate considerable population of the country with altitude more than 1500 m a.s.l. Besides human, livestock population is seriously affected by severe land degradation.



Figure 1. Typical stream erosion in the study area(photo by Aschalew D. 2009)

The soil erosion process, which is causing an irreversible damage is posing an immense impact on agricultural production and productivity in Ethiopia. Among others, loss of top fertile soil, which cannot be restored in a short period time is an indicator of the seriousness of the problem.

Land degradation and its causes are summerized on Figure 2. It highlights the proxy causes of land degradation including expanded expansion on steep lands, inadquate land cover during erosive period and lack of adaption of improved soil and water conservation measures. Furthermore, it indicates the root cause of land degradation is poverty. Poverty by itself is the result of low productivity, low investment, and lack of farmers knowledge among others. These limitations are aggravated by population growth which depends on natural resource. Increase in population requires more lands for cultivation, fuelwood, construction materials among others. These in turn encourage deforestation, and overcultivation.

Land degradation can be halted if appropriate soil and water conservation measures are undertaken. However, the low adaption and the limited soil and water conservation technology resulted low soil conservation coverage. Hence, inadequate land protection and malpractices such as soil burning, nitrification depletion, overgrazing and others exposed the land to erosion. The limited policy intervention to react on the prevailing situation further indepth the problem.

The Figure 2 also indicated the policy intervention that could positively affect the ongoing effort to soil and water conservation. Policies that improves marketing development, input supply, forest regulation, subsidies for conservation are expected to encourage land coverage from impact of rain drop or sheet erosion by encourageing farmers to access to market, increase production or protect resources. Moreover, technical assistance, credit policies, local governance and related issues if looked into will empower the community to use effeciently their knowledge, provide additional options and use the land resource sustainably by applying adequate soil conservation measures.

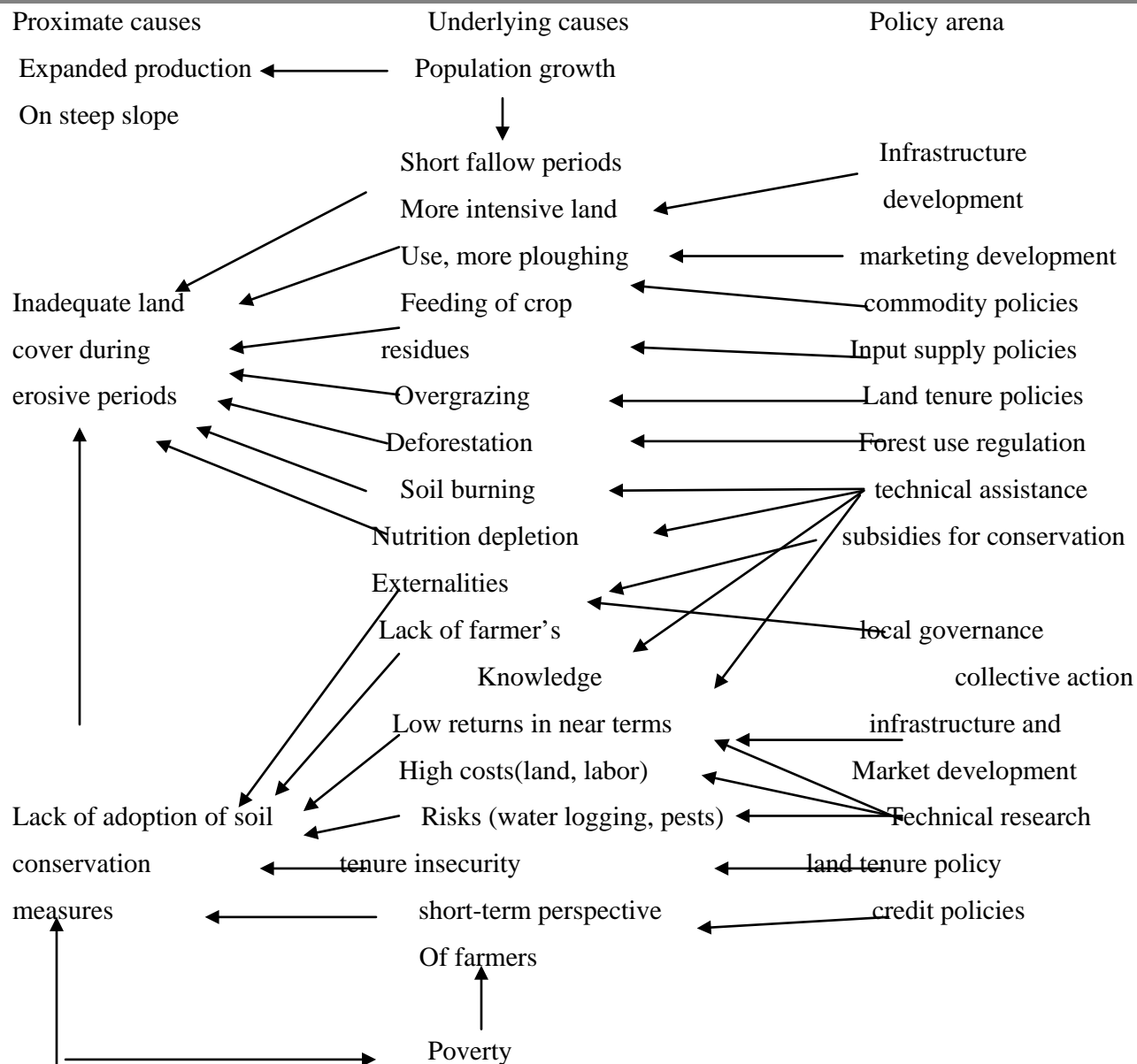


Figure 2. Cause of land degradation(Fitsum. 1999)

2.3.3. An Over View of Past Experience in Soil and Water Conservation

Inadequate soil erosion control was considered one of the factors for 1974 drought mainly in the northern part of the country. Government effort was low and traditional conservations were dominantly known in specific location in the country including, Tigray, in North and North Eastern Shewa, Chercher highlands in Harerghe and Konso (FAO,1986). The drought draws the attention of many professional and donors to work for conservation. Conservation measures were initiated either by Food for Works or mobilizing the community (Tilahun Amede, 2003). However, the efforts were not coordinated and the desired objective was not attained (MoA,1989).

Later, a National Soil and Water Conservation Programme was formulated with a number of objectives. These objectives were to reduce soil erosion, ensure self-sufficiently in animal fodder, fuel wood and construction material, provide water for irrigation, increase the agricultural land by draining swamps. Moreover, organizational framework to implement this programme was also set up. The established Soil and Water Conservation Department in 1981 was a great step to the proposed activities.

The organizations working on the area besides MoA were Relief and Rehabilitation Commission (RRC) and Forestry and Wildlife Conservation and Development Authority. Moreover Soil Conservation Research Programmes (SCRPs) started in 1981. In addition, proposal for a National Soil Conservation Strategy for Ethiopia was formulated in 1989. Catchment planning on degraded areas was used as a strategy and implemented.

In order to reverse such environmental, economic and social problems of the area, the government launched massive land rehabilitation and soil and water conservation measures and implemented a wide range of techniques including construction of soil bunds, stone bunds, Fanya juu terraces, cutoff drains, waterways, check dams and micro basins during the past three decades. In this process of massive land rehabilitation, various land use types including the farmlands, degraded forest or grazing lands and lands affected by gullies were treated. Similarly huge size of degraded hillsides were closed from livestock and human interference and were treated with the various soil and water conservation (SWC) interventions to enhance the rate of natural regeneration, establishment of vegetation and intensification of the overall biomass production.

The implementation of various soil and water conservation structures was complemented with extensive vegetative measures where various multipurpose species were planted on conservation structures, in degraded hillsides in the form of hedges or dispersed agro-forestry and in gullies. As a result, considerable size of cultivated lands were protected from soil erosion and their productivity enhanced. The enrichment plantation of the degraded hillsides with multipurpose species boosted the amount of biomass production from the closed areas which availed a great opportunity of accessing fuel wood, construction material and livestock feed. The huge biomass created is used either for generating income or for meeting the domestic needs of the community. However, there were many factors that impede its effectiveness and hence, structures partially destroyed or modified.

Chapter III

3. Description of the Gado Subwatershed

3.1 Location

Gado subwatershed/subcatchment is located between longitude $39^{\circ} 28' 31'' \text{ E}$ - $39^{\circ} 44' 24'' \text{ E}$ and latitude $9^{\circ} 41' 13'' \text{ N}$ - $9^{\circ} 55' 49'' \text{ N}$ (Figure 3). The study area is about 500 km^2 .

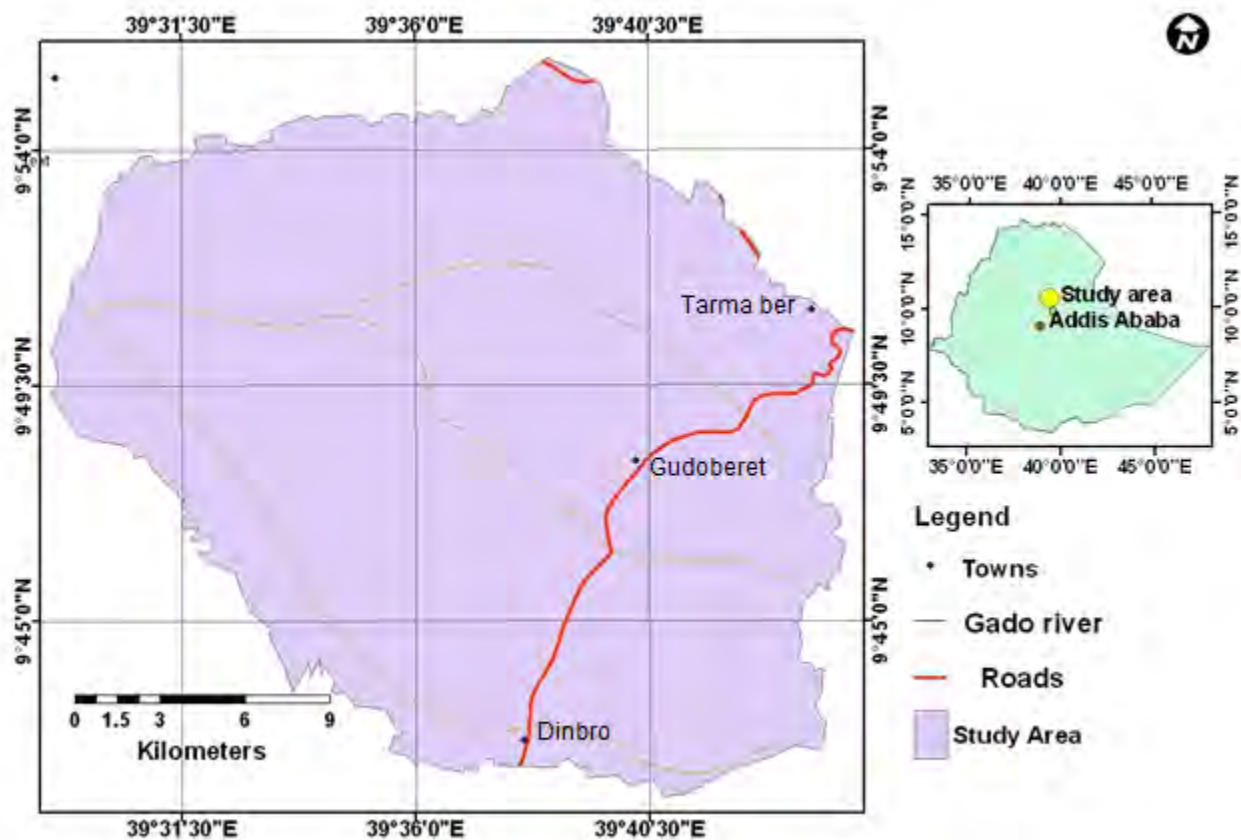


Figure 3. Gado subwatershed location

Addis Ababa – Desse Asphalt road crosses this watershed from south west to north east direction as shown on Figure 3. Similarly, gravel road links Tarmaber –Sasit towns which looks partially broken as indicated in the northern part almost on the divide line of the watershed.

The subwatershed is bounded in two Woredas namely Basona Worana and Mojana Wodera as indicated in Figure 4. Basona Worana Woreda covers most of the catchement.

The subwatershed as it is listed on attribute (Table 1) has a total of 17 Kebeles that are within or partially enclosed in the subcatchemnt.

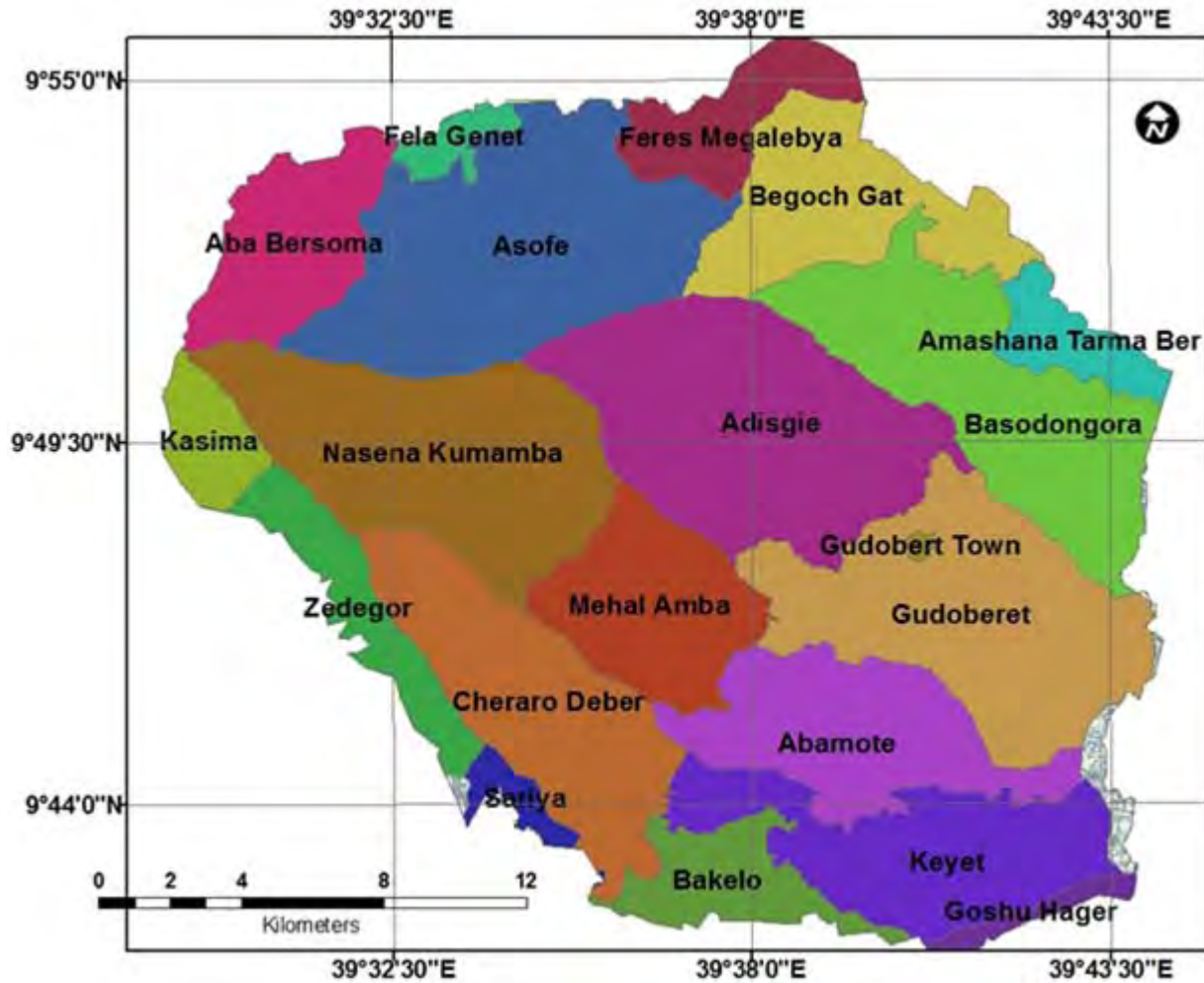


Figure 4. Gado subwatershed Kebeles

Kebeles contained and partially enclosed in Basona Worana Woreda are namely Nasena Kumamba, Adisgie, Basodongora, Gudoberet, Abamote, Mehal Amba, Cheraro Deber, Zedegor, Kasima, Bakelo, Keyet and Sariya. The remaining five Kebeles which are partially enclosed in Mojana Wodera are Asofe, Aba Bersoma, Fela genet, Feres megalebiya, and Begoch gat. Gudoberet is the only town identified in the subwatershed in Basona Worana Woreda.

Table 1. Gado Kebeles Attributes

Attributes of GadoKebele										
FID	Shape ^	R_NAME	R_CODE	Z_NAME	Z_CODE	W_NAME	W_CODE	RK_NAME	RK_CODE	COUIT
0	Polygon	Amhara	3	North Shewa	305	Basona Werana	30519	Gudobert Town	3051901	1
1	Polygon	Amhara	3	North Shewa	305	Mojana Wedera	30511	Aba Bersoma	30511005	5
2	Polygon	Amhara	3	North Shewa	305	Mojana Wedera	30511	Fela Genet	30511007	7
3	Polygon	Amhara	3	North Shewa	305	Mojana Wedera	30511	Feres Megalebya	30511010	4
4	Polygon	Amhara	3	North Shewa	305	Mojana Wedera	30511	Asofe	30511011	7
5	Polygon	Amhara	3	North Shewa	305	Mojana Wedera	30511	Begoch Gat	30511012	6
6	Polygon	Amhara	3	North Shewa	305	Mojana Wadera	30511	Amashana Tarma Ber	30511013	6
7	Polygon	Amhara	3	North Shewa	305	Basona Werana	30519	Kasima	30519005	7
8	Polygon	Amhara	3	North Shewa	305	Basona Werana	30519	Nasena Kumamba	30519006	6
9	Polygon	Amhara	3	North Shewa	305	Basona Werana	30519	Adisgie	30519007	8
10	Polygon	Amhara	3	North Shewa	305	Basona Werana	30519	Basodongora	30519008	6
11	Polygon	Amhara	3	North Shewa	305	Basona Werana	30519	Gudoberet	30519009	5
12	Polygon	Amhara	3	North Shewa	305	Basona Werana	30519	Abamote	30519010	4
13	Polygon	Amhara	3	North Shewa	305	Basona Werana	30519	Mehal Amba	30519011	4
14	Polygon	Amhara	3	North Shewa	305	Basona Werana	30519	Cheraro Deber	30519012	4
15	Polygon	Amhara	3	North Shewa	305	Basona Werana	30519	Zedegor	30519013	4
16	Polygon	Amhara	3	North Shewa	305	Basona Werana	30519	Sariya	30519020	3
17	Polygon	Amhara	3	North Shewa	305	Basona Werana	30519	Bakelo	30519021	6
18	Polygon	Amhara	3	North Shewa	305	Basona Werana	30519	Keyet	30519022	5

3.2 Geology

Ethiopia can be divided into four physiographic regions widely known as

- The Western Plateau
- Southern Plateau
- The main Ethiopia Rift and
- Afar Depression

Ethiopian plateau is underlain at depth by precambrian rocks of the Afro-Arabian shield (Mengesha, T., Tadiwos, C. and Workineh H., 1996). The Precambrian basement rock (23%), Paliozic and Mesozic sediment (25%) , Tertiary volcanic (34 %), Quartery basement and young volcano (18%) is the geology of Ethiopia. The Precambrian basement rocks, which are metamorphosed to varying grade are exposed to the norther, southern, western, eastern and southwestern part of the country(Abu Wube,2005)

Gado subwatershed is part of these processes and located in the western plateau. The geology of the area is Cenozoic rock, early mid tertiary basalt. In Ougocene-Miocene period, the watershed and surrounding area is

dominated by Alaje formation, which is Rhyolite trachyte transitional and subalkaline basalt. The Alaji basalt is Oligocene age, from 36-34 to 28-26 million years (Alaji- Molale) (Nigussie Kebede, 2005).

3.3 Topography

Topography of the area is rugged mountainous and dissected by a number of rivers, streams and gullies. This is displayed in 3D elevations (Fig. 5) developed from Shuttle Radar Topographic Mission (SRTM). The North-South and East- West cross-sections (azimuth 196.8°) of the watershed (Figure 6) taken approximately middle of the watershed and perpendicular (azimuth 103.9°) to each other also demonstrate variation in the elevations and terrain undulation. Figure 7 indicates three streams which have cut the landscape deep. More than 600 meters vertical difference is found in about 4 km horizontal distance, which shows a slope of 10 % on the average.

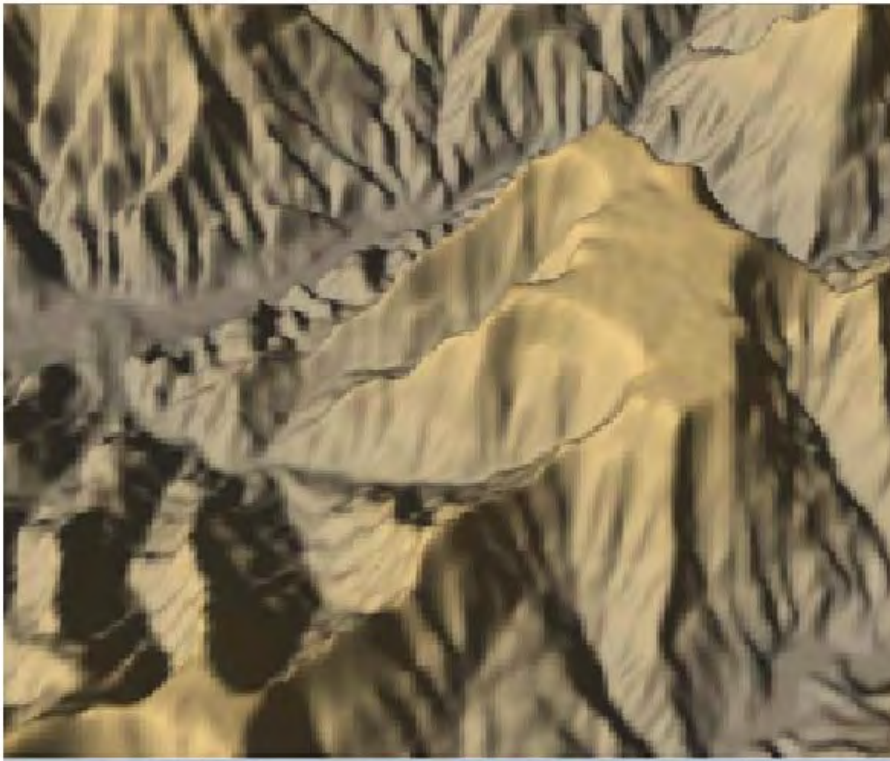


Figure 5. Exaggerated Vertical Elevation and Typical Three Dimension of the SWD's Landscape

Elevation of the subwatershed ranges between 2000 to 3700m a.s.l. (Figure 8). According to the agroclimatic zone classification, the area is categorized into three zones namely Woinadega, Dega and Wurch with altitude 1500-2300 meter, 2300-3200 meter and more than 3200 meter a.s.l respectively (Alemneh Degene, 1990).

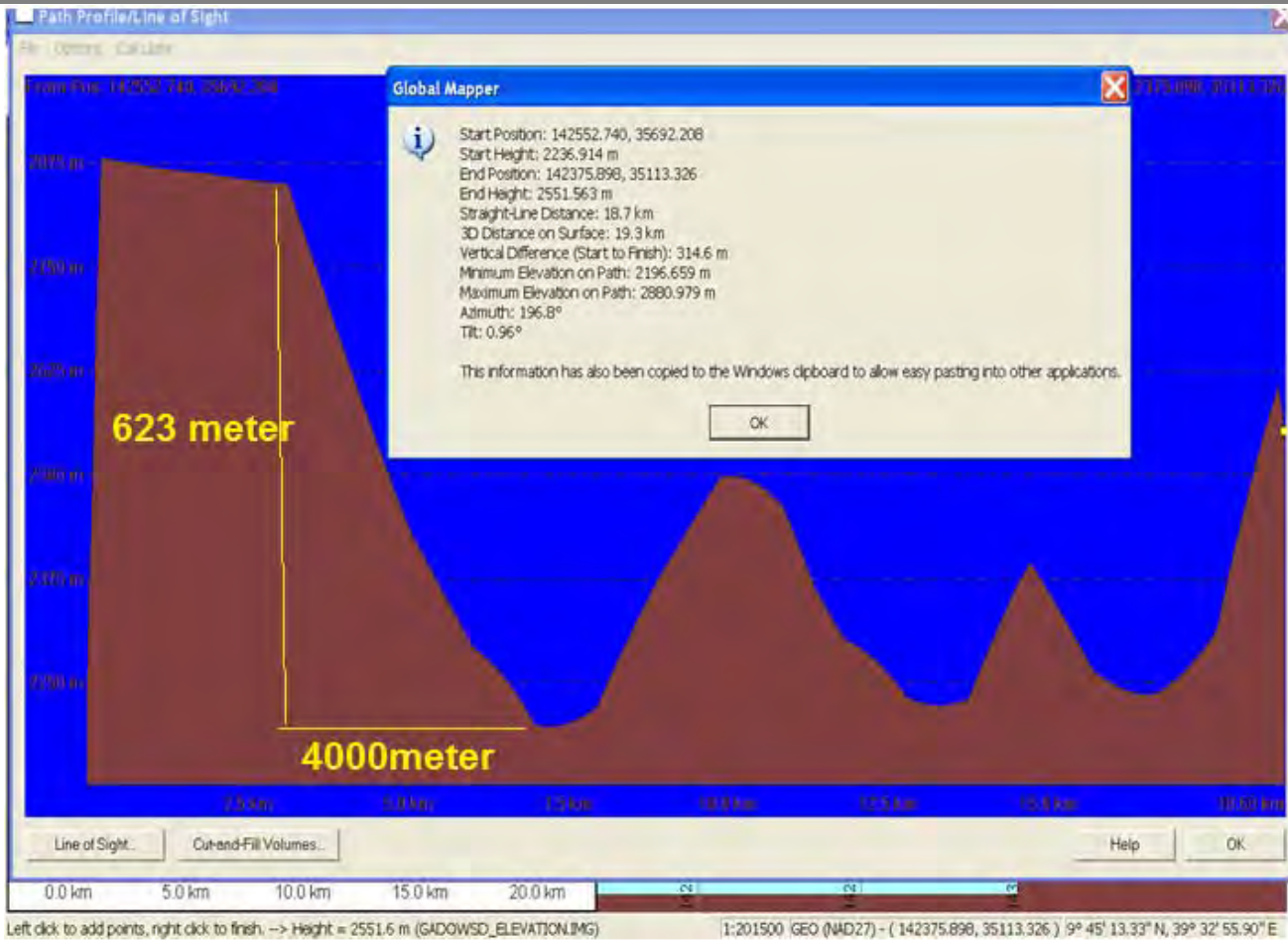


Figure 6. The Exaggerated Vertical Elevation and Typical North-South Profile of the Subwatershed

$$\begin{aligned}
 \text{Slope (\%)} &= \frac{\text{Vertical elevation Difference}}{\text{Horizontal distance}} \times 100 \quad \dots\dots\dots\text{Equation 3.1} \\
 &= \frac{2860-2237}{4000} \times 100 \\
 &= \frac{62300}{4000} \\
 &= 10.6\%
 \end{aligned}$$

In general the elevation of the subwatershed declines from east to west except intercepted by stream/valley as it could be shown on Figure 7. The subwaterhed drains to Jama river, the tributary of Abay. The subwatershed eastern boundary divides the subwaterhed to drain either Abay or Awash basin and it is almost the edge of the rift valley.

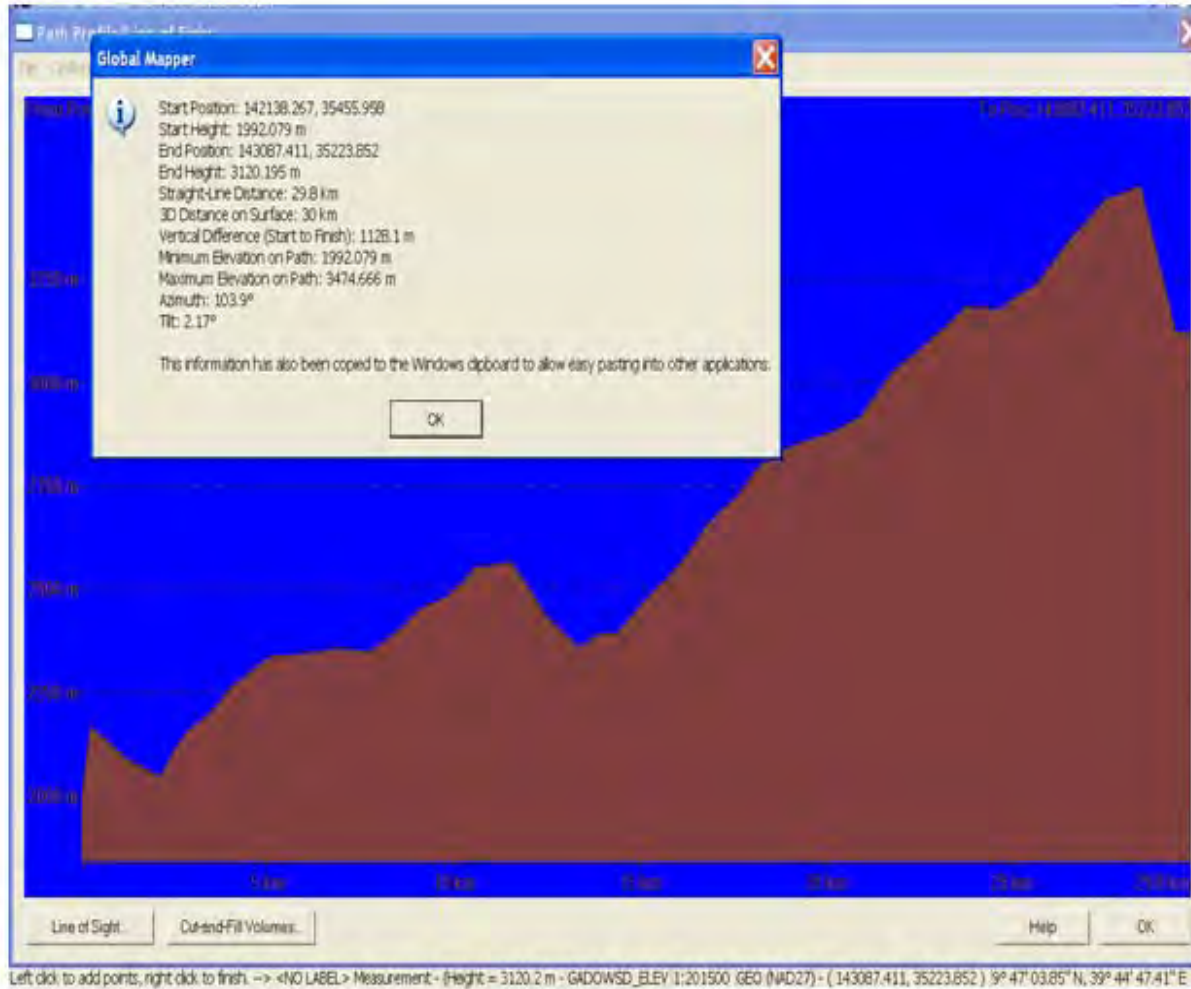


Figure 7. Typical East – West cross-section of the basin

The elevation variation has impact on the precipitation. The high altitude areas have high precipitation but lower evapo-transpiration. But they are likely affected with frost and only limited crops are grown, dominantly Barley. Exceeding, 3000 m.a.s.l elevation special local grass known as guassa is grown that is used for hut cover or feed of cattle during drought. However, increase in population has forced the area to be converted to cultivation. Limited productivity and erosion is partially affecting the area in this respect.

The contours and the direction of drainage network (Figure 8) is interesting and it indicates how land degradation is affecting the area. Drainage network is shown like a tree, dendritic pattern.

This also can depict that the streams are eroding their channels and progressing upward deeply dissecting the landscape which could extend further unless the erosive force of the runoff is controlled. Therefore, the elevation map indicates the fluvial process that is shaping the earth.

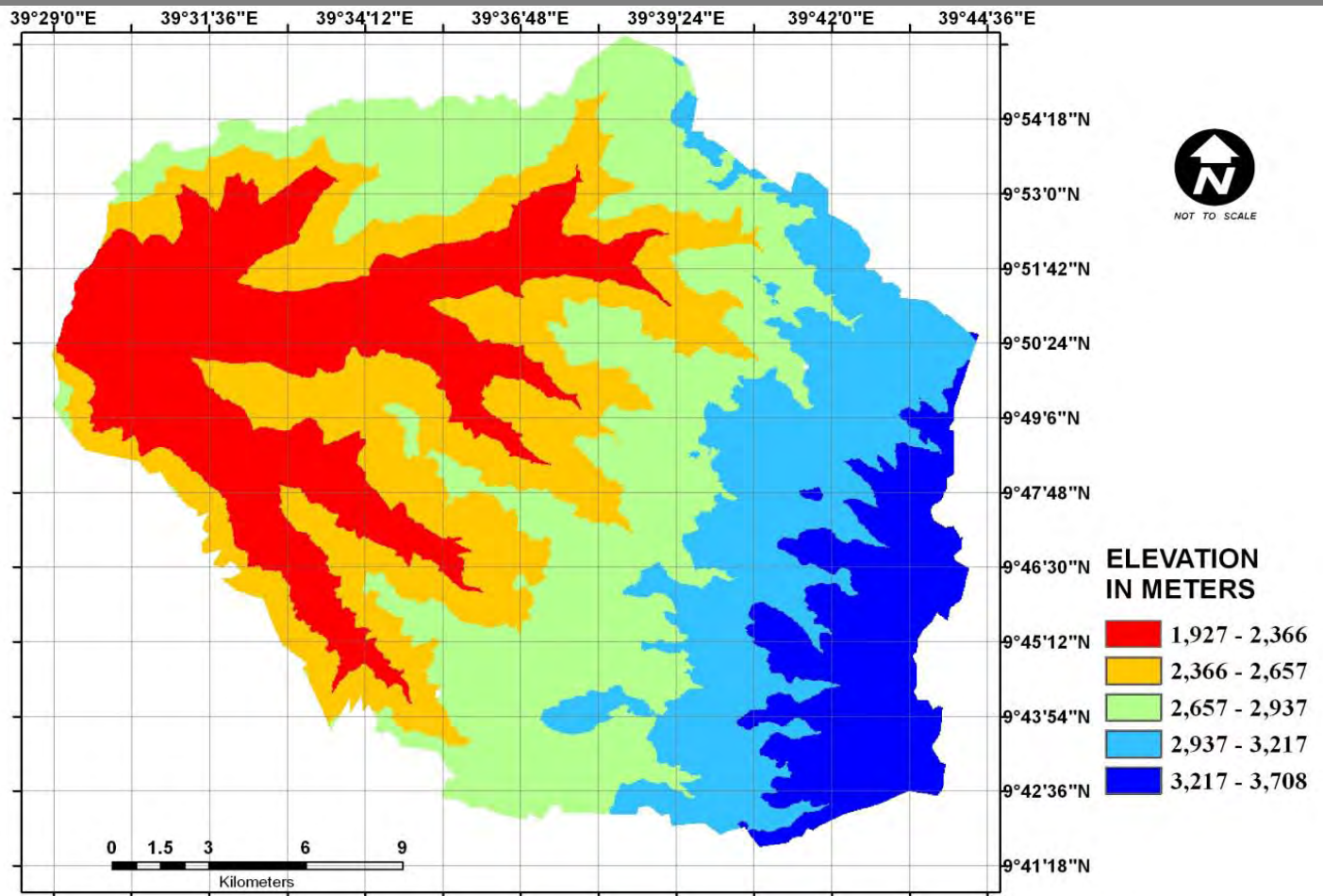


Figure 8. Elevation map of the study area

Table 2 indicated the altitude range in the SWD which it also point out the agroclimatic zones contained in the SWD. Accordingly the Woina dega, Dega and wurch zones cover 14 % , 75% and 11 % respectively. Hence, Dega is the dominant agroclimatic zone.

Table 2. Elevation and Area Coverage of the subwatershed

Serial Number	Altitude	Area K.m ²	%	Agro-climate
1	2000-2300	68.60	13.7	Woinadega
2	2300-3200	377.79	75.4	Dega
3	3200-3700	54.37	10.9	Wurch
Total		500.76	100	

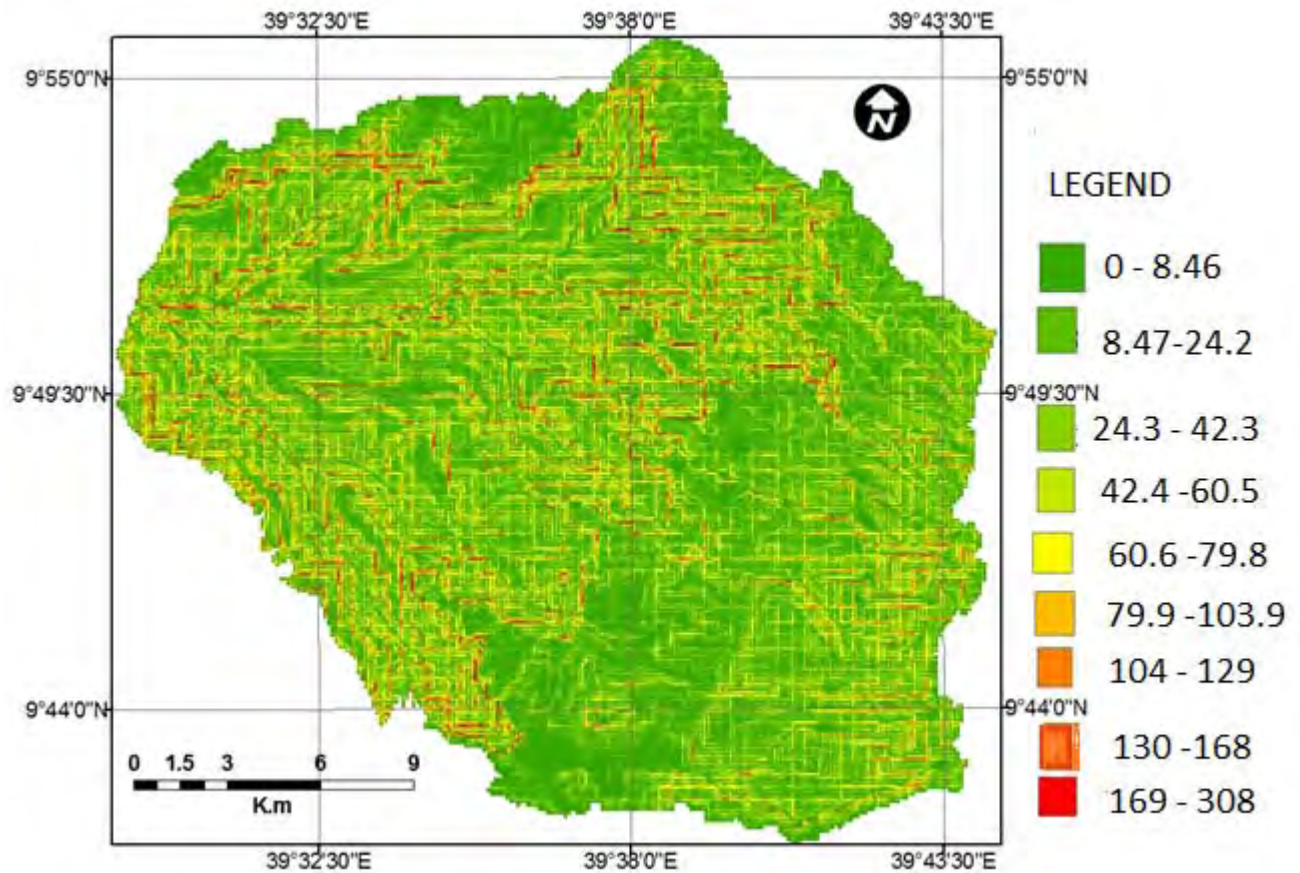


Figure 9. Slope map.

The topography of the area is mountainous. This can be exhibited by slope variation and the contour. Slope reaches up to 308 percent as shown on Figure 9, but the area coverage is only one percent (Table 3). The same Table, further indicates the different slope classes that the SWD accommodates. Moreover, Figure 10 depicts the slope classes, the corresponding cell count and area as briefly summarized (Table 3).

Table 3. Gado SWD Slope in Percentage and Area in Hectares

Slope class	0-5	5--10	10--20	20-30	30-50	50-100	100-152	152-308	Total
Land(cell)	820.00	39000	70000	60000	90000	94000	19000	4000	558000
Land(km ²)	163.08	34.95	62.72	53.76	80.65	84.23	17.03	3.58	500.75
area(%)	33	7	13	11	16	17	3	1	100

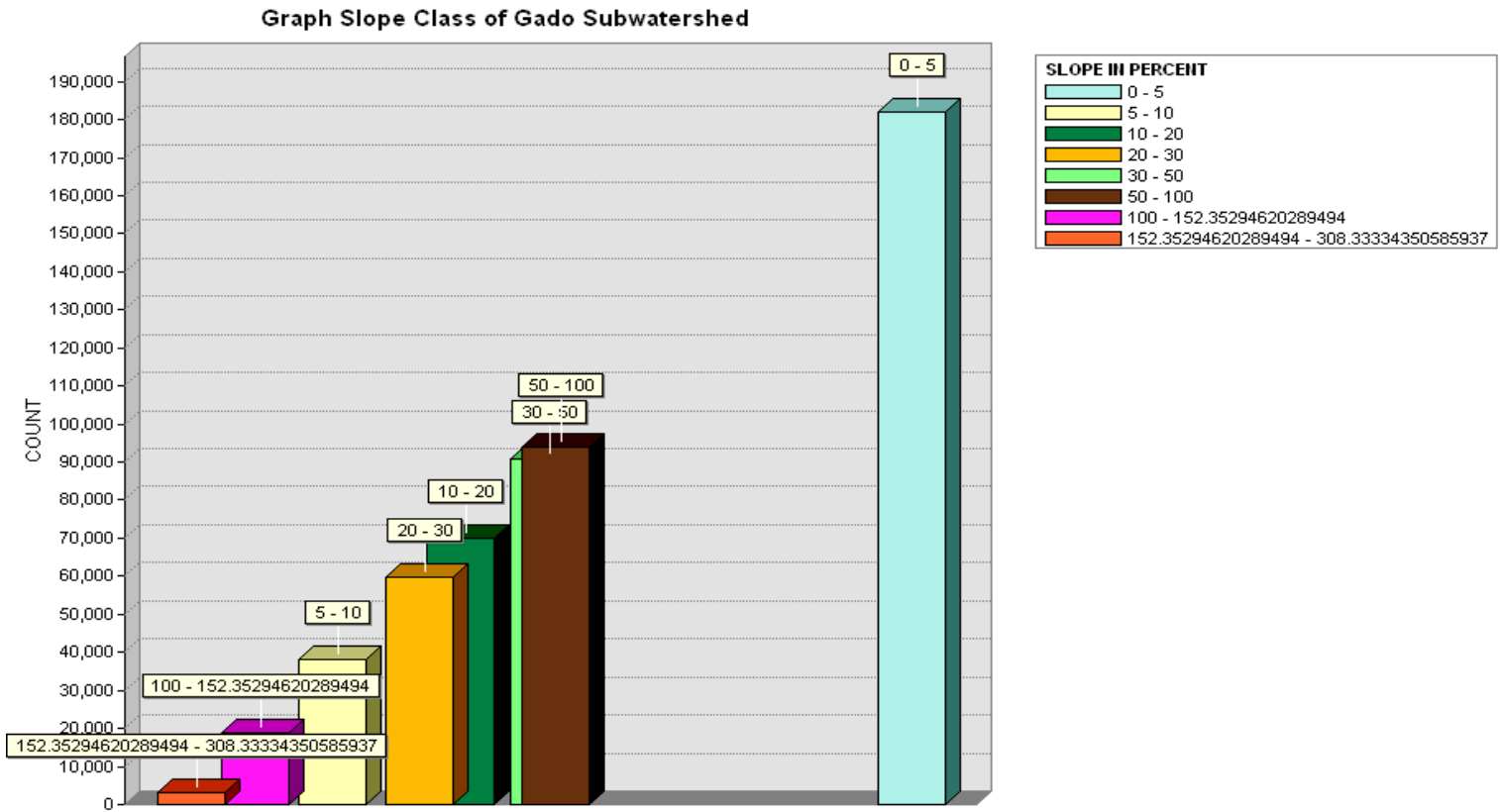


Figure 10. Gado sub-watershed slope class cell

According to slope category, 33%, 7%, 13% , 11%, 16% and 17%, of the SWD area has slope less than 5%, 5%-10%, 10%-20% , 20% -30% ,30% -50%, and 50% -100%, respectively. This means, more than 47% of the area has slope more than 20% indicating the area mountainous and undulating,

3.4 Soils

3.4.1 Soil Types

Soil is the naturally occurring, unconsolidated or loose covering on the earth's surface. It is the product of parent material, climate, topography and biological factors on interaction with time. Interaction between soil forming factors determine the soil physics and chemistry of soil as a whole.

The soil type of the area is categorized into 8 as shown in Table 4 and they are arranged in decline area coverage that eutric cambisols (88%), eutric regosols (8.9%), pellic vertisols (2.1%), while soils leptosols, eutric nitisols, chromic cambisols cover the rest. Soil distribution of the subwatershed is indicated on Figure 11.

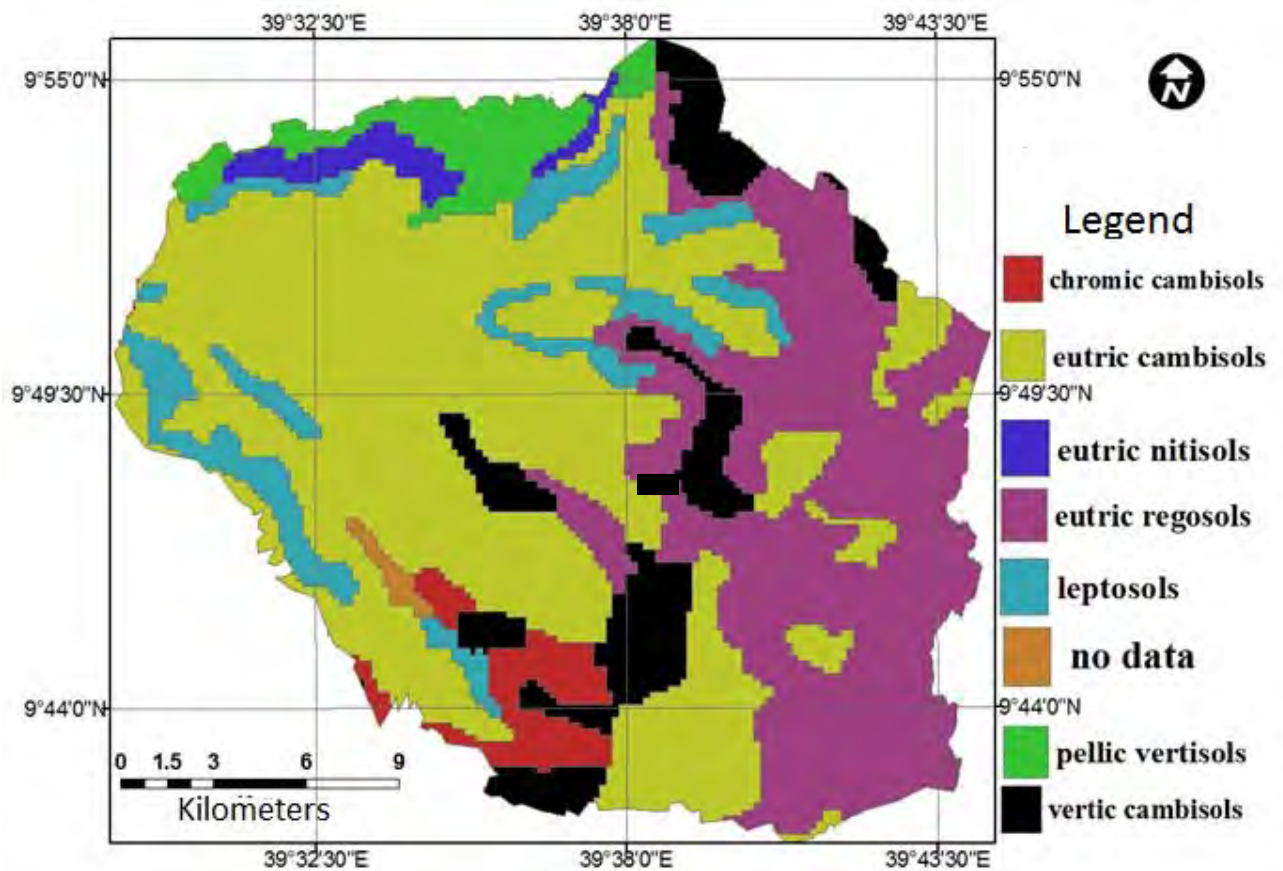


Figure 11. Soil Map

Table 4. Soil Types and Area Coverage

Serial Number	Soil	Area in K.m ²	%
1	Eutric cambisol	441.05	88.1
2	Vertic cambisol	2.98	0.6
3	Leptosol	0.46	0.1
4	Eutric regosols	44.57	8.9
5	Eutric nitisols	0.27	0.05
6	Chromic cambisols	0.23	0.05
7	Pellic vertisols	10.96	2.19
8	No data	0.24	0.05
Total		500.75	100

3.4.2 Soil Depth

Soil depth map of the subwatershed dominantly ranges 30-90cm (Figure 12) while more than 40 percent is below 30 cm. This implies that further decline of soil depth due to erosion would have an impact on the environment. Abay Basin Master Plan study has identified the area cannot tolerate further soil erosion.

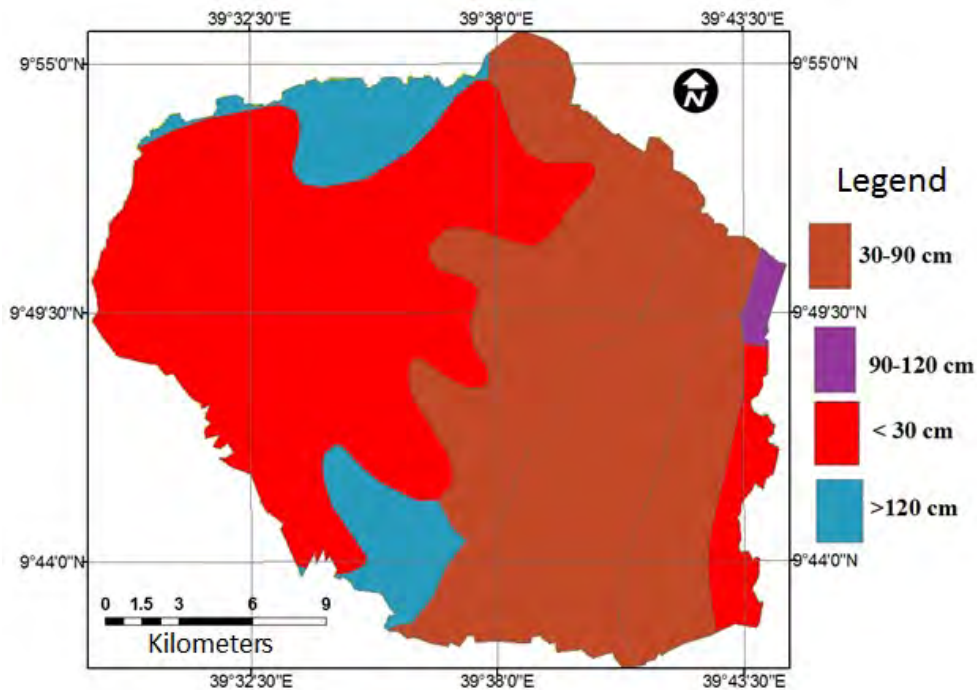


Figure 12. Soil Depth Map

3.5 Rainfall in the Subwatershed

Precipitation mechanism cools air below its dew point forming clouds in the presence of condensation nuclei (Tenalem Ayenew and Tamru Alemayehu, 2001). Pressure-gradient forces large enough to drive air up and over a mountain range to form rain. Annual average rainfall in the subwatershed ranges between 900-2200mm (Figure 13).

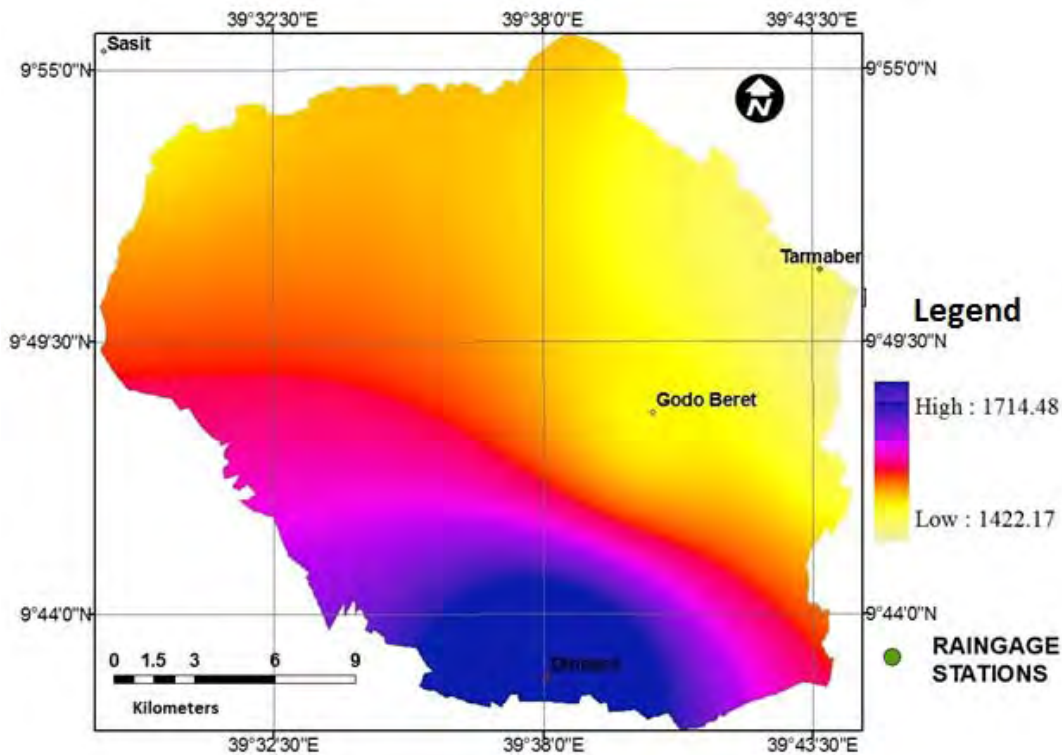


Figure 13. Mean annual rainfall map

To derive rainfall distribution in the watershed, six raingage station data as point source were obtained from Ethiopian Metrological Agency. The rainfall is dominantly monomodal mostly concentrated between months of June-September (Figure 14).

Gudo Beret station is the only raingage station in the project area. Considering the topographic feature difference, and distribution of stations Inverse Distance Weight (IDW) method is preferred for estimating rainfall distribution of the area under consideration. IDW reflects that rainfall distribution is inversely related to the distance from raingage stations. Increasing the distance from the point source/ station results in increase in value difference of the respected point. In view of this, point data of these stations bounding the sub-watershed were plotted. Furthermore, Spatial Analyses tools specifically Interpolation to Raster the point data mean annual rainfall is applied and interpolated by IDW in ArcGIS program. The study area was clipped later.

Mean monthly distribution of the six raingage stations bounding Gado SWD was obtained from Metrological Agency. The monthly distribution highlights moisture situation in the SWD. In respect of soil erosion by water is inevitable and high in June where field is bare .

The twenty and above years of mean monthly rainfall distribution (Table 5) is given, which indicates months of the year that rainfall is maximum and minimum. The rainfall distribution also can highlight the growing seasons of main crop.

Table 5. Mean Monthly Rainfall (mm) of the SWD

stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean period
S/ Dingay	15.8	6.3	44.2	44.0	36.77	66.7	397.25	330.8	114.7	32.37	19.21	10.3	1983-2006
Mendida	17.7	15.9	62.1	60.9	34.6	77.7	20.9	284.5	70.7	19.1	7.9	4.3	1981-2006
Deneba	20.2	1.3	61.6	58.5	22.1	71.5	347.2	299.7	98.6	11.7	4.6	4.9	1985-2007
D/ sina	70.6	1.68	21.9	67.6	96.7	69.1	331.2	422.8	15.1	28.16	01.65	74.8	1985-2005
Gudo Beret	24.9	1.52	39.7	50.7	43.7	83.32	385.82	359.3	50.6	59.12	25.1	10.9	1988 -2006
D/Birhan	14.8	7.8	39.9	53.9	36.1	60.3	327.5	261.0	77.2	23.4	5.7	4.4	1987-2007

The graph of mean annual rainfall (mm), (Figure 14), indicates monomodal rainfall pattern and Debre sina station mean annual rainfall recorded highest.

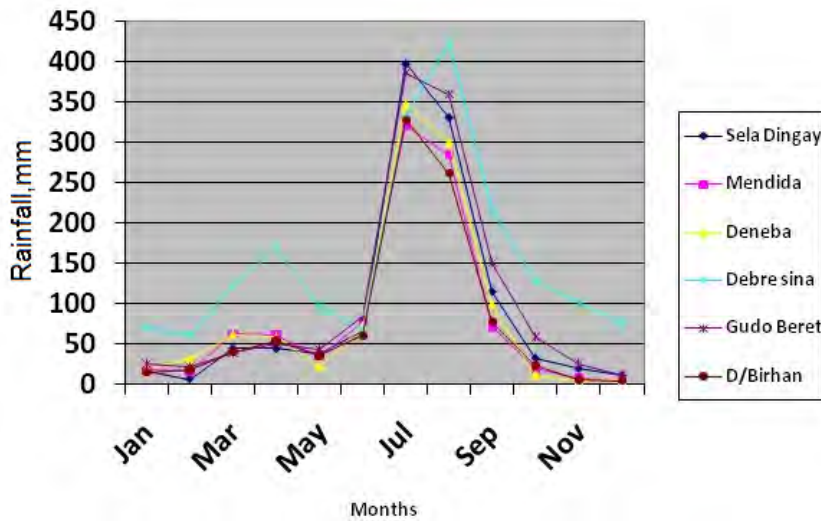


Figure 14. Graph of mean annual rainfall of Gado bounding stations

3.6 Land use / landcover

Land use and land cover are different. Land use refers to the purpose, which the land is being used by the owner of the land. This could be plantation, cultivated land, park, grassland. while land cover is related to the dominant feature occupying the area. Water body, forest, grassland and others can be mentioned. However, sometimes it would be difficult to differentiate in between and hence landuse/landcover is used

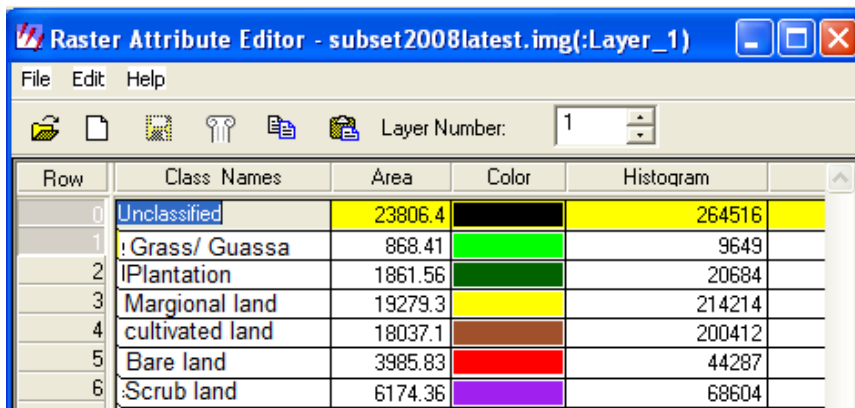
synonymously. The land uses identified from analyses of satellite image of the year 2008 were classified into cultivated lands, marginal land, plantation, grassland, degraded land and scrub lands. Brief description of the land uses is as follows.

3.6.1 Cultivated land

This is the land that is used to grow crop annually. Normally, gentle or level lands are preferred but due to shortage of lands, very steep lands which cultivation by animal power is difficult are still under cultivated land. Very slope areas are cultivated by hand tools, such as hoe. As per the classification of the subwatershed, it enclosed an area 500km² and more than 180.00 km², 36%, intensively cultivated land.

The main crops grown are barley, wheat and lentils. Subsistent farmers who use traditional farming tools, low fertilization, low land holding are dominant in the subwatershed like other part of the country. Increase in population has an influence on existing natural resource of the area and land degradation is a common phenomenon. Cultivation of marginal land, over cultivation, soil erosion, deforestation is common problems. Low job opportunity to youth made existing natural resource as a possible means of livelihood for which the land is used beyond its capability.

Table 6. Raster Attribute editor



Row	Class Names	Area	Color	Histogram
0	Unclassified	23806.4		264516
1	Grass/ Guassa	868.41		9649
2	Plantation	1861.56		20684
3	Marginal land	19279.3		214214
4	cultivated land	18037.1		200412
5	Bare land	3985.83		44287
6	Scrub land	6174.36		68604

3.6.2 Forest land

Trees which are densely grown or planted, which cover a certain area is called forest. The forest area in the SWD is estimate according to the 2008 satellite image to be more than 18.60 km² (3.6%) which is higher than national average. There are two categories forests in the subwatershed, plantation and natural forests.

3.6.2.1 Natural forests

Indigenous trees grown are relatively decline or became rare. The natural vegetation has completely disappeared in these areas and remainant can only be found locally above 3300 m a.s.l.

Natural vegetation remnants above 3300 m in the escarpment were *Helicrysum*, Thyme and different *Festuca* species, afro-alpine heather with *Erica* and *Phlippia* – bushes. Furthermore, in the most elevated parts, which Andit Tid Research Unit is located *Lobelia rhynchopetalum* exist (R. Bono and W.Seier , 1984). Andit Tid is located in the subwatershed around Gudoberet town, which was one of the six sites where Soil Conservation Research Project (see Annex IV) was conducted in the country.

3.6.2.2 Plantation

They are man-made forests in the study area. Figure 15 indicates a typical plantation in the sub-watershed. Plantations can be further classified according the nature or purpose of plantation. These could be fuel wood plantation, state forest, and community forest.

The man made-forest, especially *Eucalyptus* spp. has been common since King Minilike(Tilahun Amde2003). In the 1900th seeds brought from Australia were planted for the first time. *Eucalyptus* is used for such as fuelwood, construction material, electric pole. Its fast growing characteristics has made it most preferable plant in many areas. The discussion made with the Woreda Development Agent and farmers and Woreda experts specified that plantations according to ownership can be categorized into three in the swd. These are state forest, community forests and individual holdings.



Figure 15. Typical Eucalyptus plantation (Photo by Aschalew D., 2009)

3.6.2.2.1 State forest

These plantations were conducted by a fuelwood project and it is government owned. Mainly Eucalyptus tree spp. were planted during the demise Derge and partly by Ethiopian People Revolutionary Democratic Front (EPRDF). Area in the sub-watershed identified forest is 18.61 km². The plantation areas are continuous and large while they can be given to community if small in size. This is also true that those plantations that were wide and planted by the community through different initiatives such as mass mobilization. They are managed by government while the community may be benefited certain amount when sold or feed their cattle in the area. This plantation sites were once farmers holdings and partially compensated without full understanding of the community interest for sake of socialization.

3.6.2.2.2 Community plantation

They are owned and managed by the community. They are either planted by the community during Derge regime for motivation of socialism in the country where individual holding were discouraged. Plantations were either voluntarily or partially by mobilization of the community in Amharic known as zemecha (mass mobilization). The community selected leaders/committee manage the forest. It has been source of income to the community.

3.6.3 Grassland

The grassland of the SWD can be categorized into two, the alpine climate and flooded plain. On elevation above 3000m a.s.l there is a local grass known as guassa which grow in alpine environment that withstand the cold temperature. The grass is used for the construction of hut, rope or cushion to cover floors. Moreover, it will be used as a feed during drought/feed shortage. The area coverage estimated more than and 8 km² but disrupted. It is normally communal owned despite located in certain Kebeles. However, the area coverage is declined due to expansion of cultivated land and degradation due to over grazing and over cultivation.

Another area of grassland is located on flat topography and marshy lands near by rivers. They are wet during most of the year which grass grow. Depending to moisture condition, some of these areas are drained and partially irrigated for crop production.

3.6.4 Degraded lands

Degradation is common in the subwatershed due to overgrazing, over cultivation and others. The monoplantation /Eucalyptus spp./ though important for its products and by products, its eradicates/removes under growing vegetation that could have covered the ground. Moreover, leaves accumulate raindrops and pour on surface where erosion is observed.

About 40 km² bare land has been notice mainly concentrated on cultivated lands. Shallow soil depth areas are exposed to such damage if not properly handled. Moreover, stream/gully erosion (110 km²) which are related to drainage net work seems greatly affecting the area. Deeply dissecting /incising rivers are eroding the channel and protruding/extending up stream. It is also shaping stream edge for active erosion. These lands are mainly concentrated on marginal lands and the total degraded land becomes 150 km² which is about 30% of the subwatershed. The degraded lands on cultivated lands those noticed are disconnected, which later could expand unless land management is not properly handled.

Cultivated lands with low fertilization, limited fallowing and improper drainage structures aggravated the erosion in cultivated lands. Use of cow dung for fuel or sell deteriorated the fertility status of the soil and hence degraded.

The soil and water conservation structures constructed indicates their importance for which plants growing around bunds show better growth. However, poor maintenance, increase in vertical interval between terraces and the poor design decline their effectiveness. As per the discussion with Development Agents, group/team approach is encouraged to construct/maintain new one or old terraces but its application is limited.



Figure 16. Typical degraded land of cattle track (photo by Aschalew, D. 2009)

The degraded lands identified during field visit and location registered using GPS were cattle tracks, water ways and over cultivated lands that develop into gullies or bare land.

3.6.5 Marginal lands

These are lands that covers about 82.8 km² which is 16.6 percent of the study area located from the middle to down stream of the SWD. They are characterized as very sloppy topography, with shallow soil and mostly abandoned lands for which agricultural practices are difficult. But still under strict conditions, they are used for growing of crop with long fallowing/rotation. Strong conservation structure are required or low productivity is registered. They are likely change to degraded land with poor land management. The problem is also related to geological erosion where streams cut the landscape into streams and gullies.

3.6.6 Scrub lands

These are lands with sparsely populated bush lands. Their area coverage is about 61.7 km² and the community is partially accessing fuel wood. Located mainly in between marginal lands and intensively cultivated lands.

Chapter IV

4. Materials and Methods

In order to meet the objectives of the study both primary and secondary data were collected and analyzed. The soil loss of the study area was estimated using USLE erosion Model. In view of this, factors contributing for the soil erosion by water were collected from available sources. These were rainfall, soil type, slope and length, satellite image and conservation practices.

4.1 Materials Used for the Study

Table 7. Materials used for the study

No	Item	Source	Remark
1	Literature	Different libraries	
2	Satellite image	USGS	MSS, TM, ETM+
2.1	Path180, row 53 of the year 1973, Jan.30,	Internet www.landcover.org	Multispectral sensor (MSS),
2.2	Path168, row 53 of the year1986, March 26	www.landcover.org	Thermal Mapper (TM),
2.3	Path 168, row 053 of year 2008, April15	Ministry of Water Resource	Enhanced Thematic Mapper (ETM+),
3	Shuttle Radar Thematic Mapper (SRTM)	www.landcover.org	30m resolution
4	Erdas Imagine, ArcGIS, Global Mapper, QuntumGIS	Addis Ababa University	GIS laboratory and laptop
5	Geographical Positioning System(GPS)	Addis Ababa University	
6	Rainfall	National Meteorological Agency	Point data of Long years Proxy to the site
7	Soil	Ministry of Agriculture and Rural Development	Soil map of Ethiopia
8	Topographic map	Ethiopian Mapping Agency	1:50000scale
9	Scan image	Ethiopian Mapping Agency	
10	Soil depth	Ministry of Water Resource	Shape file

4.2 Methods

4.2.1. Collection of Secondary Data

4.2.1.1. Literature review of available books, reports, magazines.

Literatures from different government institutions were referred. Ministry of Water Resources, Ministry of Agriculture, Ethiopian Institute of Agricultural Research (EIAR), Ethiopian Soil Laboratory, Addis Ababa University both at Sidist kilo and Arat kilo.

4.2.1.2 Topographic maps

Topographic maps of scale 1:50000 were acquired from Ethiopian Mapping Agency. They were Sela Digay sheet No 0939B1, and Sheet No 0939B3 Debre Birhan, which were used for image interpretation, land classification and field assessment. Scanned maps of the watershed of Sela Dingay, Debre Birhan and Sasit was also bought for watershed boundary delineation.

4.2.1.3 Satellite imageries

Satellite images acquired at the same month and day are recommended to minimize errors especially atmospheric effect. Moreover, images of the months January-April are preferable to differentiate cultivated vs. grass/ grazing lands and benefit relatively cloud free condition. However, this is not true always. The 1986 TM satellite image had cloud. Image stacking conducted and subsetting of the project area undertaken using Area Of Interest (AOI tool).

on the images pre and post processing (georeferencing, radiometric correction, rectification) and classification (supervised and unsupervised) were undertaken which results in land use/ landcover of the area. Topo-map is used as ground truth to assist classification. The Land use/landcover map developed was further improved after field check.

4.2.1.4 Shuttle Radar Topographic Mission (SRTM)

Shuttle Radar Thematic Map data was acquired from the Department of Earth Science server. The available raster image was compressed and hence was unzipped for use. Raster image of the elevation map of the specific project site image was extracted using ArcGIS tool, Extraction by mask. Similarly, satellite image of the site clipped applying AOI using Erdas Imaging, Analyses tool. The reduced image size improves efficiency of storage and prompt processing in the computer.

The Shuttle Radar Topography Mission is an international project spearheaded by the U.S. National Geospatial-Intelligence Agency (NGA) and the U.S. National Aeronautics and Space Administration (NASA).

4.2.1.5 Thematic map

Likewise, the thematic vector images, soil maps were clipped from the countries respective thematic maps through the ArcGIS program. Soil depth, soil types, soil erodability (K) maps are extracted from Soil map of Ethiopia. Monthly Rainfall of the catchment was obtained from Metrological Agency.

4.2.2 Collection of Primary data

Missed data and data verification was conducted through primary data collection. A field visit to the study site was undertaken to take training sites and interviews with the concerned institutes and individuals. Discussed with North showa zone administration Office, in particular Basona Worana Woreda Natural Resource Conservation related experts. Moreover, Development Agents (DA) in Gudoberet were consulted.

Primary data were also collected using a GPS. GPS is used to measure location (point data) which was finally copied in Excel program as X and Y coordinate, exported as point data (x,y) in ArcGIS. It also pathway indicating the direction of motion so that go to any point recorded in the instrument. However, the instrument extension cable, which connects to the computer was unavailable and hence data is encoded through keyboard. This obviously demands patience for proper checking otherwise point data which thought nearby will be displayed at different location. This was experienced during this study. Point data collected was digitized to develop polygon shape file, which indicates surveyed sites where the top soil of the land is mostly eroded. These areas were animal tracks, water ways, or extensively cultivated lands. These areas also were used as training area in the supervised classification. This was with the assumption that different earth features will have different spectral reflectance that distinguished from others.

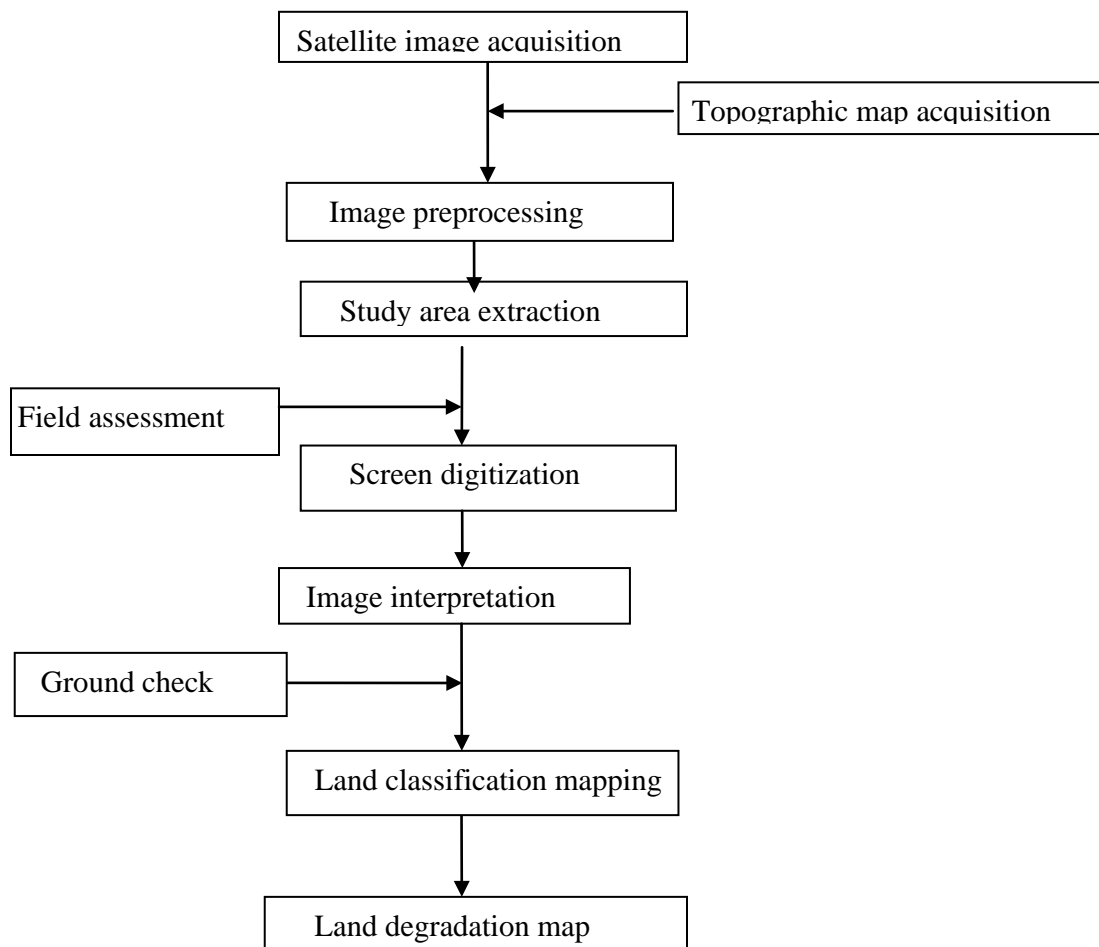


Figure 17. General Methodology of the Study

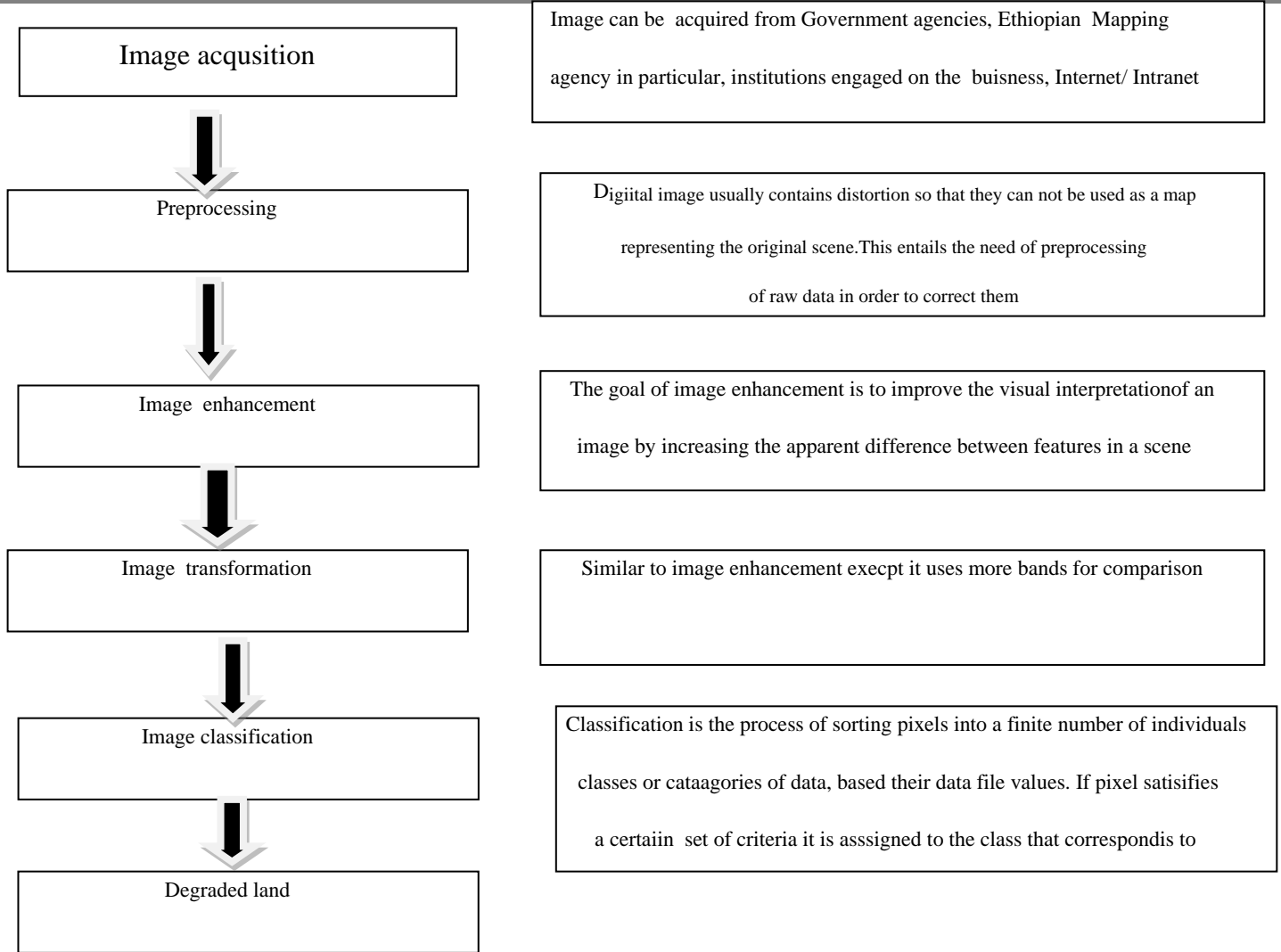


Figure 18. Schematwic representation of method of image interpretation.

4.2.3 Data analyses and interpretation

4.2.3.1. Image processing

Satellite images have been useful to draw important information about earth features. This information would be valuable when they are used in decision making for improving human livelihood and bring sustainable development to particular area or the system it operates in general. To this end, the information obtained from satellites should pass a serious of steps before use (Figure 17).

I) Preprocessing

Preprocessing is needed to remove geometric and radiometric errors during image acquisition (Figures 17 and 18). Geometric corrections include correcting for geometric distortions due to sensor-Earth geometry variations, and conversion of the data to real world coordinates (e.g. latitude and longitude) on the Earth's surface (Jensen, 1996).

a) ETM+ of 2008 image

In conducting this research, a number of radiometric error corrections were used. The satellite image of the year 2008 (Figure 19) was degraded due to considerable systematic errors, periodic noise strips. The spectral reflectance recorded in each bad pixel was initially valued (0,1,2,3...), which were very much reduce to that of the neighboring pixel values. Hence using Erdas Imagine 9.1 program and applying image interpreter, Morphology operators iteratively, strips were removed.

Moreover, moving window 3x3 corrected the errors. Hence, Excluding and ignoring the specific values in the analyses was done to improve the result. The corrected image is then further manipulated to discriminate between features in scene.

However, a number of rectangular areas with considerable grid size were developed that seems projected outwards from the surface. These also affected spatial reflectance. Therefore, as alternative Periodic Noise Removal program from Image Interpreter was applied and major portion of the strips were removed (Figure 20).

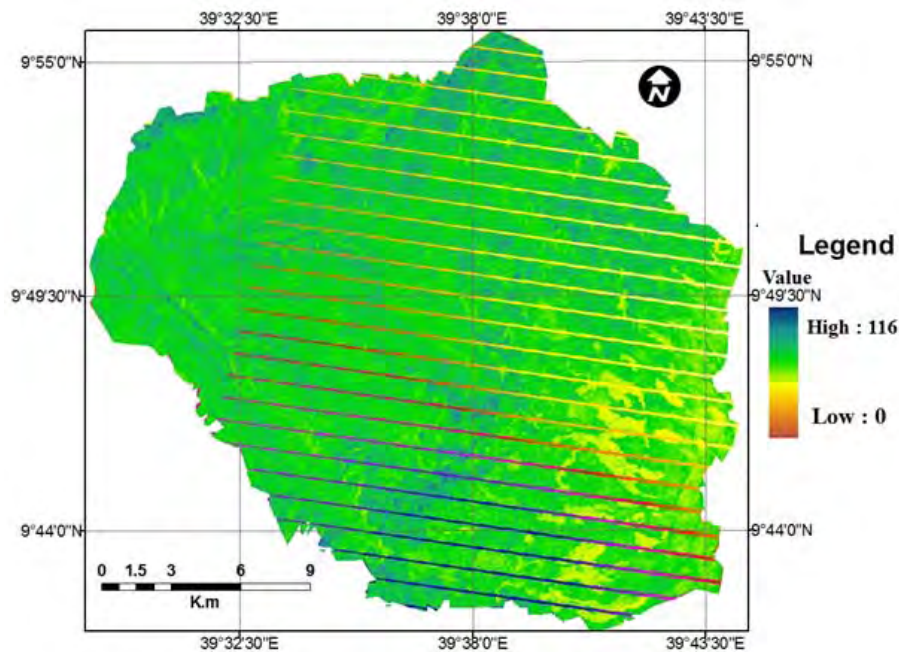


Figure 19. Periodic Noise of 2008 Landsat Image.

To improve the pixels values, generalize missing data on the line of the strips convolution filter 3X3 low pass kernel Window is applied and hence the image spectral resolution improved (Figure 20).

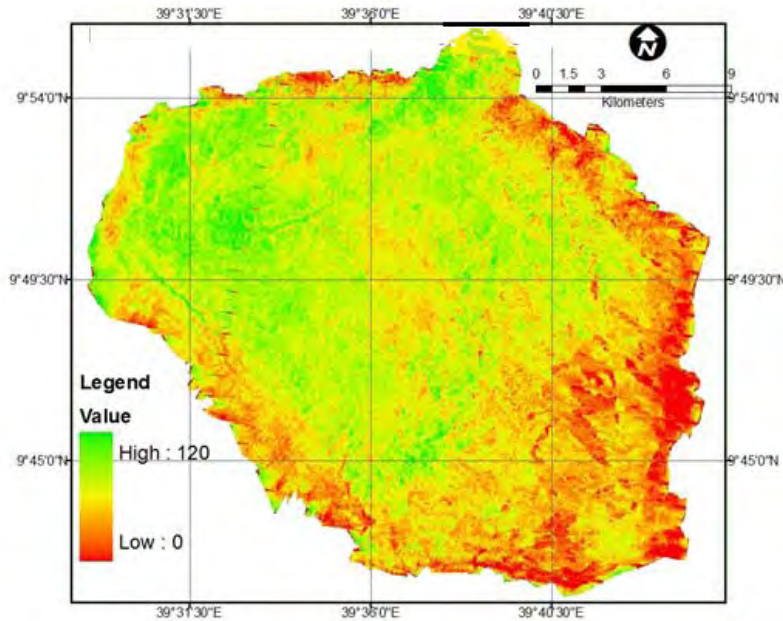


Figure 20. ETM+2008 strip removed.

b) Thematic Mapper (TM) of 1986 image

The satellite image acquired for the study site TM of 1986 image was not free from cloud which required a considerable effort. Modeler was used in this respect. The spectral resolution of cloud was with range of 240-250 and above. These values were adjusted by modeler applying conditional statement. This, however, doesn't eliminate the cloud. But, the effect was not reflected in image classification.

Similarly, the Destriping program was applied, but failed to remove the strips which were recommended for TM 4 Sensor.

c) Multispectral Sensor of 1973 Satellite Image

On the image there were two strips crossing the image along the row and periodic striping seems rather deteriorated the image. This is for the fact that areas beyond the boundary of the watershed were registered with some values in which masking was applied.

4.2.3. 2. Image Enhancement

The goal of image enhancement was to improve the visual interpretability of an image by increasing the apparent distinction between the features in a scene after removal of errors as indicated in preprocessing.

Spectral reflectance of different land feature varies due to the characteristics (physical, chemical) of the object under investigation. Variation also exists band to band within the same scanner for the same object. In this respect, Histogram equalizer, color combination and NDVI were applied in this study.

a) Histogram equalizer

Despite radiometric resolution for 8 bit arrays 0-255, the acquired radiometric resolution of the image (Figure 20) which is under discussion after preprocessing was low (0-120) that visual discriminating of object in a scene is limited. Hence the Histogram Equalizer applied and enabled to enhance the resolution to the full scale and can be shown in Image information (Figure 21).

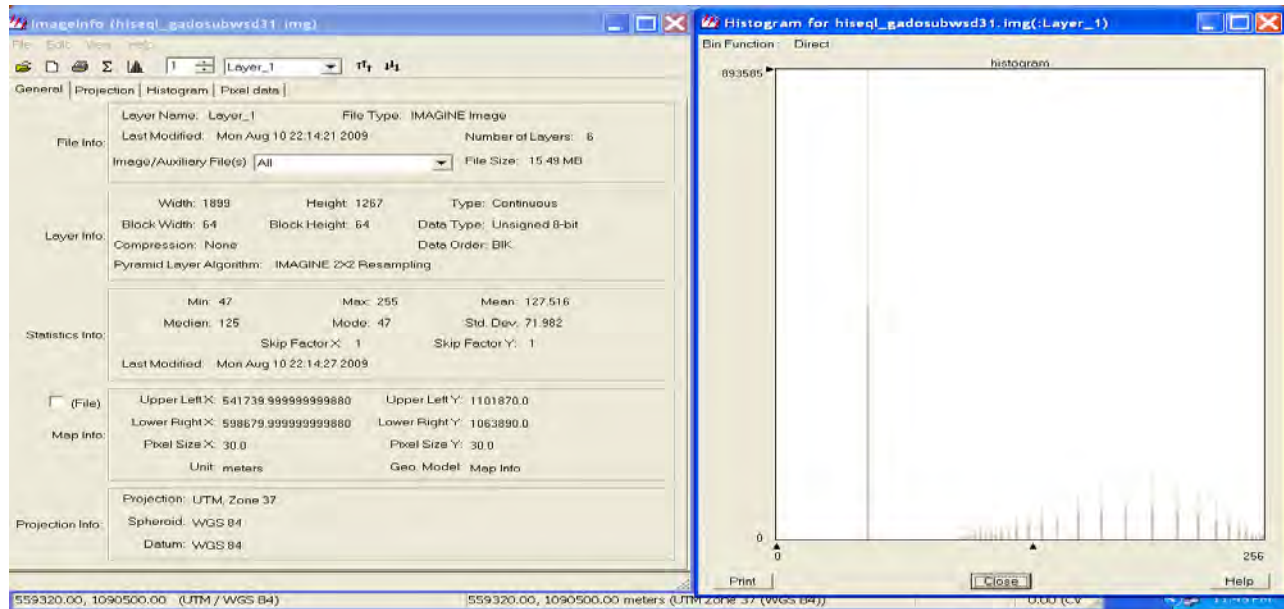


Figure. 21 Typical image information of Gado sub-watershed.

b) Band combination

For visual interpretation of a satellite image is possible through different color combination. In this respect, band combination of 4,3,2 for band red, green, and blue, respectively are important. In this false color combination, vegetation will be shown red color while bare land/settlement pink color and water body nearly blue/ black. True color combination is however, 3,2,1 with similar color order as specified above in which green object are green, and others possess their natural color similarly.

c) NDVI

Normalize Difference Vegetation Index (NDVI) can be used as a tool to define vegetation, soil and water bodies for their value ranges between 1 and -1. Depending on health, stress or maturity, vegetation shows value less than 1 and water bodies around -1. The value of water is influenced with the availability of sediment, water depth or green plants as an example. Soil usual has value around zero.

In the analyses of study site, the NDVI ranges between -0.378 to 0.672 for satellite image ETM+2008 and between 1 to -0.55 for 1973 Multispectral Sensor (MSS), (Figures 21). The value -0.378 refers to moist lands

and 0.673 related to grassland and partially for the plantation. The image could also be displayed in gray scale, black and white.

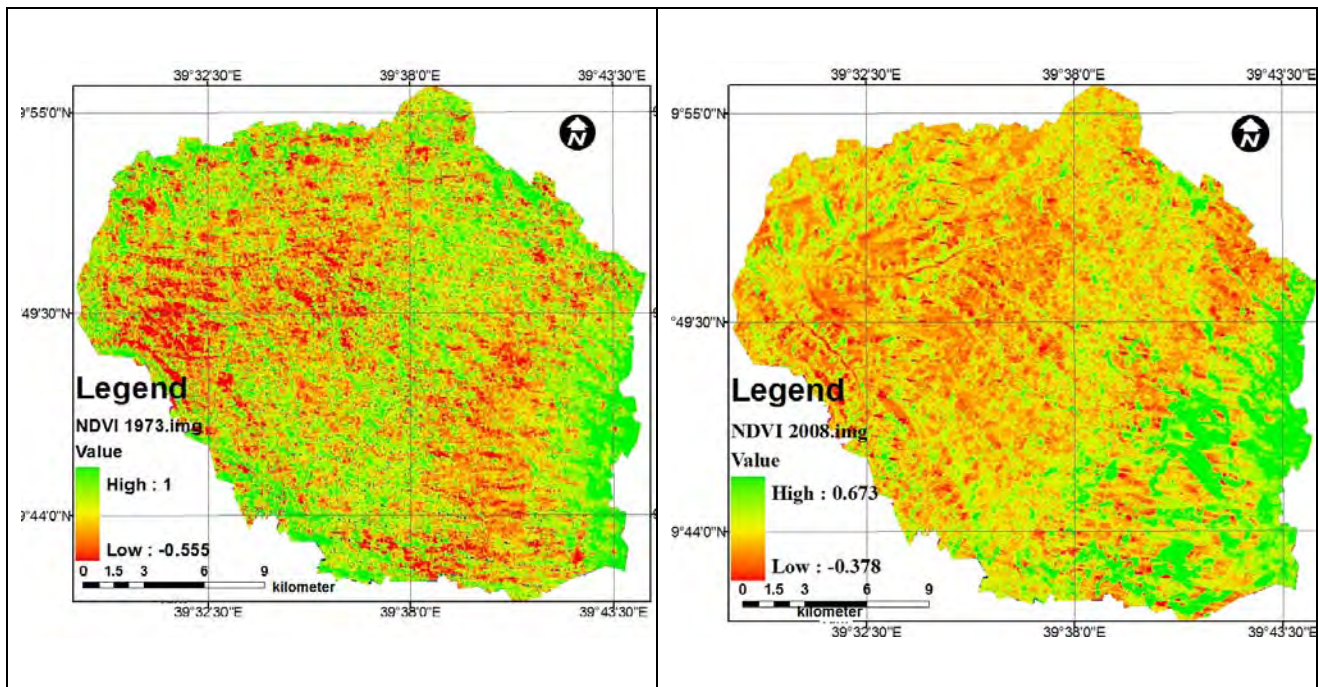


Figure 22. NDVI map of 1973 and 2008.

The water body which is displayed in red color most probably exhibits areas that are partially used in irrigation. The discussions that was made with the Development Agents in Gudoberet has indicated the presence of irrigation within the kebele. Similarly, this could also be true in other Kebeles in the SWD as well. In regard to vegetation cover visual interpretation can be made and valued. Hence, vegetation of the years 1973 and 2008 can be compared. This is related to grasslands or alpine in the very high altitude more than 3000 m above sea level common in both years, on eastern direction. Vegetation of fuelwood plantation is dominant in 2008 while scrub land is deminishing. The reverse is true for 1973 where the plantation is missing in eastern part continuous to high altitude alpine vegetation. On north western part of the year of 1973 however, vegetation is very well seen and distributed in the central part as well which 2008 year shows disturbed vegetation.

Similarly the years 2008 and 1986 can be compared. On figure 23 NDVI of 1986 year is shown. Green colors with value around 0.7 and 0.5 indicate vegetation in both years. Moreover, plantation in particular eucalyptus is know well established in the year, 2008 on the eastern direction of the subwatershed. The plantation of the year 2008 is missing in 1986 similar to 1973..

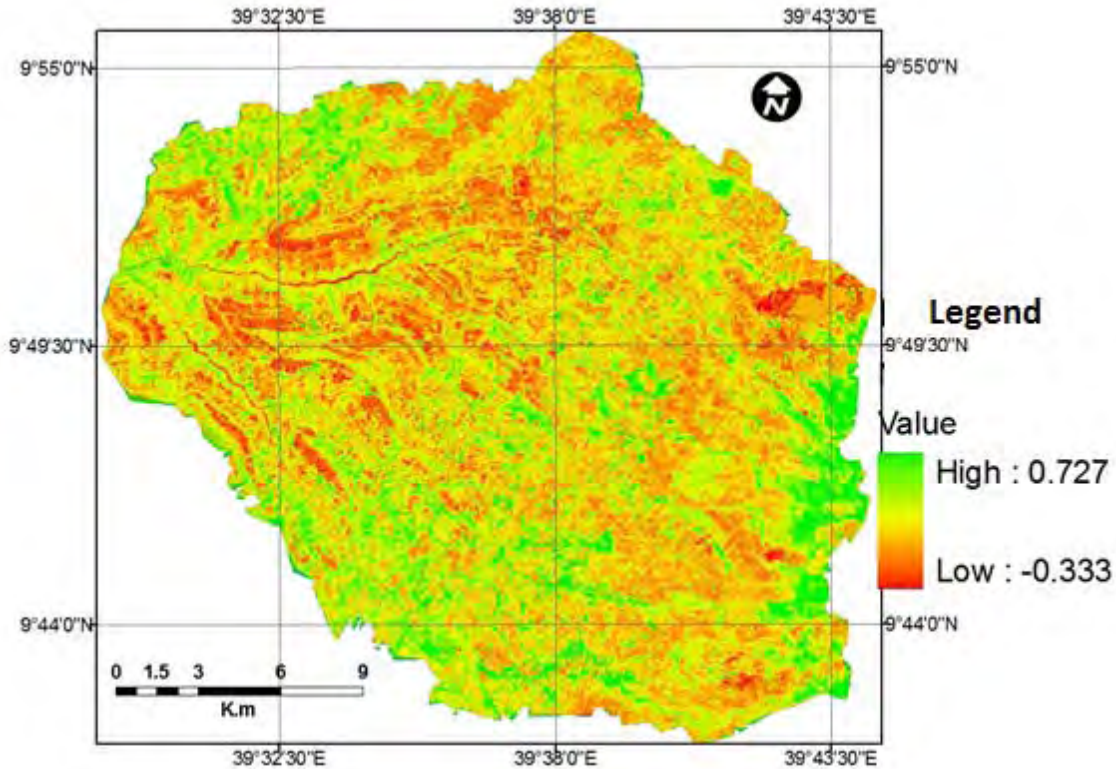


Figure. 23 NDVI map of 1986.

Hence, NDVI can support identify the image features and enable discriminated objects with reasonable area coverage. Visual judgment of 1973, the grassland/guassa coverage reduced while grass/vegetation coverage around the boundary better than the other two.

d) Spectral profile

Spectral profile tool is one of the possible means of discrimination of features of earth. Green vegetation has low reflectance in band one (blue band) and band three (red band) while high in green in which what we see is that part of energy reflected. Hence spectral profile tool is used to display the response of objects to the bands. Observing the graph, it is possible to define the object we are observing.

4.2.3.3 Image Classification

Image classification is the process of sorting pixels into a finite number of individual classes, or categories of data, based on their data file values. If a pixel satisfies a certain set of criteria, then the pixel is assigned to the class that corresponds to that criterion.

In classifying landsat image of Gado SWD, supervised classification is preferred for the availability of information of the area. Topographic map and the field visit have considerable importance. The altitude difference between 2000-3700 m in the study area have impact on the type of vegetation growing and hence

very high altitudes are then easily classified by taking sample pixels and defining the class. In this regard, the high altitude areas were defined as alpine/ grassland or local grass known as guassa. Moreover, the NDVI value is used in categorizing the pixels. Furthermore, the selected seed pixels were expanded to likely accommodate similar values using seed pixel tool.

Evaluation of training pixels was done for the histogram of seed pixel value. In case there is a single class, the histogram will look bell shape while irregular shape can be observed in the mix classes and an overlap will be distinguished on histogram. In this respect, the histograms development looked bell shape and overlap with cultivation land on band four, which implied the existence of same similarity. Accuracy assessment through drawing of contingency matrix was another option to check the classification.

4.2.3.4 Watershed

Watershed can be defined as a land surface bounded by a divide and contributing runoff to a common point, confluence point (MoARD, 2005). Drainage basin or catchment are similar terms used as equivalent as watershed in different literatures. When delineating watersheds or defining stream networks, a series of steps are followed. Some steps are mandatory, while others are optional depending on the characteristics of the input data. Digital elevation model is the first requirement to this effect.

a) Fill Sink

Digital elevation model is used to determine which cells flow into other cells (the flow direction). However, if there are errors in the elevation model or if the area is karst geology, there may be some cell locations that are lower than the surrounding cells in that, all water traveling into the cell will not travel out. The number of sinks in a given DEM is normally higher for coarser resolution DEMs. Another common cause of sinks results from storing the elevation data as an integer number. This can be particularly troublesome in areas of low vertical relief. DEMs may also contain noticeable horizontal striping, a result of systematic sampling errors when creating the DEM. Again, this is most noticeable on integer data in flat areas.

These depressions are called sinks. The hydrologic analysis functions allow identifying the sinks and tools to fill them. The result is a depression less elevation model. You can then determine the flow direction on this depression less elevation model. The identification and removal of sinks when creating a depressionless DEM is an iterative process. When a sink is filled, the boundaries of the filled area may create new sinks, which then need to be filled.

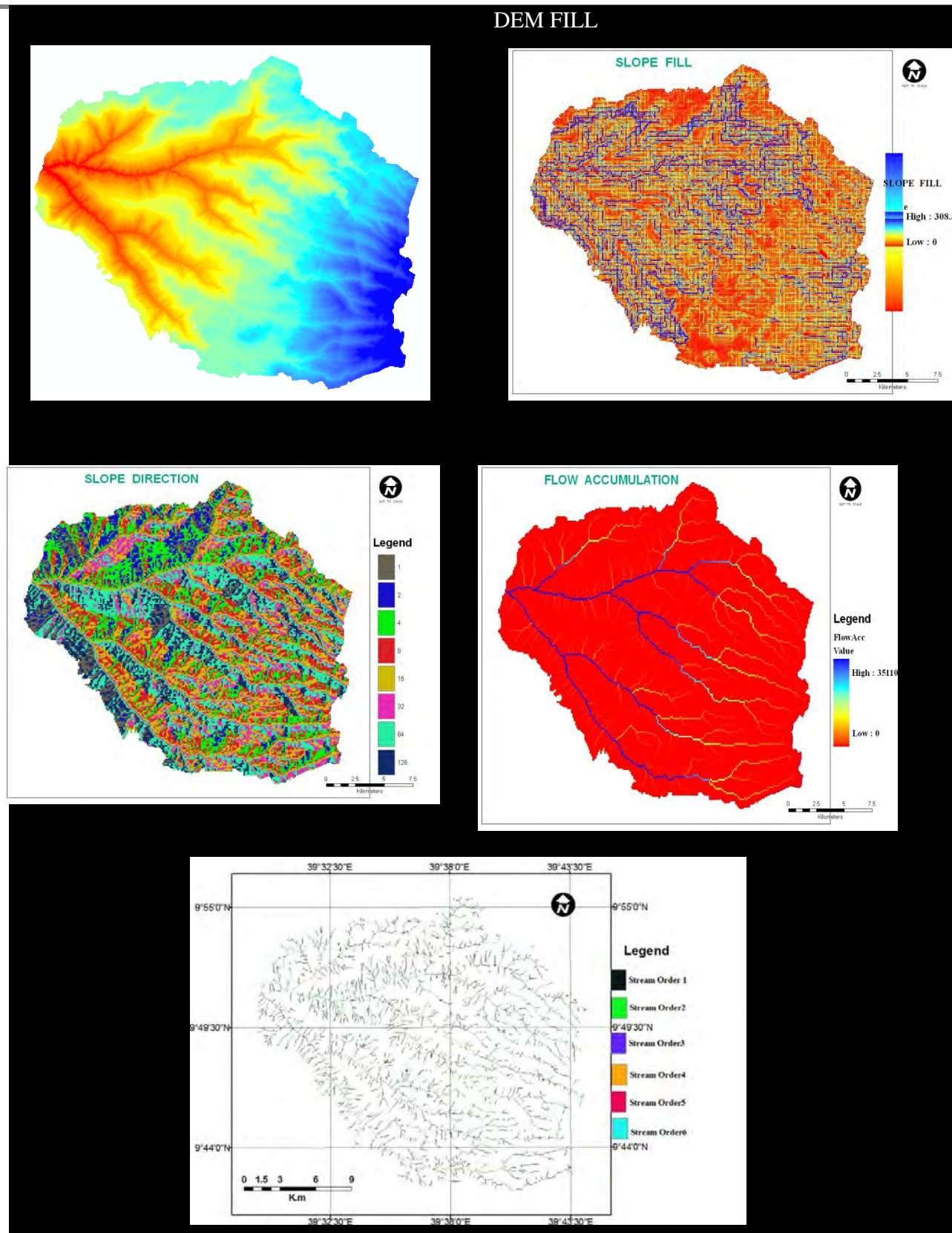
C) Flow Accumulation

The Flow Accumulation function calculates accumulated flow as the accumulated weight of all cells flowing into each down slope cell in the output raster. If no weight raster is provided, a weight of one is applied to each cell, and the value of cells in the output raster will be the number of cells that flow into each cell. Cells with a high flow accumulation are areas of concentrated flow and may be used to identify stream channels. Cells with a flow accumulation of zero are local topographic highs and may be used to identify ridges. Flow accumulation in its simplest form is the number of upslope cells that flow into each cell.

d) Stream ordering

Stream ordering is a method of assigning a numeric order to links in a stream network. This order is a method for identifying and classifying types of streams based on their number of tributaries. Some characteristics of streams can be inferred by simply knowing their order. First-order streams are dominated by overland flow of water; they have no upstream concentrated flow. In the Strahler method, stream order increases when streams of the same order intersect. Therefore, the intersection of two first-order links will create a second-order link, and the intersection of two second-order links will create a third-order link. The intersection of two links of different orders, however, will not result in an increase in order. In this respect, the Gado subwatershed which under consideration has a level of six stream orders (Figure 24). The stream order also could indicate the drainage pattern of the area.

Drainage pattern indicates landform and bed rock type and suggest soil characteristics and site drainage (Figure 25). Gado subwatershed has dendritic drainage pattern which is well integrated pattern formed by a main stream with its tributaries branching and rebranching freely in all directions and occurs on relatively homogenous materials. But still smaller branches join to higher size streams at right angle that rectangular drainage pattern also exist revealing dendrite pattern is modified by structural bedrock.



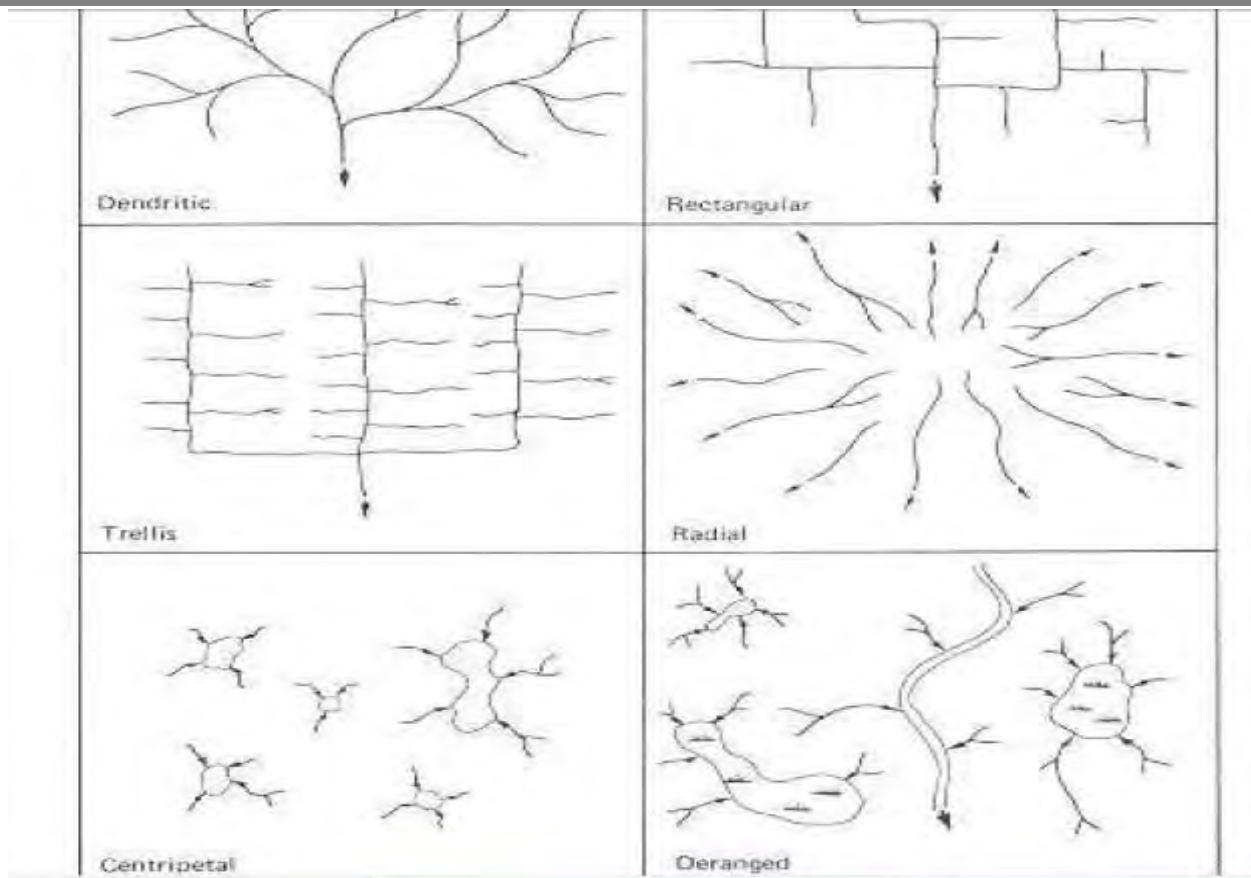


Figure 25. Six basic drainage patterns

4.3.3.5. Soil erosion estimate using Universal Soil Loss Equation Model

The USLE is an empirical erosion model based on data sets from the U.S.A. (Wischmeier and Smith 1978). The average annual soil loss is dependent on the factors: rainfall erosivity (R factor) , soil erodibility (K factor), slope length (L factor) , slope gradient(S factor), land cover (C factor) and land management (P factor) (Wischmeier and Smith 1978); (Fredric R., J.Arthur Hobbs, et al ,1999).

USLE estimates erosion on the base of

$$A=R*K*LS*C*P$$

Where A= Soil loss in ton/ hectare-year

Reference soil plot is 22.1 m long with A uniform, 9% slope, in Fallow (barren, no plant cover which is Tilled up –and down-slope

R factor = Rainfall erosivity

SL factor = slope length factor

C crop factor= land management factor

P conservation practices factor= conservation practices

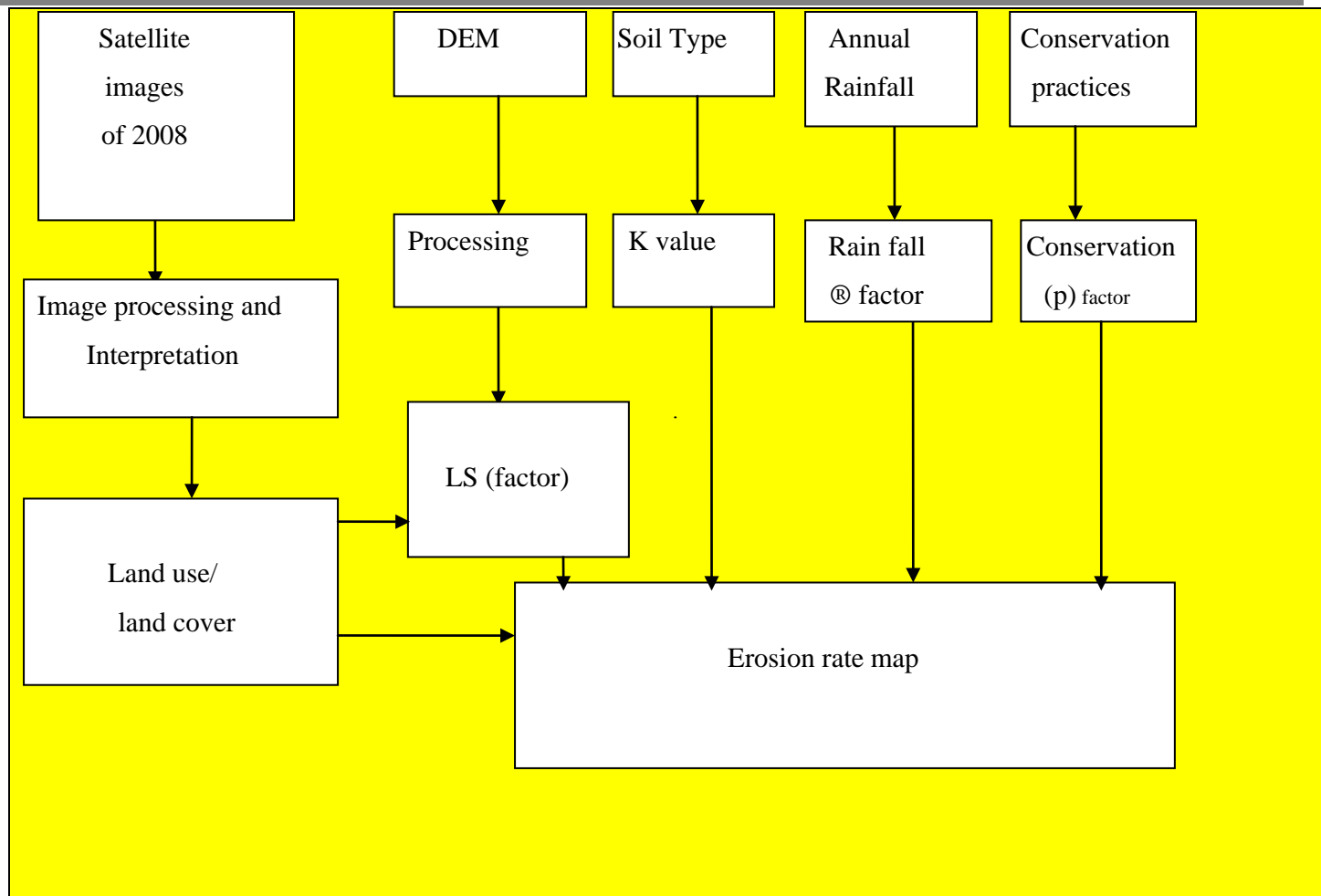


Figure 26. Soil erosion estimation model (USLE)

4.2.3.6 Parameter for USLE erosion estimate

a) Rainfall erosivity (R factor)

Soil erosion is related to rainfall in particular rainfall intensity. The higher the intensity of the rainfall the higher energy of water drop to cause splash erosion. The duration or amount of the rainfall is paramount important for consequence erosion. Unless the rainfall amount is sufficient enough to cause runoff, erosion hazard might not a serious concern.

Though in estimating rainfall erosivity, rainfall duration and intensity are important, sufficient data is not available. Hence, as an alternative to Ethiopian condition, Hurni 1985 from spatial regression analyses (Heleden, 1987) derived equation from available mean annual rainfall (P). It is given by an equation:

$$R = -8.12 + 0.562 * P,$$

Where P = mean annual rainfall in mm. In estimating P, mean annual rainfall of six sites of 20-25 years duration was obtained from Metrological Agency.

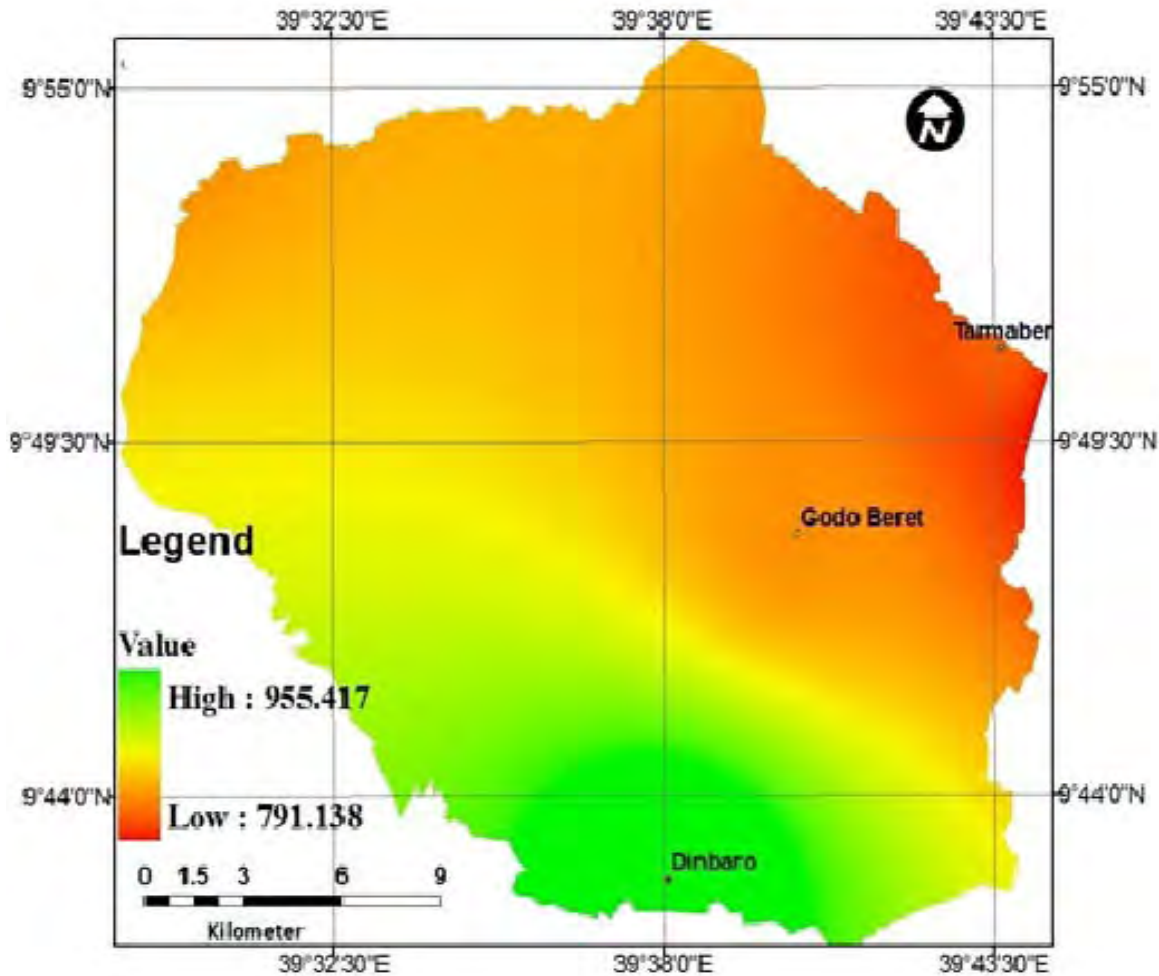


Figure 27. R Factor Map.

But, it is incomplete and for use. Hence an alternative, Ethio_GIS data is used. Derived raster rainfall erosivity of the SWD is shown on Figure 27 which ranges between 791-955 in mm.

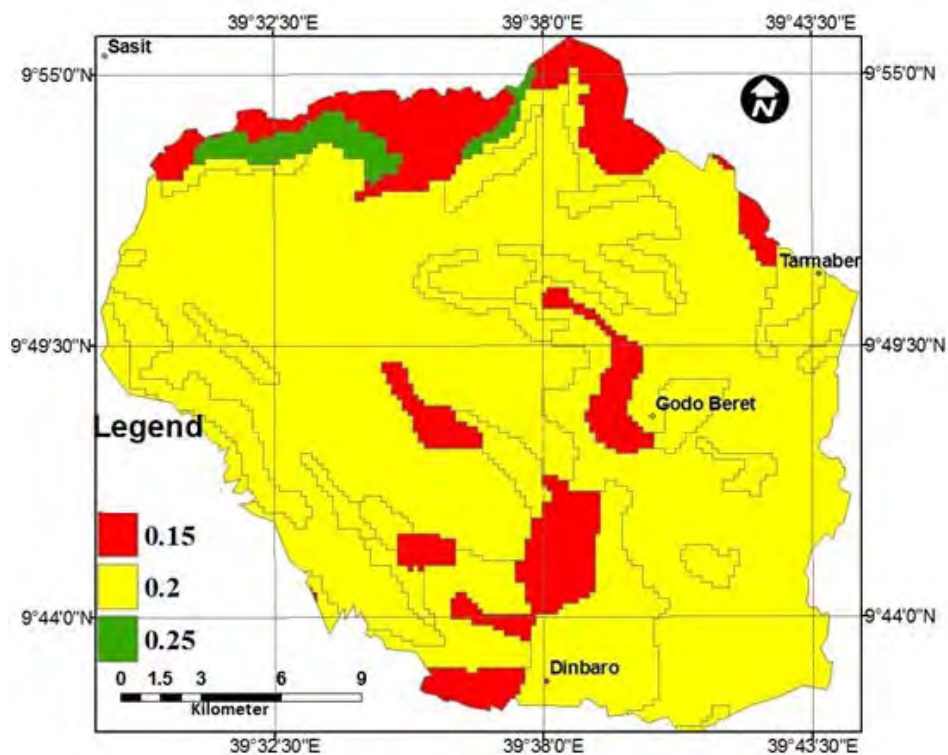
b) Soil Erodability Factor (K)

It is a function of texture, organic matter (OM) content, the structure and permeability. It has indicated that soils derived from Metamorphic rock (eg granites, schests and gneisses) which includes most of the luvisols & Acrisols are much more erodible that soils derived from volcanic rocks (eg basalt or trachyte)(FAO,1986). It is defined as mean annual rainfall soil loss per unit of R for a standard condition of soil, recently ploughed up and down, with no conservation practice and on slope of 5° and length of 22m length (Morgan,1994). The value of K varies 0 to 1 as shown on Table 8. Soil of the study area is obtained from the Ministry of Agriculture and Rural Development and K value is referred form Soil Conservation Research Project (SCRCP).

Table 8. K-factor Value of Soils in the sub-watershed.

No.	Major soil	Soil color	SCRP estimates of K factor-value
1	Eutric Fluvisols	Mostly brown but variable	0.2
2	Eutric Vertisols	Dark grey or Black	0.15
3	Eutric Cambisol	Brown or Dark brown	0.2
4	Eutric Leptosols	Brown to yellowish brown	0.2
5	Haplic Alisols	Reddish brown	0.25
6	Haplic Luvisols	Brown /Reddish brown	0.2
7	Haplic Nitosols	Reddish brown	0.25
8	Chromic Luvisol	Brown /Reddish brown	0.2
9	Lithic Leptosols	Brown to yellowish brown	0.2
10	Eutric Regosols	Brown	0.2

The value of raster K value of the SWD ranges 0.15-0.25 and its distribution in spatial scale is shown on Figure 28. This value will be used in determination of Soil erosion in the SWD.

**Figure 28. K factor Map.**

a) Slope length factor (SL)

It characterizes the topography of a landscape and the rate of erosion in USLE. It can be derived from DEM. Previously, slope (S) and length (L) were calculated independently and applied in estimating erosion, USLE. In deriving SL from DEM there are a number of measures to be taken. One of these is avoiding gaps in the DEM that the flow of water won't be disrupted. Hence, filling missing data from already available information is a common exercise. Flow across a surface will always be in the steepest down slope direction. Once the direction of flow out of each cell is known, it is possible to determine which and how many cells flow into any given cell. This information can be used to define watershed boundaries and stream networks.

Topographic factors (LS) are given by

$$L = \bar{h} / 22.1$$

Where \bar{h} is projected horizontal distance in meter between onset of the runoff and point where runoff reaches a channel larger than rill or depression occurs, and;

$$S = 65.4^2 (\sin^2 \Theta) + 4.56q \sin + 0.0654 \text{-----Equation 4.1}$$

where Θ is the angle to the horizontal in the USLE, and a number of formulas are derived or nomograph is also produced (Wischmeier and Smith, 1978).

A combined expression of SL from a standard condition of slope 9% and length of 22m equals to 1. The other option to SL determination is use of DEM and follow a number of procedures and drive flow accumulation could enable calculate SL.

$$SL = \text{pow}((\text{flow accumulation}) * \text{Resolution} / 22.1, 0.6) * \text{pow}(\sin(\text{slope}) * 0.01745) / 0.09, 1.3) \text{Equation 4.2}$$

The value of resolution corresponds to is the size of cell of DEM. The slope length calculated for the SWD ranges 0-12744 (Figure 32). Increase in the value reflects the degree of impact to cause erosion. Increase in slope increases erosion rate. Similarly increase in slope length will enable the running water/runoff to acquire energy which could have tremendous power to transport soil.

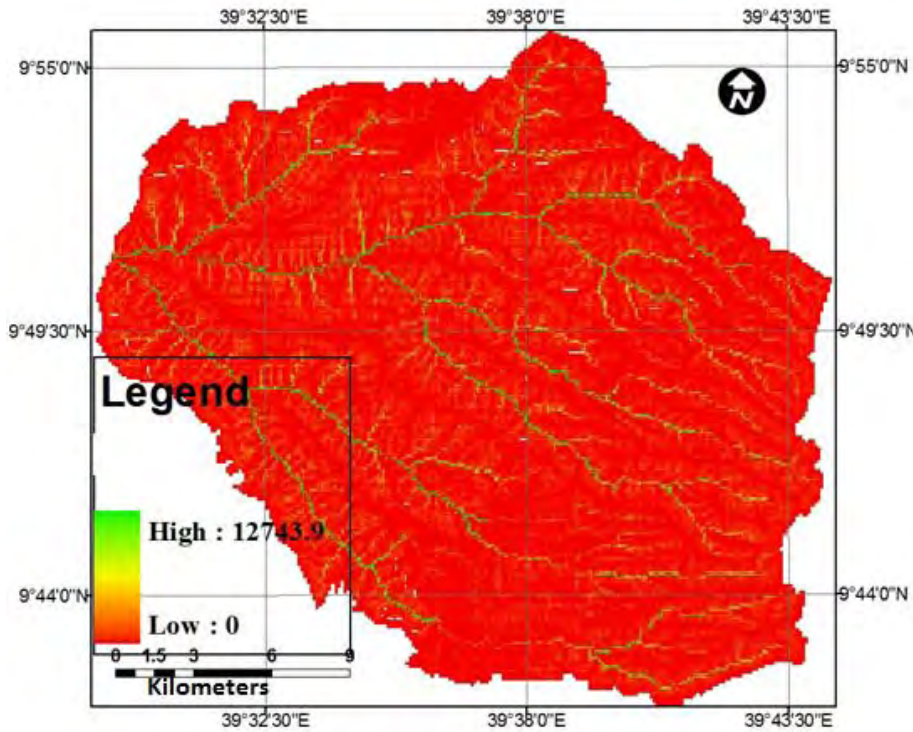


Figure 29. LS factor Map

d) Crop management, C factor value

The crop management factor, C, represents the ratio of soil loss under a given landcover/land use to that of the base soil (Morgan, 1984). The value of C has to be set seriously otherwise the result could be misleading. Hence, accurate land use/landcover should be used in the analyses. In this respect, the raster map has been converted to vector data and column is added to the look up table that the value of C is adjusted. The value ranges 0.001for dense forest or grassland to 0.6 for bare land in which soil erosion could increase by 600 times if other things keeps constant in between the two factors alone as indicated on Table 9.

Table 9 Crop management , C-factor Value of Previous Study

S.No	land use	source	C factor value
1	forest	Hunri,1985	0.01
2	scrub	CGIP,1996	0.02
3	Grass land	CGIP,1996	0.01
4	Degraded grass	Hunri,1985	0.05
5	Crop land/wooded crop land	Hunri,1985	0.15
6	Crop land teff as main crop	CGIP,1995	0.25
7	Crop land sorghum/maize	Hunri,1985	0.10

8	Afro-alpine	Hunri, 1985	0.01
9	Open scrub land	CGIP, 1996	0.06
10	Bush land	BCEOM, 1998	0.1
11	Bare land	BCEOM, 1998	0.6

With this table in mind the value of C was filled in the shape file which later converted to raster format for calculating erosion in the subwatershed.

In regard to C values of the SWD were as indicated in Figure 30. It ranges between 0.01 for forest which is not dense and where ground cover for other plants growth is limited in case of eucalyptus to 0.5 for degraded land which is with limited management practices to control erosion. Cultivated land is given 0.15 and 0.2 for scrub lands. Increase in value of C means increase in the erosion rate in the SWD and hence actions to withstand the danger need attention.

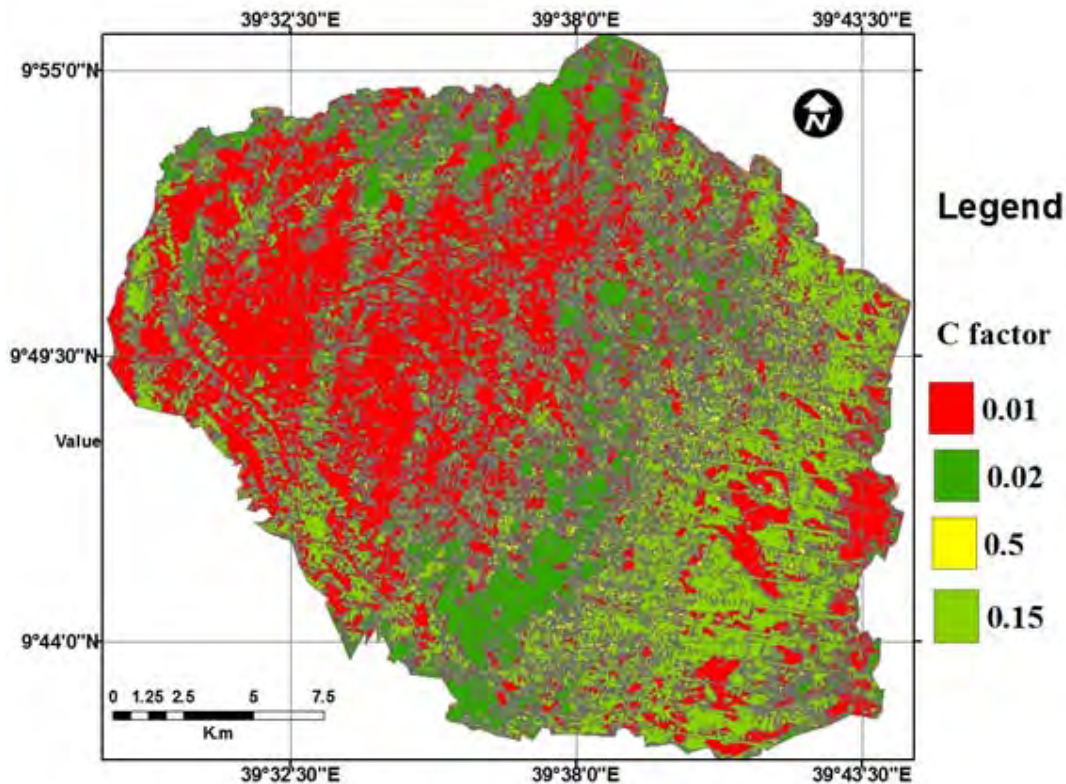


Figure 30. Land use, C Factor

b)Erosion Management Practice (P)

This is the management practice that would be undertaken to a land. Different conservation practices will play a great role in controlling runoff. If runoff is missed attention, running water could increase in size and speed that land will be exposed to degradation. Hence, it is a common practise that running water/ runoff speed is kept to the the minimun or conveyed in structure that will withstand erosivity of that specific speed. This is true in the construction of road drainages and drop structures. The other option is reducing the volume of runoff by enabling seepage, storage,divert the stream at various points and join to natural or man-made drainage structures. Management practise value ranges between 0-1. The management practiced is related to slope. Wischmeier and Smith (1984) calculated the P value by classifying the land into two groups agriculture and other. As slope increases P-value increases similarly.

Table 10 Conservation Practices and Slope Relation

S.no	Slope %	P factor value
1	<5	0.1
Agriculture land	5-10	0.12
	10-20	0.14
	20-30	0.19
	30-50	0.25
	>150	0.33
2 others	Other	1

Table . 11 Support Practices, P Factor value (Wischmeier and Smith, 1978)

Support Practice P factor Value	
Ploughing up and down	1
Cropping -----	0.8
Applying Mulch -----	0.6
Stone Cover 80%-----	0.5
Stone Cover 40%-----	0.8
Ploughing on Contour---	0.9
cropping-----	0.8
Dense Intercropping -----	0.7

Slope classes were furthermore reclassified and P value developed for the subwatershed as shown on Figure 31. In this regard value of P is defined with due consideration of the conservation measured that are undertaken and slope of the land.

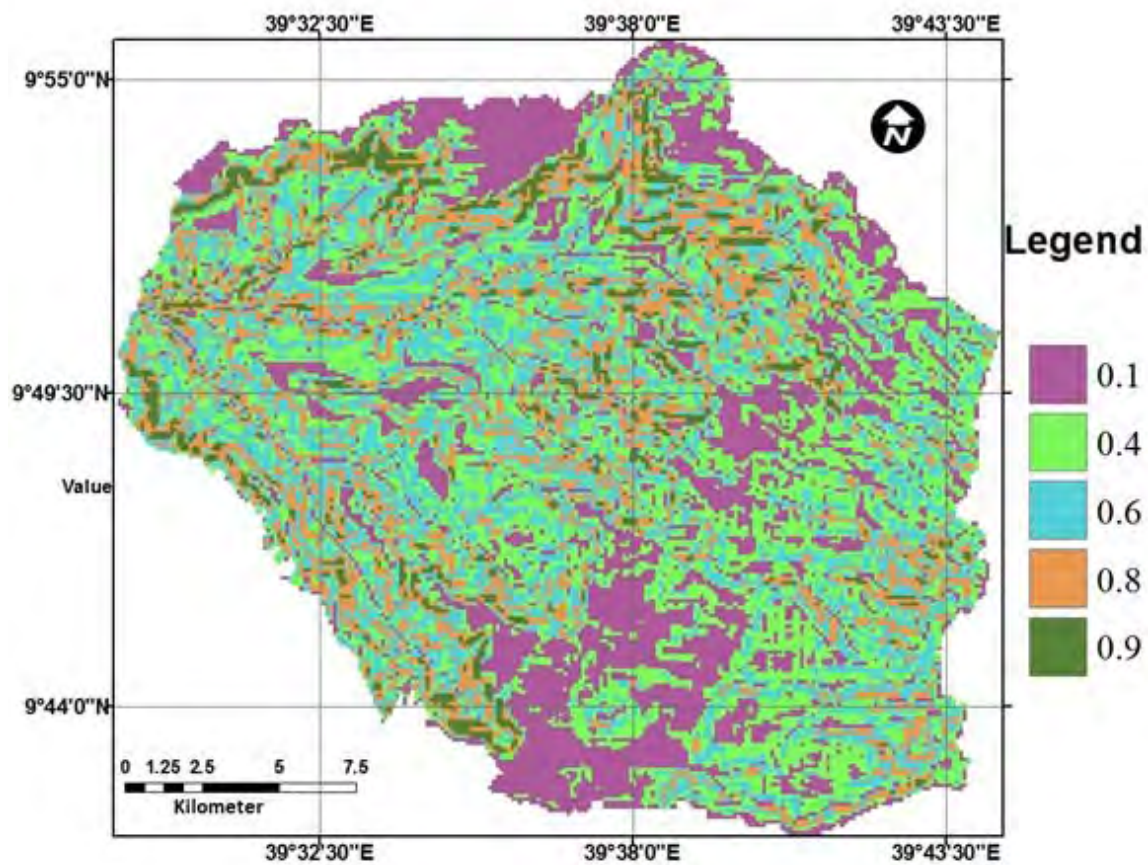


Figure. 31 P value

Chapter v

5. Results and discussion

5.1 Sheet and Rill Erosion

Land degradation in particular soil erosion is exhibited in different erosion forms such as splash, sheet, rill, gully and stream. Splash erosion appears when rain drop fall on bare soil and soil particles are displaced short distance from the point they reside on any direction. While, on slopy area downward distance due to gravity will be higher than upward direction.

Sheet erosion is uniformly scurping landscape and may not be noticed easily. In some areas the soil may settle where there are barriers such as bunds or plain area where speed of runoff declines. Mostly they seem difficult to easily identified and mapped.

Rill erosion affect lands by developing a very low size channels which could increase in depth and transformed to gully or increase in width that forms bare land depending on the depth of the soil. Identification of bare eroded lands on watershed is possible through surveying and delineate their boundary. However, it is time taking and costly. As an alternative in this study, Remote sensing and GIS is used as an additional option to the same purpose of mapping degraded lands.

In identification of degraded lands in the subwatershed it was important to identify land use /landcover of the study area where degraded land was one of the character of classification. Supervised classification is applied based on knowledge of the area under investigation. Furthermore, Fussy classification is selected for the fact that classes are not distinct at the boundary between classes. Hence, land use/land cover map of the watershed is produced (Figure 32). Bare land was one of the output . The result reflected degraded land of 40 km² distributed throught the subwatershed which is about 8 percent of subwatershed(SWD). But, degraded land is concealed by other land uses. Hence, degraded land was selected/extracted and others were hidden(Figure 33).

The Ethiopian Highland Reclamation Study (FAO, 1986) estimated that water erosion moves nearly 1.9 billion tons of fertile soil from the highlands annually. This amount is found to be equivalent to an average soil loss of 130 tons per hectare per year from cultivated lands.

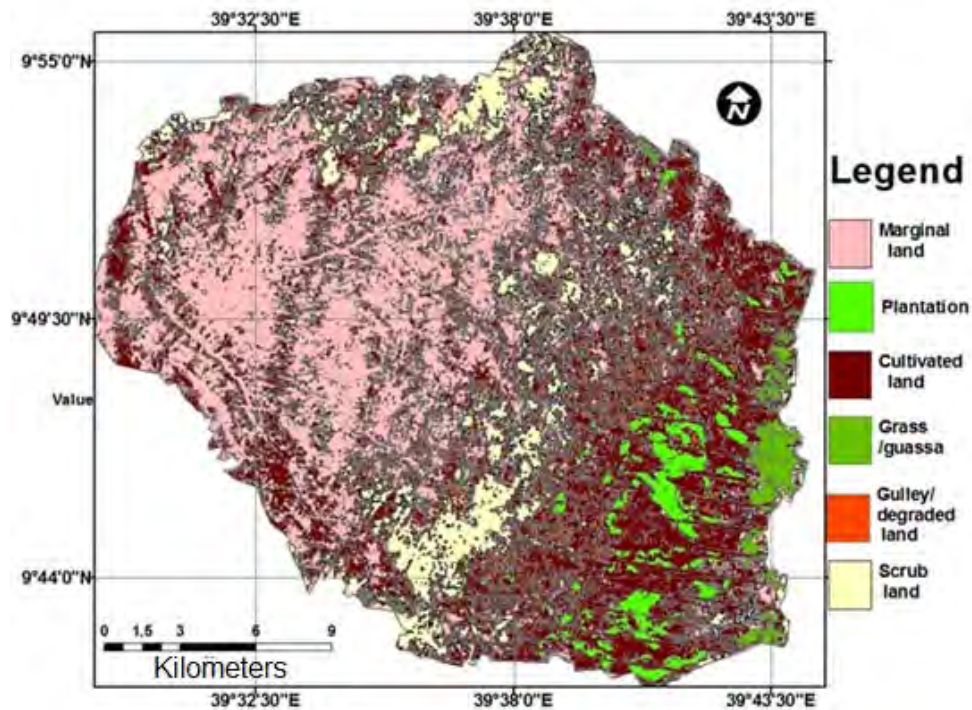


Figure 32 Land use of 2008

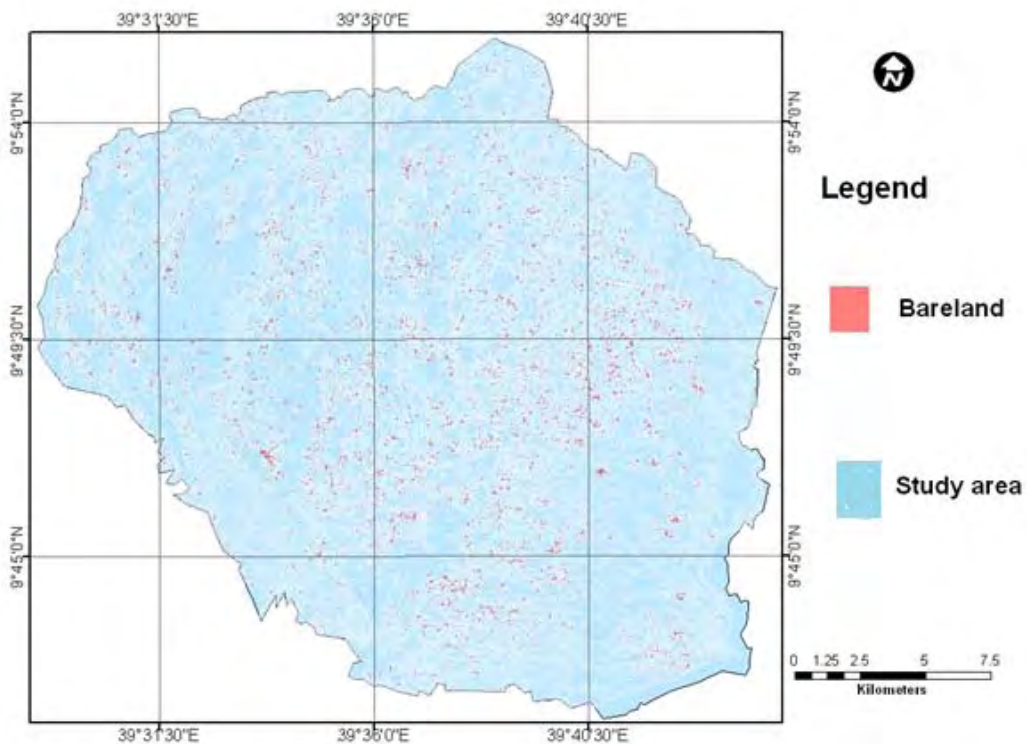


Figure 33. Bare land, 2008

The same study indicates that about 50% of the highlands have been significantly eroded and 25 percent seriously eroded. In this respect, the degraded land identified in the subwatershed is less than the average eroded percentage. This was for the fact that gullies and streams areas were not included 110km²(Figure 34).

Similarly, Abay River Master Plan study indicated the North Shewa zone one of highly affected areas and classified as can not tolerate further soil loss. Furthermore, the same study estimated the rate of soil erosion 51-100ton/hactare/year for the zone. The percentatge of degraded land was not mentioned.

Degraded land that has been notice mainly concentrated on cultivated lands. Shallow soil depth areas were exposed to such damage and form bare lands. Bare lands identified on cultivated lands were disconnected, centripetal which later might expanded unless the land is properly managed.

5.2 Gullies and Streams

The increase in size of rills both in width and depth results gully. Rills usually are considered channels developed with less than one meter depth and width as well. Gully is large enough that can not be eliminated or costly for filling the channels. Gullies are an indication of poor land management that excess runoff is generated in which existing channels could not accommodate flow. Gullies similarly, could further increase in size and develop to stream and valley. Streams could be dry, intermitent, or permanent stream.

The mapping of degraded lands from ETM+ enabled identification of bare lands which were patchy and some of which falls on gullies. Hences as an alternative, in mapping gullies and streams digital image (DEM) was used and undergone a number of processes, filling, flow direction, flow accumulation and steam order using ArcGIS program.. Stream order also indicate the elevation of drainage channels are reducing while area feeding the channel increasing for each stream (Raymond, S.,1994).

Gully and stream are characterized with depth of channel or width. Nearly vertical side slope could be clearly indentified on contours lines. Closely spaced contour lines indicate slopy areas. In this regard, slopy areas bounding the major river tributaries were digitized and area of the degraded lands defined. As an alternative, it was identified that most of gullies/streams have more than 50% side slope and hence developed from DEM. It makes the total degraded land 150 km², which is about 30% of the watershed (Figure 34).

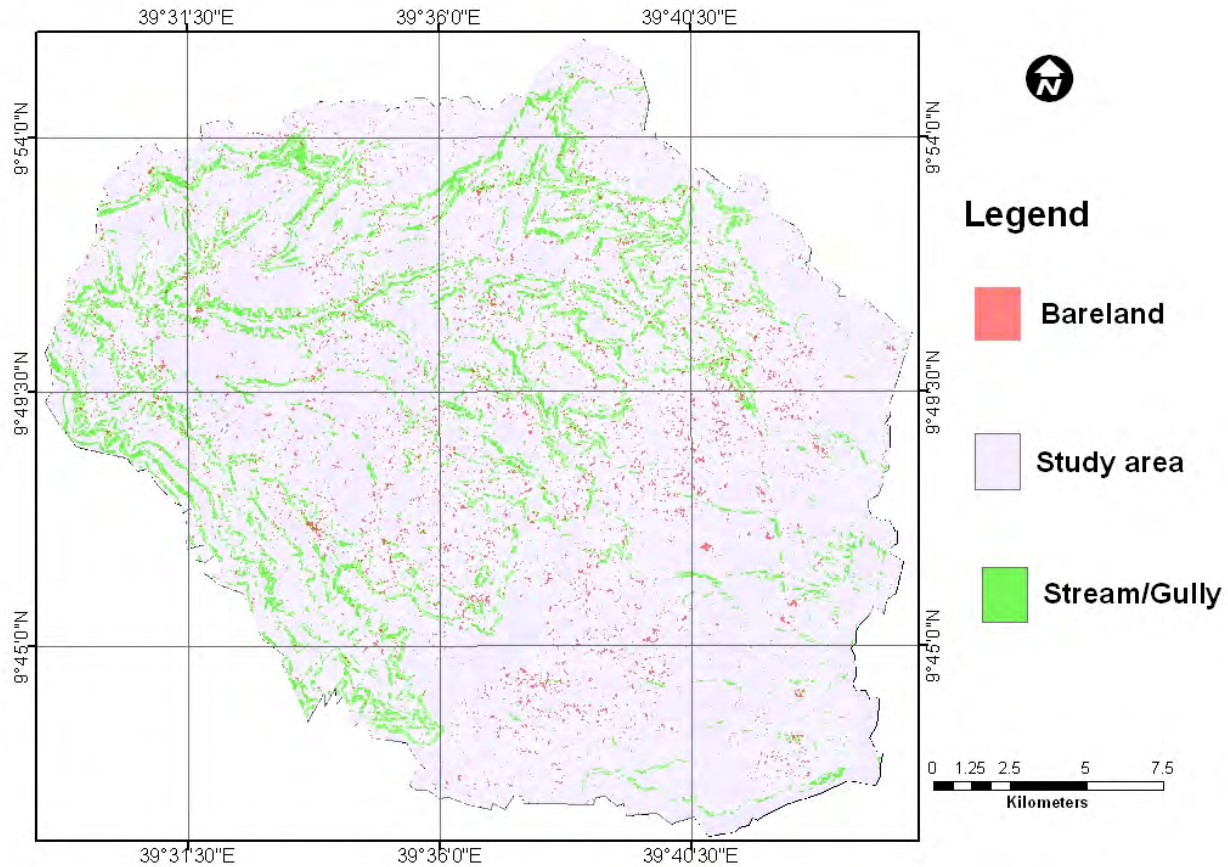


Figure. 34 Major gully and stream in Gado Subwatershed

5.3 Stream Size

There are a number of forces acting on our earth which shape our earth. The tectonic activities, uplift, folding, faulting and rift valley formation can be mentioned. However, the fluvial process and land degradation in particular gullies and streams shape landscape highly. The tectonic activities are geological and requires considerable time, millions of years. However, the fluvial process is active for which the running water is eroding and shapping the landscape (Richard, J. C.,1969).

In mapping of gully and stream it seems clear that their size increases as it goes down stream. The size can be mapped by using global mapper and the cross-section of a stream could be seen (Figure 35). Further, undertaking a number of cross-sections can ascertain the increase in width.

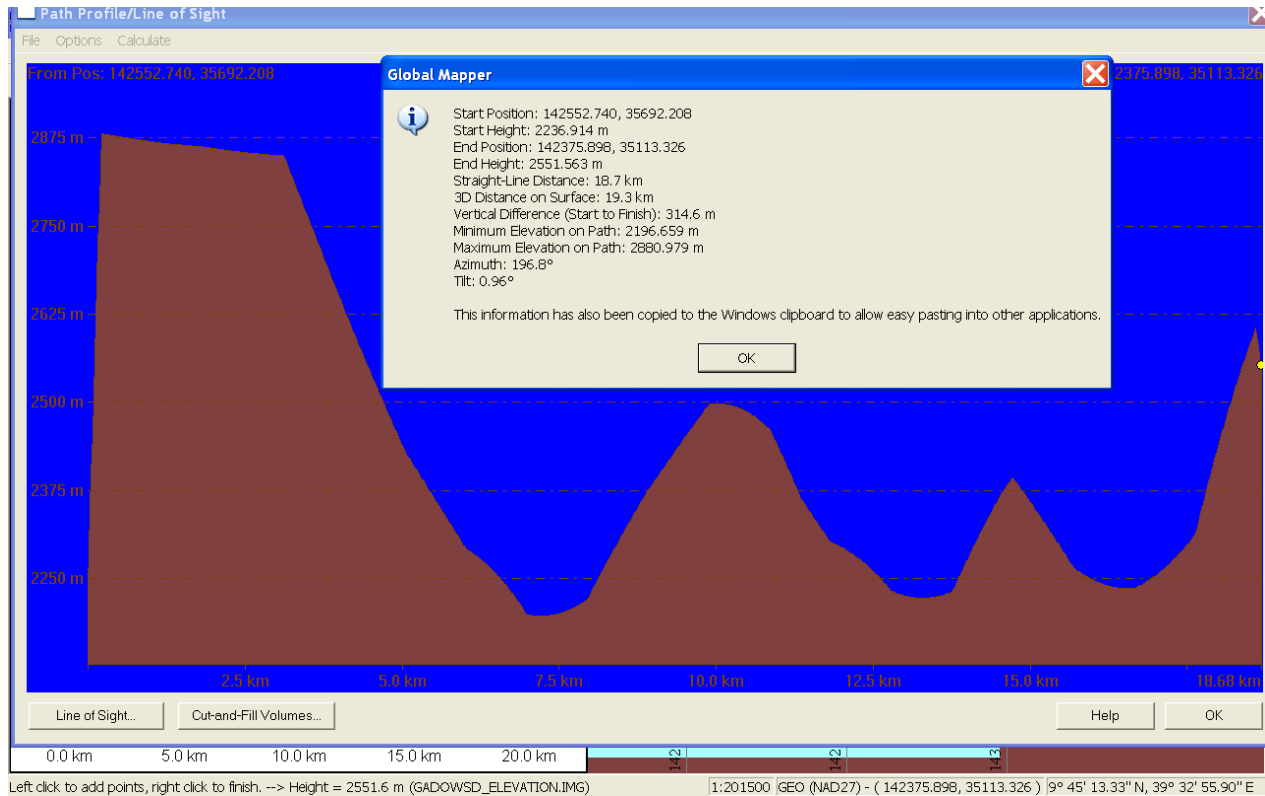


Figure 35 A typical crosssection of the SWD

The other option in defining width variation in stream could be obtained by analyzing contours. Contours tend to go straight line while curved against depression or raised lands.

QuantaumGIS program, identifier tool, indicates any of the contour, location and length of contour. Contour location in X and Y coordinates is easily noticed. Stating and end of a contour line such as 2195 meter is indicated(Figure 37). It was also noticed that length of contours vary compared to their respective straight distance.

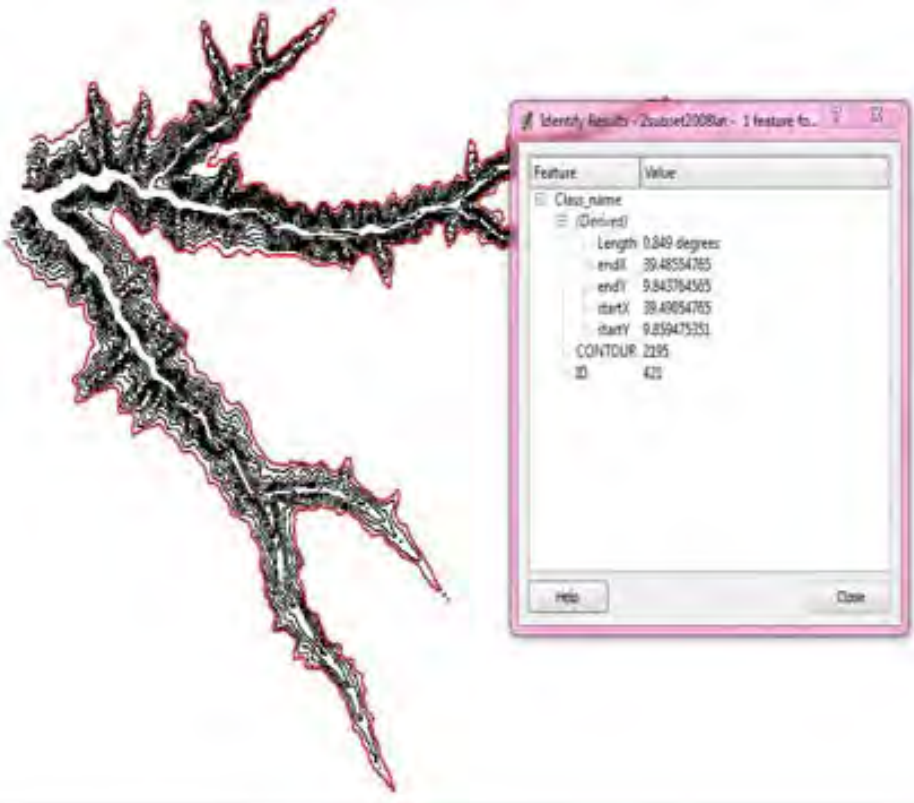


Figure 36 Contour length and location

Contour lines extend towards highest elevation as upstream erosion progresses in depth of the channel. Hence, contour length increases from time to time defining a shape as shown on the table 12 compared to its straight distance. This change in length is related to depth of the stream or gully. Therefore, increase in length of the contour results in increase in depth of channel's while slope is constant. The average slope of the landscape (see Equation 3.1) is about 10%.

$$\text{Slope} = \text{Vertical elevation difference} / \text{Horizontal distance} \dots\dots\dots \text{Equation 5.1}$$

$$\text{Vertical difference (Depth of channel)} = \text{Slope} \times \text{Horizontal length of the contours} \dots\dots \text{Equation 5.2}$$

Therefore, increase in contour line length signifies the increase in depth of channel, which could be gully or stream.

Table 12. Contour elevation, location and length

Contour Length (degrees)	Coordinates					$(Y_s - Y_e) = b$	$a^2 + b^2$	distance in degree root ($a^2 + b^2$)	change in length (degree)	Normalization	Elevation (meter)	* Gully depth/width	Change in Depth
	X start (Xs)	X end (Xe)	$(X_s - X_e) = a$	Ys(start)	Ye (end)								
A	B	C	D	E	F	G	H	I	(A-I)	(A-I)/I			
0.883	39.492	39.4855	0.0067	9.861	9.843	0.0182	0.0004	0.01939	0.8636	44.53	2215	4.45	
0.932	39.494	39.4855	0.0084	9.862	9.8425	0.0193	0.0004	0.02105	0.911	43.27	2235	4.33	0.12
0.962	39.494	39.4855	0.0084	9.862	9.842	0.0203	0.0005	0.02197	0.94	42.79	2255	4.28	0.05
1.01	39.495	39.4855	0.0092	9.863	9.8414	0.0217	0.0006	0.02357	0.9864	41.85	2275	4.19	0.09
1.053	39.496	39.485	0.0105	9.864	9.8402	0.024	0.0007	0.0262	1.0268	39.2	2295	3.92	0.27
1.099	39.496	39.4855	0.01	9.866	9.8402	0.0254	0.0008	0.0273	1.0717	39.26	2315	3.93	0.01
1.126	39.496	39.4847	0.0108	9.865	9.8397	0.0253	0.0008	0.02751	1.0985	39.93	2335	3.99	-0.06
1.157	39.496	39.4847	0.0108	9.866	9.8391	0.0272	0.0009	0.02927	1.1277	38.53	2355	3.85	0.14
1.195	39.497	39.484	0.0132	9.869	9.8392	0.0294	0.001	0.03223	1.1628	36.08	2375	3.61	0.24
1.191	39.4989	39.4839	0.015	9.8726	9.8379	0.0347	0.001	0.038	1.153	30.505	2395	3.051	0.56
1.175	39.4989	39.4839	-0.015	9.8751	9.837	0.0381	0.002	0.041	1.134	27.696	2415	2.770	0.28
1.024	39.4989	39.5655	0.0666	9.876	9.8365	0.0395	0.006	0.077	0.947	12.224	2435	1.222	1.55
1.042	39.5664	39.4989	0.0675	9.7353	9.8765	0.1412	0.024	0.157	0.885	5.658	2455	0.566	0.66
0.945	39.4988	39.5904	0.0916	9.8787	9.7389	0.1398	0.028	0.167	0.778	4.654	2595	0.465	0.10

Continued

Contour Length (degrees)	Coordinates						distance in degree root (a^2+b^2)	change in length (degree)	Maximum increment in length	Normali- zation	Elevation (meter)	*Gully depth/ width	Change in Depth
	x start (Xs)	X end Xe)	$(Xs-Xe)=a$	Ys(start)	Ye (end)	Ys- Ye)=b							
A	B	C	D	E	F	G	H	I	(A-I)	(A-I)/I			
0.868	39.5281	39.5773	0.0492	9.8975	9.7273	-0.1702	0.031	0.177	0.691	3.899	2775	0.390	0.04
0.823	39.628	39.6155	0.0125	9.914	9.7041	0.2101	0.044	0.210	0.613	2.91	2815	0.29	0.10
0.523	39.693	39.6219	0.071	9.832	9.7054	0.1263	0.02	0.14	0.38	2.61	2835	0.26	0.03
0.422	39.626	39.6224	0.0031	9.706	9.8322	0.1267	0.02	0.13	0.30	2.33	2855	0.23	0.03

*Average slope of the landscape is 10%. Hence, depth of gully or stream will be the product of slope and contour length. This holds true mostly at downstream.

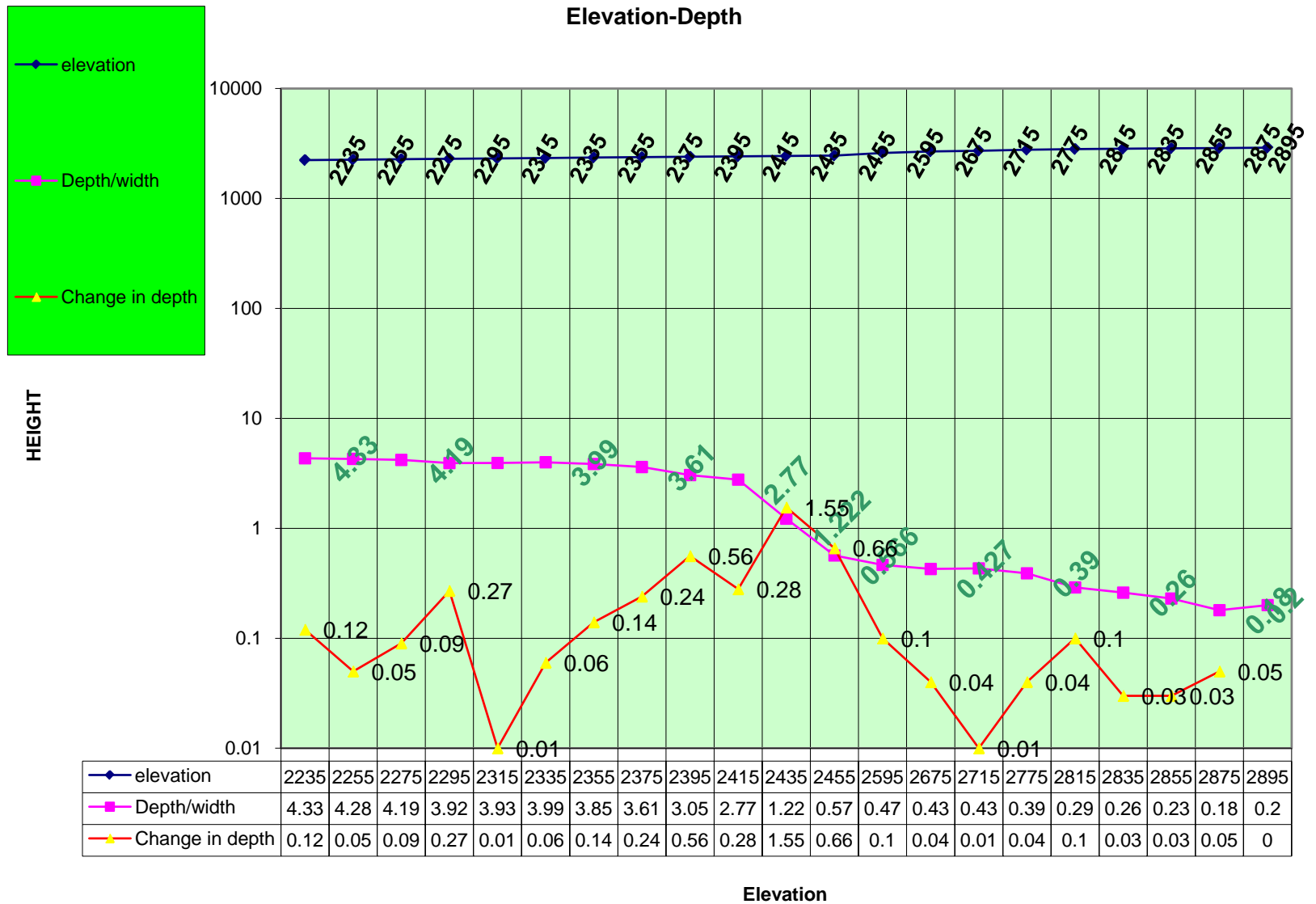


Figure. 37 Graph of average depth of stream(gully)/width

This is mainly for the reason that contour lines are affected by downward and sideward erosion that shapes the landscape. Moreover, geological erosion which are related to natural phenomenon seems considerable. Deeply dissecting /incising rivers are eroding the channel and protruding and extending up stream shaping stream edge for active erosion. Hence, stream erosion is dominant and continuous in the subwatershed.

Regarding the erosion damage of the subwatershad, it was observed that deep gullies are found on almost all steep slopes especially starting from middle of subwatershed. This was due to climatical condtion, properties of the local soils and human activities (agriculture). They are moderately deep and quite narrow on the steep slopes, retain and sometimes even increase their depth, becoming much wider as topography flattens out , particularly in the alluvial fans (BONO, R. and Seier, W. , 1984).

Depth of the streams in general increases as elevation decreases (Table 12). On the same table , it is indicated that at elevation of 2215 meter a.s.l. the depth of the channel is 4.45 unit per each width of channel. At 2315 meter a.s.l. depth of stream decline to less than 4.0 meter. This also indicate how much the landscape has been undulating. The higher the contour length in relative to straight distance, the more the landscape is shaped. However, at certain location where the topography is level due to the presence of hard rock like elevation 2315m and 2715 meter a.s.l. depth is maintained and capacity of stream are adjusted by mainly increasing of width of channels to transport the same amout of runoff when velocity of flow is uniform.

$$Q =V \times A \dots\dots\dots\text{Equation 5.3}$$

$$=V \times (W \times D_{av}) \dots\dots\dots\text{Equation 5.4}$$

Where Q= discharge

V=Velocity of runoff

W=width of channel

D_{av}= Average depth of channel

The graph (Figure 37) shows a sharp decline in depth of channel between elevation 2395 meter a.s.l and 2435 meter a.s.l.. In regard to the relation between depth/ width of stream (gully) to elevation, it is more or less closer to polynomial function(see Annex VI) than linear relationship. Polynomial graph to the third degree is more approximate to the linear decreasing trend line graph.

5.3 Soil Erosion Rate Estimates

Soil erosion is one of the major factors causing severe land degradation problem in Ethiopia, which in turn is threatening the agricultural productivity and the very survival of the overwhelming majority of the rural population. The rate of soil loss, depletion of soil organic matter and nutrients as a result is so high and much faster than they can be replaced.

The first scientific investigations of soil erosion were those carried by German soil scientist Wollny between 1877-1895 on small plots to measure the effect of vegetation and surface mulch on interception of rainfall and other related researches (Kebede Tato and Hans, H.,1992). Furthermore, attempts were made to estimate World distribution of erosion by Fourmier. World erosion was estimated in range between 0-30 ton/ha/year. Fourmier forwarded the relationship that exists between sediment yield and basin size (Richard, J. C.,1969).

In estimating erosion in particular rills and gullies, a simple mathematical equation was used. Eroded soil is estimated by measuring length and average width and depth of channels. The product of the three parameters resulted volume of soil (Hans H. and Kebede Tato,1992). Further considering bulk density, it is possible to estimate erosion in ton/ha. But the problem lies in estimating rate of soil erosion for sheet erosion in particular and minor rills. In this regard, researchers have made a considerable effort through modeling.

In modeling soil erosion, there were a number of alternatives that could be employed. But, the common would be broadly applicable, simple and workable with available of data for analyses is preferred. The Universal Soil Loss Equation (USLE) is an empirical erosion model based on data sets from the United States of America. It predicts the long term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices (Wischmeier and Smith 1978), (Frederic, R., Trieb, J., Arthur, et al, 1999). USLE only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, wind or tillage erosion. The other alternative which is recently applied in estimation of erosion is the Revised Universal Soil Loss Equation (RUSLE; Reynard, et al., 1997) which estimates erosion rate from mostly undisturbed land experiencing overland flow or from lands undergoing disturbance and from newly reclaimed lands (Frederic, R., Trieb J., Arthur, et al, 1999). Even in Europe, similar European Soil Erosion Model (EUROSEM) is used. These are applied on specific areas where adjustment is required

which USLE could also demand as well. In this regard, Hans Hurni had applied some modification in Ethiopian cases in particular to soil erodability which is related to soil color (Ermias Teferi, 2007).

Soil erosion rate calculated using USLE model for the Gado subwatershed has resulted value of very furious. Erosion rate that could reach more than 170 ton/hectare/year was identified(Figure 38). .

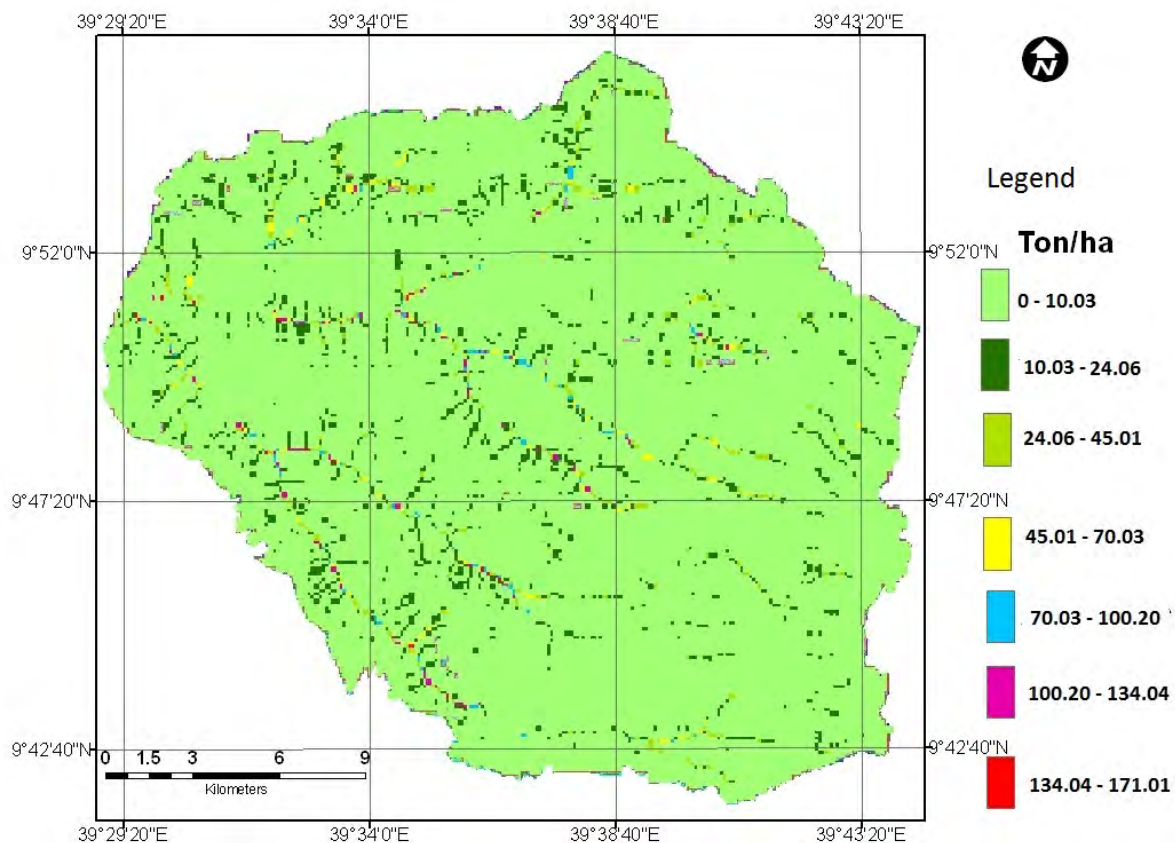


Figure 38. Erosion rate map

Soil erosion estimates in ton/hactare/year were 0 – 10.3, 10.3 - 24.06, 24. 06 - 45.01, 45.01-70.03, 70.03 - 100.20, 100.20 -134.04, and 134.04 – 171.01 with an area of 317.94 km², 92.73 km², 44.16 km², 22.08ha km², 13.48 km², and 7.07 km² respectively. The average erosion rate calculated shows 22 ton/ha/year which is higher to Richard J.C.,1969, estimates for Ethiopian highlands. He estimated to 100-2000 ton/km²/year.

Abay Basin Master Plan Study estimated soil loss 51-100 ton/ha/year for the Semen Shewa zone which the subwatershed is located. Furthermore, the Master plan commented that USLE undermines erosion.

The Master Plan estimates and the mean erosion of this study seems closer. It is clear that the Master Plan was made at low scale and might not reflect the specific study area condition.

The rate of erosion identified in the subwatershed compared to the result of the study in Amhara regional study still shows some variation. The region's study identified the regional average erosion rate was 12ton/ha/year and estimated the region erosion volume to be 50% of the Ethiopia(Tilahun Amede, 2003). In view of this, the rate of erosion in the subwatershed is higher and above 90% of the region average.

Although soil erosion problem is located throughout the subwatershed, it is concentrated on marginal lands where wide and steep channels are developed. These lands also have limitation in regard to soil depth(see Figure 13). Shallow soil depth make the area risky. Erosion can alter productivity of the area to the minimum. Hence, it requires undertaking strong measure in order prevent the situation before going worst. Abay Basin Master Plan study classified the area under category cannot tolerate further soil loss.

Intensive cultivated lands are located on gentle slope which are used to grow annual crop. However, it is not without risk. Rather, considerable bare lands have been detected. The degraded land which has been indicated (see on Figure 36) reveal the situation. During the field visit, these areas were cattle track, stream, and over-cultivated lands. Moreover, the mono-crop, Eucalyptus plantation areas are also influenced in particular at border of the plantation where sheet erosion is observed and tree roots exposed.

Regarding the distribution of erosion in the Kebeles within the SWD, it can be noticed that Kebeles located in marginal lands, such as Adisgie, Basodengora, Chiraro Debre, Mehal Amba are seriously affected. The mountainous part of Gudoberet, and Keyit are in similar threat.

It can be also easily visualized that erosion rates are related to streams location. Areas where there are streams increased erosion rate could be noticed. High erosion rate around streams could be observed for the fact that parameter used in particular LS value is maximum. Moreover, in regard fluvial processes streams transport considerable amount of runoff from upstream. In addition, slopy or mountaineous topography enables for the running water to acquire speed that sum up with the volume of water and resulted in increased erosion rate in the stream. Streams are extending upstream eroding its channel and near by areas.

Some of the reasons that the soil erosion related problem are not seriously dealt include,

- erosion processes might be misleading or unnoticed and costly to take strong action,
- monitoring system weak to identify changes that could influence others including users,

- low understanding of natural resource in that these resources such as water and soil are simply obtained/no serious cost and free.

Economic situation, poverty has been the main driving force for land degradation (MoA,1989); (Alemneh Dejene,1990). In this regard, economic interventions have been an integrated component in fighting the problem. Income generating activities are undertaken besides physical and biological conservation measures.

Different conservation structures constructed alter water movement by giving enough time for the water infiltrate and store at different points as an alternative. Excess water is removed through well constructed waterways safely without causing serious damage.

In defining solution to the problems, it is equally important to given attention to the community participation. They need to be involved in identification of problems, causes and propose actions. Hence, the community is part of the problem and solution.

The outputs of the interventions in some projects have been reported encouraging. The problem lies on identifying the degree of sustainability of undertaken actions and results. Those activities ones believed marvelous may be damage some days. This however, should not be discouragous. Rather identifying causes and design strategy/long term evaluation (Yohaness G/Medhine,2000) would be a better solution.

Government policy has considerable role in combating land degradation. In this regard, Amhara Region has formulated Conservation based Agricultural Development Led Industrialization policies for sustainable development(Tilahum Amede,2003). Materializing the policy at site level is still a challenge. In the Gado subwatershed as per Development Agents explanation and observation during site visit the undergoing conservation activities are not encouraging.

Therefore, an institution responsible in planning, implementing and monitoring natural resource management is crucial. Strengtheninig this institute with sufficient staff, facility and finance is indispensable. Research on ongoing efforts both local and international level with understanding of past efforts should be given emphasis. Hence, commitment of government, the community and other partners is decisive.

Remote sensing and GIS in this regard will have considerable importance. Collection of data/data acquisition, analyses and identification of both positive or negative changes could be employed. Organizing data and provide the findings to all stakeholders could influence the prompt action to be taken.

Chapter VI

6. Conclusion and Recommendation

The undertaken study revealed that land degradation is affecting considerable areas in Gado SWD. The process of soil erosion has resulted bare or thin depth of soil where crop and feed has been grown. Erosion also damaged feeder roads and affected people transport. Gully and stream widening and deepening at the down stream which further aggravating the problem. On marginal lands in particular where soil depth is shallow and landscape steepy, they are already severely affected. Land degradation is also concentrated on cultivated land where intensive cultivation is exercised. High population in the area has forced for continuous farming/overcultivation. Marginal lands which are liable for degradation are converted to cultivated land and the prevailing high rainfall and runoff highly affected areas near by streams. Flooding and waterlogging negatively affected production at down stream.

Cattle tracks were observed to be converted bare lands and big boulders emerging affects movement. Furthermore, road drainage which divert the natural flow of water and drain without proper conveyance structure erode the channel and increases the width and depth of channel to form gully.

Fluvial process in particular for gully and stream seems strong where antropogenic contribution could be considerable with steep topography and high rainfall. Deforestation, overgrazing, over-cultivation, and acidification contribute for increased erosion. Eventhough, plantation is recommended in the subwatershed, the Eucalyptus monoplantation without additional input to halt erosion could be damaging.

The soil erosion rate identified in the subwatershed estimated more than 171 ton/ha/year indicates the problem to be severe. The higher average erosion rate 22 ton/ha/year is in tolerable where soil tolerance is 2 ton/hectare/year. This reveals the need of strong action to avert the trend. Estimation of soil loss in terms of volume such as tones/hectare/year is important but sometimes it may be meaningless to others. Hence, losses can be estimated in monetary terms that could sound somehow. Costs could be categorized direct or indirect. Evaluation of the need of undertaken erosion control is suggested economical in long-terms.

Some of the reasons that erosion problem is given less attention include, erosion processes might be misleading or unnoticed. Moreover, monitoring system weak to identify changes. Solutions are not simple as the problem is complex. Environmental protection should also consider human aspect for which the beneficiaries' interest/aspiration should be given attention in assuring improved livelihood (Kebede Tato and Hans, H., 1992). Availability of sufficient skill, man power, financial resource, incentives or appropriate policy to proper land management have significant importance. Undertake studies and organized actions should be taken urgently to avert the situation before go to worst and affecting the life of many people in particular and the country's economy in general.

Therefore, the efforts to map degraded land in the subwatershed was possible using satellite image landsat (ETM+) and Digital Elevation Model in particular for gully and stream delineation. Techniques applied enable extract information with relatively short, reasonable time and resource. Improvement in satellite system and software facilitated analyze complex issues that support decision making process. Therefore, beyond estimating erosion rate, the application of remote sensing and GIS also justify why changes are significant on some areas than others.

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[http.www.gis.comwhatisrs/dowithgis.htm.](http://www.gis.comwhatisrs/dowithgis.htm)

<http://www.gisdevelopment.net>

www.landcover.org

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WWW.unu.edu/env/plec/1-degrade/index-toc

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http://en.wikipedia.org/wiki/Digital_elevation_model

<http://www.informaworld.com>

Annex I Point data collected for degraded land identification and sampling land use

No	Point	X	Y	Remark	No	Point	X	Y	Remark
1	5	574128	1083613	Gully Gudoberet					
	7	574119	1083592		27	574358	1084010		
	8	574093	1083584	waterfall	28	574334	1084010		
	9	574086	1083601		29	574314	1083982		
	10	574107	1083596		30	574382	1083888		
	11	574120	1083630		31	574471	1083939		farm degraded
	12	574136	1083651		32	574499	1083904		
	13	574149	1083663		33	574524	1083890		
	14	574139	1083632		34	574572	1083934		
	15	574225	1083883	Gully Gudo Beret2	35	574646	1083921		
	16	574213	1083883		36	574675	1083960		
	17	574202	1083924		37	574659	1083890		
	18	574229	1083997		40	574577	1083874		
	19	574235	1084016		41	574577	1083892		
	20	574245	1084022		42	574515	1083841		
	21	574267	1083991		43	574496	1083846		
	22	574312	1084023		44	574511	1083868		
	23	574361	1084049		45	574479	1083881		
	24	574386	1084049		46	574432	1083835		
	25	574479	1084089		47	574394	1083854		river bakelo
	26	574490	1084070						
	49	568926	1071785	river bakelo	79	568728	1072069		
	50	568910	1071733		80	568682	1072093		
	51	566910	1071732		81	568646	1072122		

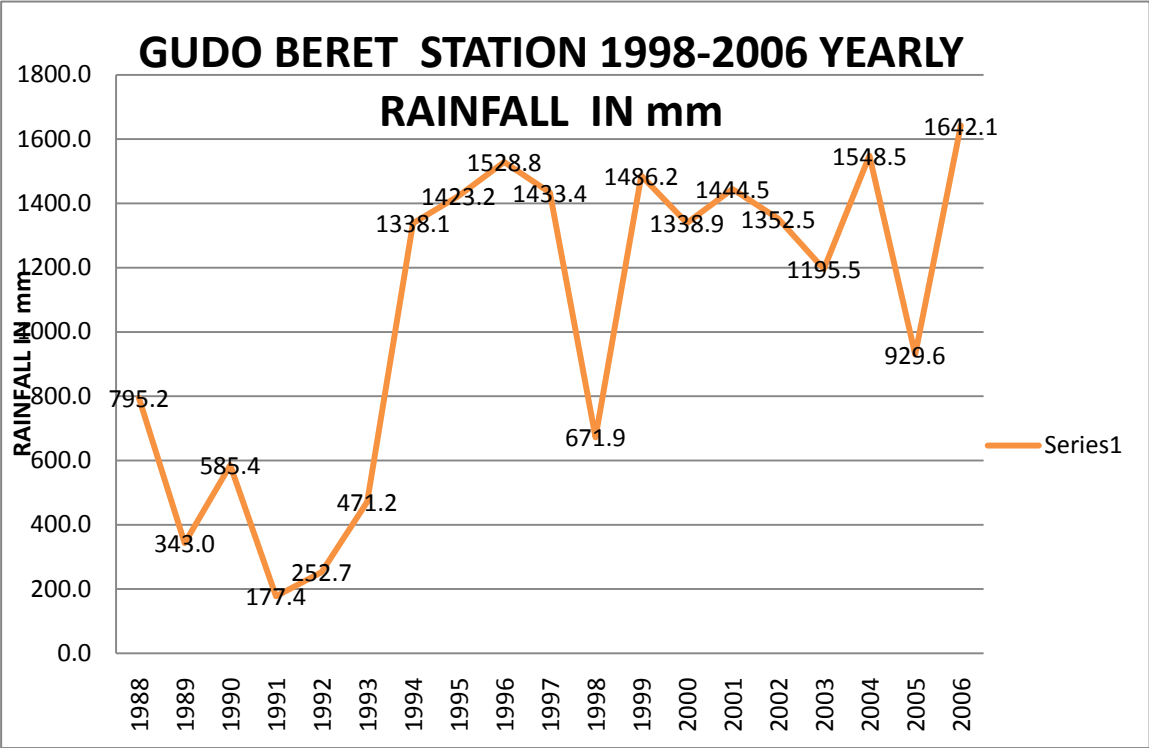
	52	569067	1071711			82	568643	1072115	
	53	569057	1071711			83	568672	1072101	
	54	568983	1071716			84	568682	1072086	
	55	568971	1071702			85	568730	1072059	end to 65
	56	568957	1071704			86	568632	1072539	stone field
	57	568955	1071717			87	568703	1072547	
	58	568881	1071732			88	568706	1072572	
	59	568814	1071778			89	568672	1072586	
	60	568759	1071770			90	568688	1072569	
	61	568724	1071791			91	567796	1072291	gully bakelo
	62	568732	1071801			92	567803	1072300	
	63	568765	1071782			93	567791	1072222	
	64	568803	1071792			94	567791	1072222	
	65	568755	1072052	gully bakelo		95	567781	1072349	
	66	568781	1072046			96	567738	1072354	
	67	568791	1072039			97	567731	1072377	
	68	568787	1072025			98	567706	1072372	
	69	568797	1072052			99	567700	1072375	
	70	568804	1072043			100	567692	1072369	
	71	568796	1072051			101	567680	1072376	
	72	568815	1072056			102	567661	1072359	
	73	568825	1072064			103	567664	1072353	
	74	568820	1072075			104	567683	1072374	
	75	568837	1072083			105	567694	1072361	
	76	568852	1072095			106	567718	1072364	
	77	568825	1072083			107	567645	1072330	
	78	568785	1072062			108	567769	1072335	
	109	567784	1072299						
	110	571118	1073825			138	569887	1073996	

Land Degradation Mapping and Erosion Esttimate in Gado Subwatershed Using Remote Sensing and GIS

111	571098	1073797			139	569887	1073929	
112	571045	1073809			140	570003	1073926	
113	570991	1073803			141	570029	1073977	
114	570994	1073849			142	570070	1073993	
115	570892	1073976			143	570124	1073960	
116	570878	1073989			144	570210	1073976	
117	570833	1073965			145	570257	1073988	
118	570838	1073983			146	570305	1074011	
119	570840	1073985			147	570316	1074008	
120	570815	1073974			148	570342	1074022	
121	570755	1074007			149	570376	1074057	
122	570651	1074128			150	570435	1074059	
123	570607	1074124			151	570495	1074068	
124	570580	1074146			152	570562	1074123	
125	570478	1074072			153	570662	1074033	
126	570437	1074065			154	570678	1074086	
127	570396	1074076			155	570707	1074001	
128	570258	1074009			156	570777	1073983	
129	570168	1073984			157	570853	1073945	
130	570067	1074004			158	570881	1073970	
131	569938	1073972			159	570893	1073875	
132	569816	1074029			160	570970	1073824	
133	569772	1074000			161	570920	1073796	
134	569760	1073919			162	571103	1073771	
135	569766	1073917			163	571120	1073740	Roadside drainage
136	569787	1073927			164	571120	1073710	
137	569805	1074006			165	571112	1073710	
166	571115	1073655			175	571115	1073609	175
167	571105	1073633			176	571116	1073615	176

	168	571113	1073622			177	571110	1073644	177
	169	571109	10735850			178	571119	1073669	178
	170	571088	1073555			179	571118	1073695	179
	171	571083	1073545			180	571139	1073717	180
	172	571088	1073542			181	571132	1073736	181
	173	571105	1073567			182	571160	1073779	182
	174	571116	1073581						

Annex II Graph of Gudo Betet station 1988-2008 yearly rainfall in mm



ANNEX III LOCATION OF GADO BOUNDING STATIONS

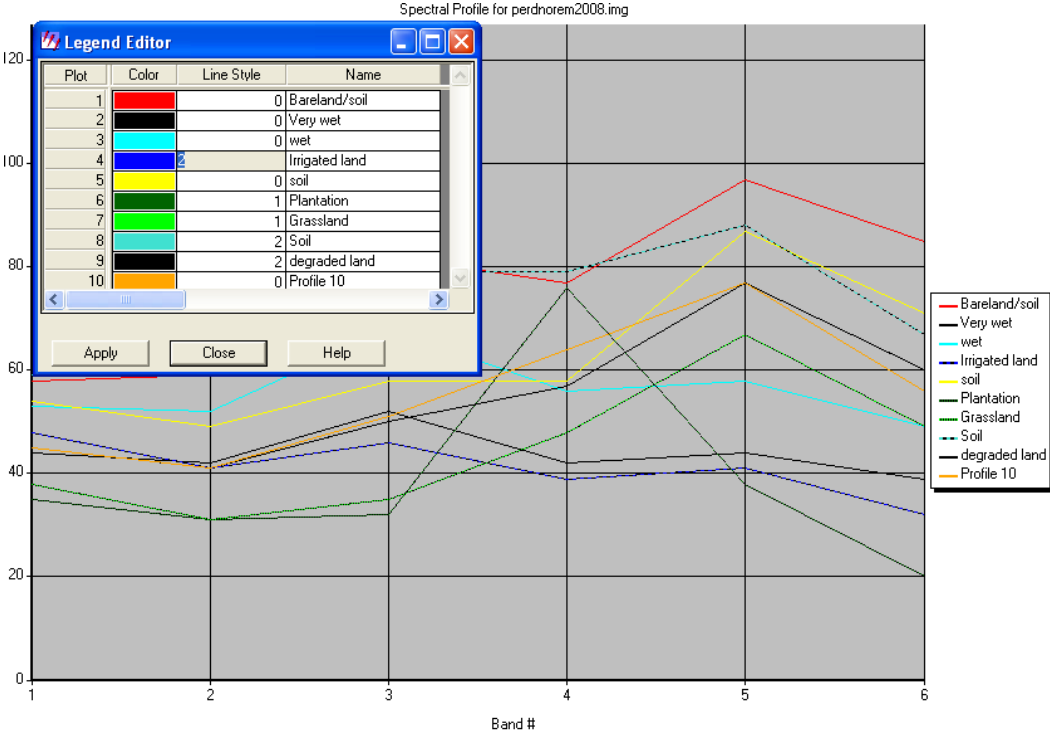
No	Station	Latitude	Longtitude	Altitude m a.s.l	Rainfall mm	Recording period
1	Debre birhan	9 40 39N	39 31 37.08 E	2636	921.9	1987-2003
2	Gudo Beret	9 48 08.N	39 40 11.36 E	2945	1254.9	1987-2003
3	Deneba	9 46 54 N	39 10 57 E	2665?	1031	1985t02007
4	Seladingay	9 57 12 N	39 37 3 E	2810	1118.43	1983to2006
5	Mendida	9 40 19N	39 18.08 E	2763	976.3	1981to2006
6	Debresina	9 50 43 N	39 45 E	2679	1807.23	1985t02005

1.83

ANNEX IV soil loss of the six SCRP sites

Site name	Soil loss amount(ton/hectare/year)
Sidamo	41.2-49.5
Harar	25.5-27.8
North shoa	152.4-214.8
Gojjam	40.2-199.2
Illibabor	18-135.3
~South wollo	36.5- 53.8

ANNEX V. Spectral Profile for 2008 image



ANNEX VI. Elevation Vs Depth/Width of Stream/Gully

