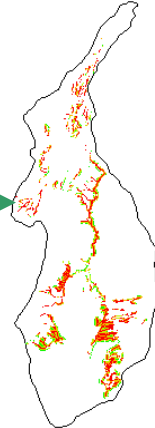
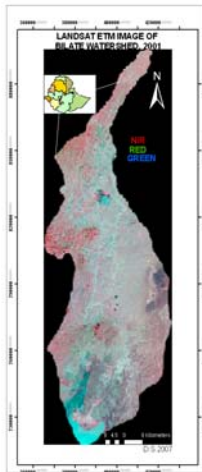




ANALYSIS OF BIOMASS DEGRADATION AS AN INDICATOR OF ENVIRONMENTAL CHALLENGE OF BILATE WATERSHED USING GIS TECHNIQUES



**Dissertation submitted for Partial Fulfillment of the Requirements for
the
Award of the Degree of
Master of Science
in
Remote Sensing and Geographical Information Systems (GIS)**

**BY
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**ADDIS ABABA UNIVERSITY,
JULY, 2007**

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D E C L A R A T I O N

I here by declare that the dissertation entitled “**Analysis Of Biomass Degradation as an Indicator of Environmental Challenge of Bilate Watershed Using GIS Techniques**” has been carried out by me under the supervision of Dr. Dagnachew Legesse, Department of Earth Sciences, Addis Ababa University, Addis Ababa during the year 2007 as a part of Master of Science programme in Remote Sensing and GIS. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

Place: Addis Ababa

Date: July 16, 2007

(Degelo Sendabo)

C E R T I F I C A T E

This is certified that the dissertation entitled “**Analysis Of Biomass Degradation as an Indicator of Environmental Challenge of Bilate Watershed Using GIS Techniques**” is a bonafied work carried out by Degelo Sendabo under my guidance and supervision. This is the actual work done by Degelo Sendabo for the partial fulfillment of the award of the Degree of Master of Science in Remote Sensing and GIS from Addis Ababa University. Addis Ababa.

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Acknowledgements

Although many have contributed a lot during my research writing process, I hope that mentioning some may not hurt the feelings of those who are not mentioned here. My deepest gratitude still goes to them.

First of all, I would like to thank my Lord Jesus Christ who made things simple and is still in my side in all the challenges which I faced throughout my life.

My deepest feelings of gratitude go to my advisor Dr. Dagnachew Legesse whose benevolent guidance and constant encouragement helped me to complete the present research work successfully. He is the person who is very kind to help and guide me in the whole process and the challenges. His constant encouragement made me strong to face every ups and down with confidence during the research study.

I am also very thankful to the Ethiopian Mapping Authority for sponsoring me and giving all the necessary facility including field work support, relevant data and working environment. Without such facilities I might have faced challenges to complete the work timely.

Words cannot express my feelings which I have for my wife, Zenebech Gebre, My children (Massame, Assencha, Itta and Mitta) and the whole family for scarifying their time and encouraging and supporting me. I am highly indebted to my parents Workie Achiso (Mom) and Sendabo Sariko (Dad) for their blessings, guidance, advice, encouragement and support.

My Thanks also go to Dr. Tesfaye Yacob, Ato Fantahun Belayneh and Ato Berhanu Tegicho for their invaluable cooperation and encouragement.

Finally, I would like to convey my special thanks to my late brother Zeleke Sendabo, who had been encouraging me for further studies since my childhood.

(Degelo Sendabo)

Abstract

Advancement in spatial data processing especially using GIS techniques has been playing an important role in different applications. Multiple source spatial and non-spatial data can be processed for the analysis of spatio-temporal conditions of a given area. Having such an approach in mind the Bilate Watershed Biomass is analysed using multi-temporal Landsat images acquired in 1973, 1986 and 2001. Such data are processed using digital image processing techniques including NDVI and Tasseled Cap analysis. Besides, different vector data are extracted from the images as well as other topographic and thematic maps. Land use land cover of the watershed is interpreted and based on that the level of biomass degradation is analysed. Using the integrated spatial information, decision support system has been applied for the identification of priority areas to be conserved due to their sever damage. The study identified major causes and effects of biomass degradation of the watershed.

Key Word: *Remote Sensing, GIS, Biomass, Environment, Degradation, decision making, conservation multitemporal, multispectral, land use, land cover.*

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Chapter One

General Background

1.1. Introduction

Human relationship with biomass can be divided into four basic categories. The first one is that biomass as a resource like source of food, timber, fuel, forage for livestock and so on. The second one is as an environmental conditioning factor such as soil and water conservator, wind shelter and the likes. The third category is that as an indicator of landscape features. The fourth one is also as a challenge for human life being habitat for endemic diseases like tsetse fly, source of weeds of plague like desert locust, hindrance of accessibility and so on (ITC: 1994). In general the existence of biomass is directly related with the existence of human life or other fauna.

Degradation of biomass occurs due to natural and/or anthropogenic factors. Natural factors here include drought, land sliding, and related geological factors. Anthropogenic factors are those related human activities like expansion of cultivated area, overgrazing, settlement, desertification, infrastructure development and etc. Such problems are common in the developing countries in general and sub-Saharan ones specifically (Muthoka and others: 1998). Because of such and similar factors, biomass degradation becomes core problem for loss of natural resources especially that of soil, decrease in its fertility, eradication of wildlife, increasing demand for fuel and the likes are becoming common problems.

Once the problem of biomass degradation happens, analysing its level may take significant period of time. That is because realizing its effect is not simple issue to be identified easily. It can be recognized when some environmental change occurs or affects human life. The worst among all is that people in the area cannot give attention may be due to lack of awareness or similar reasons.

Watershed based conservation practice and sustainable development is under introduction in some of the Regional States of Ethiopia. That is because it incorporates the whole topography, landscape and drainage system, flora, fauna etc and their relationship.

On top of all the above, biomass, habitats, way of living of the community and physiographic conditions of the area are interdependent. If there is failure in one of them, the whole system can be affected in one or other way.

Biomass condition in general is a good indicator of the soil, water resource, farming system, ecological system, and the likes. Therefore once the biomass is exposed for degradation, their survival can be under question mark.

The abundance, productivity, species composition and canopy structure of natural vegetation are good indicators of level of degradation. According to some studies in Kenya, soil acidity, salinity and alkalinity are directly related with degradation of biomass or substitution of the indigenous by exotic ones (GOK: 1996).

Land use land cover conditions are interrelated with that of biomass condition. If interpretation of land use takes place it is also interpreting the biomass condition. Through land use and cover analysis one can also generalized overall resource condition of natural and man made resources (FAO: 1997). Every parcel of land on the earth's surface is unique in the cover it possesses. Both land use and land cover are distinct but closely linked characteristics of the earth's surface. Land use affects land cover and changes in land cover also affect the land use. Here changes in both cases do not necessarily imply degradation of the land. However, many shifting land use patterns, caused by socio-economic factors result inland cover change which affects the ecological system as a whole (Bottomley 1998 .

Recently global climatic changes are also considered as a result of cumulative change. Such a cumulative change is the most common one and induced by human beings in one or other way. Changes in landscape, cropland, grasslands, wetlands, settlements and etc are good examples of cumulative changes. Such

cumulative changes can be extended from local to global and affect the whole environmental system (Bottomley 1998 .

Changes in land use cover can be categorized into modification and conversion. Here modification means a change of condition with a cover type. A good example can be changing of species of plants. On the other hand, conversion is a change from one cover type to another. Examples can be that of deforestation to create croplands.

According to the assessment done by the Environmental Authority, in Ethiopia there are different species of plants. More than 7000 higher plant species are identified and among them 12% are endemic (EPA: 2003). Although that is related with the suitable agro-ecological system and landscape diversity, their number is diminishing from time to time due to expansion of farmlands and overgrazing dominantly. Here agriculture is the mainstay of the economy and its share is about 43.3%.

Although biomass degradation and its consequence are becoming serious problems in different parts of the country, measures undertaken are in a very small scale. There are some water, soil and forest conservation practices taking place in disintegrated way. Most of them are practiced by institutions like that of government, NGOs and the community. The Bilate watershed, in general is on the process of conversion process.

GIS based approach is useful tool to assess and interpret the biomass distribution and its type, areas exposed for degradation spatially and temporally. Spatially areas with problems can be identified and mapped including their database. Temporally the extent of degradation through time and its consequences can be analysed (Meijerink and others: 1994)

Remote sensing and GIS techniques are best suited for watershed management in the area of soil, terrain analysis and vegetation surveys. With this approach

the natural features such as landforms, vegetation types, drainage system and etc can be distinguished (FAO: 1990). From this one can conclude that change in biomass can be good indicator of change in land use land cover, degradation of vegetation, depletion of natural resources and as a whole environmental vulnerability.

Having the above discussion in mind, the aim of this research is to assess biomass degradation as indicator of environmental challenge using GIS as a tool specifically for the Bilate Watershed.

1.2. Definitions

Different terms are applied in this research and therefore, defining them is expected to fulfil the interest of its users. Although the definitions are given by different groups depending on their study objective, there is no conceptual difference. Some of them are discussed as follows.

Watershed

Watershed is topographically delineated area that is drained by a stream system i.e. total land area that is drained to some point on a stream or river. It is a hydrological unit that has been described and used as a physical-biological unit and also, on many occasions as a socio-economic-political unit for planning and management of natural resources. (FAO: 1990)

Watershed Management

Watershed management is the process of formulating and carrying out a course of action involving the manipulation of resources in a watershed to provide goods and services without adversely affecting the soil and water base. (FAO:1990)

GIS A. *A system of hardware, software and procedures designed to support the capture, management manipulation, analysis, modelling and display of spatially referenced data for solving complex planning*

management problems

- B.** *A computer system capable of assembling storing, manipulating and displaying geographically referenced information i.e. data identified according to their location. (USGS, 1997)*

Remote Sensing *Collecting and interpreting information about a target without being in physical contact with the object. (Sabins: 1991)*

Land Cover *is observed (Bio)physical cover on earth's surface. It should be confined to describe vegetation and manmade features.*

Land Use *is characterised by the arrangements, activities and inputs people undertake in a certain land cover type to produce change or maintain it. (FAO: 2000)*

Biome *Can be defined as a largest unit of a land community. Regional climate interacts with regional biota and substrate to produce large easily recognizable communities called a biomes. Each biome is characterised by uniform climax vegetation.*

(Rana S.V.S. :2005)

1.3. Statement of the Problem

Ethiopia is one of the developing countries with high population increase. The annual average growth of the country is more than 3%. Currently the total population accounts more than 75 million and this number is expected to be doubled in the coming 25 years (CSA: 2004).

Among the total population, the rural areas share 85%. Although the remaining 15% live in the urban centres, they are still dependent on the rural socioeconomic activities and related primary products (EPA: 2003). For instance, food items, charcoal for fuel, textile and related factory input items come from

the rural areas. In some cases, one can hardly observe sharp demarcation among the rural and urban communities.

Unplanned exploitation of natural resources, which is also related with traditional farming, use of primitive technology and the likes, are among the major problems in the country. In addition, limitations in sustainable development programs especially in land use planning and conservation practices have been playing significant negative role. That leads to vegetation degradation which can be cause for wildlife eradication, soil fertility depletion, biodiversity degradation, ecological crisis, poverty, out migration of the community and the likes.

These days, the most recommended approach to overcome problems related with environmental degradation is that of watershed based planning and management. Although watershed is an area covered by water body (river, lake, etc.) including tributaries or streams flowing to them, diversified agro-climatic, agro-ecological and landscape exists over there. That indicates environmental system dependency from the upper course to the mouth of drainage system.

Watershed based development programs, plans and conservation practices are related with the objective of assessment and solution of water related problems, proper land management, environmental protection, conservation practices, sustainable development Planning and the likes.

As it has been assessed and observed techniques and tools under utilization for watershed planning and management in Ethiopia are conventional. Even though GIS is said to be applied, it is not more than simple mapping. Integrated geodatabase analysis approaches are not yet practiced. Besides most of the resource analysis techniques are of single period of time. Multi temporal data analyses are not well practiced. With such a single period inventory, one cannot judge and analyse the problem scientifically.

Bilate watershed has tremendous land use land cover change and vegetation loses in relation with the increase of the rural population. Expansion of farmlands including the river bank is very common especially in the upper and middle courses. The lower course where the sediments cover is associated with woodlands, wetlands, extensive farming areas grazing areas and so on (See Figure-21).

Although it needs further analysis by other researches, some of the tributaries are on the transformation from perennial to intermittent. At the mouth and around Lake Boyo in the middle course area the sedimentation area is increasing from time to time. Such problems are directly related with biomass degradation followed by erosion.

As some records indicate, three decades ago, some parts in the west and most in the east were covered by forests and wildlife of larger animals such as lion, buffalo, leopard and the likes. Currently one can see only smaller ones such as antelopes and birds due to deforestation (EPA: 2003)

On the other hand, conservation practices are very much limited. Where there is conservation practice, its sustainability is questionable because most of them are not community based or government supported. Their life span of such projects depends on the good will of the NGOs.

Although there are many factors contributing to the physical environment change of the Bilate watershed, the main one is that of biomass degradation. As it is discussed in the previous cases, once the vegetation is endangered, the whole environment is exposed.

1.4. Need for GIS based Watershed Management and Degradation

Analysis

GIS techniques these days are playing an important role as the a tool in data processing, analysis and modelling. Based on the above discussion it is

considered that GIS based watershed management planning and analysis can be useful because its approach incorporates the following points.

- Change in land use/cover of River Bilate Basin can be analysed using multi-temporal remotely sensed data interpretation.
- Existing natural resources distribution and the agro-ecological zoning and the landscape condition can be mapped.
- Population distribution and density can be mapped and its impact on the physical environment can be analysed.
- Areas exposed for degradation can be identified.
- Sedimentation areas and flood plains can be identified and analysed.
- Criteria can be developed to analyse to prioritize conservation areas through modelling.
- Based on the past and current situations, future can be predicted.
- Multiple source data can be integrated and combined to analyse an overall situation
- It can be very essential tool for planning and sustainable development programs.
- Larger area can be processed and analysed within short period of problem.

1.5. Benefits and Beneficiaries

The research results on the woody biomass analysis will be benefit on the application of GIS techniques, monitoring of the environment, conservation practices and sustainable development programs of the Bilate watershed. Having this in mind, the most beneficiaries of the research result will be:

- Governmental Institutions because there are plans to apply watershed based approaches for environmental protection and sustainable development.
 - Community because they are the most users of the watershed
 - NGOs because they can implement different development plans and sustainable programs in cooperation with the concerned institutions.
-

- Researchers and academia. Since such and similar studies are not practiced in the country, similar approaches can be enhanced and applied in other areas. Besides it can be base for further analysis and study.

1.6. The Study Area

1.6.1 Location

Bilate is one of the inland rivers of Ethiopia. Its coverage is about 5680 Kilometre Square area. From the relative location point of view, its upper and middle courses are found in the eastern fringes of western highlands and the lower course is within the Great Ethiopian Rift Valley specifically in the lakes sub-basin (Figure-1).

Its absolute location south-north extends from 6° 36'N 38°00'E to at Lake Abaya Wolayita Zone SNNPR to 8°05'N 38 °12'E at Gurage and Silte Zones border, SNNPR. On the other hand its west-east extension is from 7°18'N 46'E at Kambatta Zone to 7°12'N 38°22'E Sidama Zone.

The main river flows straight southwards to Lake Abaya. Most of the perennial tributaries come from the western side. On the contrary, the contribution water from the eastern side is very insignificant mainly with intermittent streams.

From the regional location point of view, the watershed covers mainly north-eastern part of the SNNPR and some parts of the South-central Oromiya Regional States. Although the upper course lies in Silte and Guraghe Zones, most of its tributaries as well as large volume of water come from Kambata, Wolayita and Hadiya mountains respectively.

In general peculiar characteristics of the Bilate watershed are diversified topography, high range of profile within short distance, high population density in the western compared to the east, increase in vegetation degradation through time and the likes.

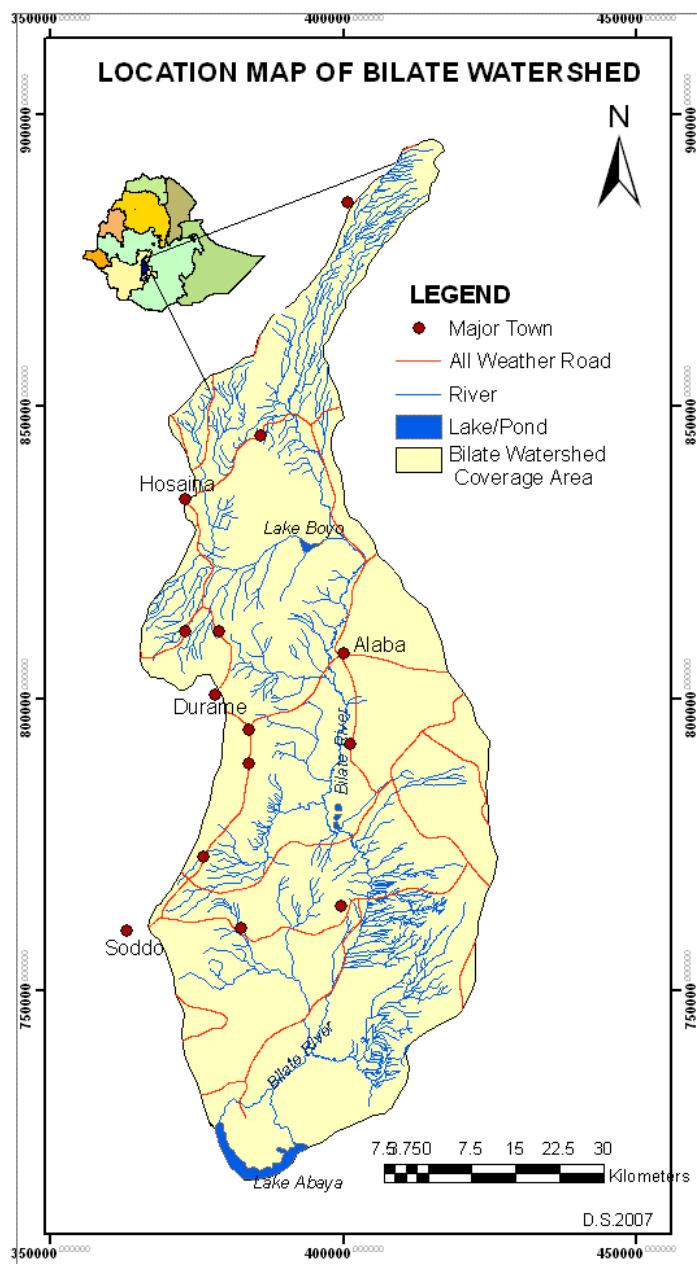


Figure-1. Location Map of the Bilate Watershed

1.6.2. Topography

The altitude of the watershed ranges from 1300 at Lake Abaya to 3050 meters above sea level at Mt. Ambaricho. Such a range indicates the watersheds formation with diversified landscape within short distance. Because of the topography and climatic conditions, the watershed has different ecological zones ranging from lowland acacia and riparian to afro-alpine. Besides, the climatic condition is also variable depending on the agro- ecology as well as the altitude.

As it is demonstrated in Figure-2, the cross section from North to South (Alichu Weireo, Silte Zone to Lake Abaya) shows that the watershed is mostly in a steep slopes almost up to the river's mouth. In addition, the cross section from West to East (Mount Ambaricho, Kambatta Zone to Leku in Sidama Zone) shows the diversity of topography and steepness.

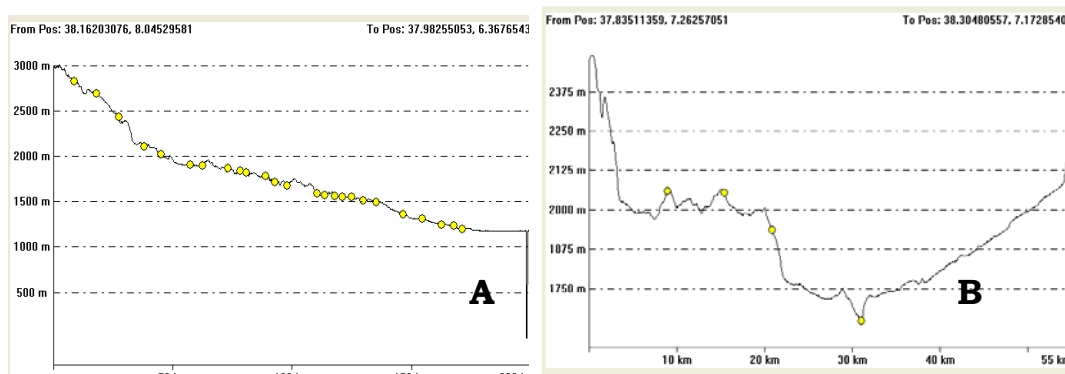


Figure-2 Cross Section of Bilate Watershed North South (A) and West-East (B)

1.6.3 Climate

Depending on the topographic condition, the climatic condition of the watershed is varies from one area to another in terms of both temperature and rainfall. The western highlands from where the main stream and its tributaries come, the annual average rainfall ranges from 1300 to 1700 mm. On the other hand in the rift valley it ranges from 700 to 1000 depending on the wind ward and leeward sides of the mountains (NMA :2007). Most of the rains are westerly and come from the Atlantic Ocean. Maximum rainy

seasons are from June to July. There are little amount of rains in the months of January to March which locally called *Belg* rains.

Concerning the temperature it is also variable like the rainfall. Within the rift valley especially around Lake Abaya where the Bilate River mouth exits, the maximum exceeds 30°C in warm seasons. On the other hand in the western highlands like Mount Ambaricho freeze in most times of the year. As it is presented on Tables 2 and 3, the highest temperature stations are those which found in the rift valley like Alaba and Aje..

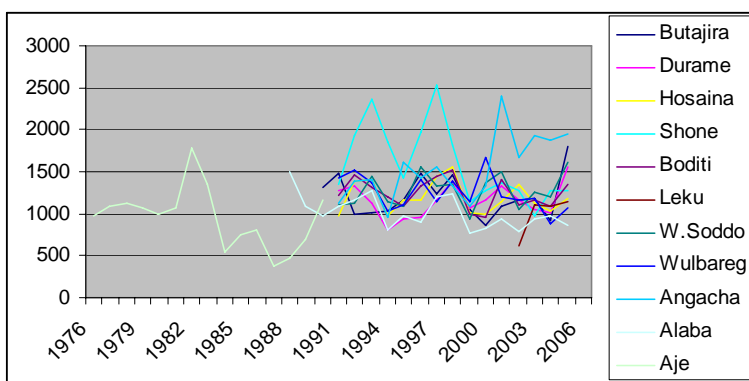


Figure-3 Graphic Presentation of Annual Rainfall of Major towns of Bilate Watershed

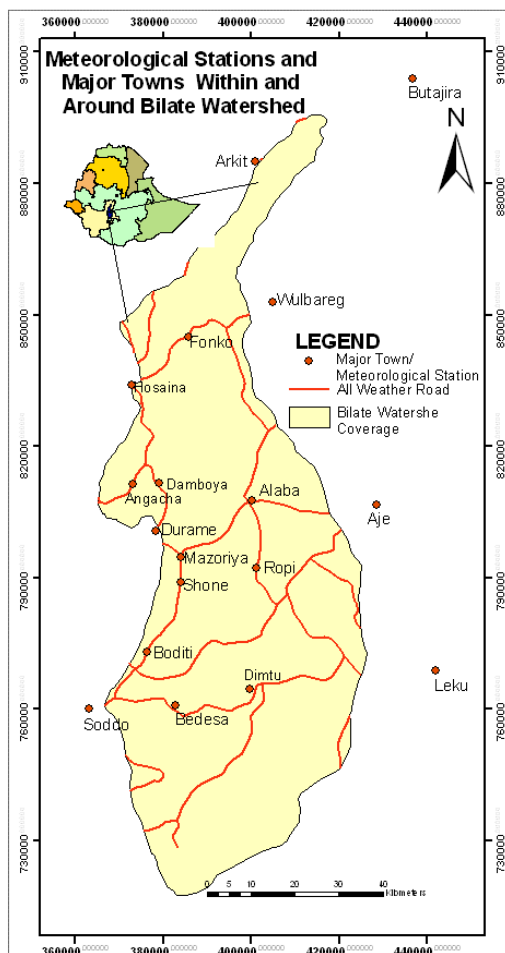


Figure-4 Meteorological Stations of Bilate Watershed

Table-1 Annual Rainfall of Major Towns of Bilate Watershed 1976-2007

Year	Butajira	Durame	Hosaina	Shone	Boditi	Leku	W.Soddo	Wulbareg	Angacha	Alaba	Aje
1976											970.3
1977											1088.1
1978											1126.6
1979											1062.6
1980											987.3
1981											1074.4
1982											1778.5
1983											1356.8
1984											534.5
1985											750.2
1986											797.3
1987											370.4
1988										1496.0	460.0
1989										1083.2	697.3
1990	1311.5									967.5	1158.1
1991	1475.5	1277.3	979.6	1349.5	1213		1112.7	1424.3	1123.6	1087.4	
1992	989.2	1326.7	1387.6	1932.4	1463.6		1126.7	1525.7	1383.4	1157.6	
1993	1006.8	1117.2	1413.5	2365.2	1304		1443.5	1376.4	1412.6	1276.4	
1994	1031.2	812.8	974.6	1848.5	1199.2		1152.7	1028.1	956.0	801.8	
1995	1168.8	940.4	1160.7	1419.1	1079		1080.2	1101.1	1621.1	978.2	
1996	1483.8	960	1168.2	1965.3	1339.1		1551.3	1408.3	1416.7	893.0	
1997	1240.3	1162.3	1442.5	2533.3	1449.9		1333.6	1152.3	1553.3	1192.7	
1998	1459.9	1378.6	1556.4	1824.6	1526		1343.9	1387.7	1340.1	1241.0	
1999	1054.4	1066	1011.3	1152.1	1002.5		938.2	1136.4	1092.6	759.4	
2000	865.6	1162.2	991.9	1281	948.4		1364.1	1663.0	1331.8	832.0	
2001	1096.7	1323.7	1145.5	1376.4	1412		1506	1195.0	2397.6	943.9	
2002	1159.9	1155.4	1346.4	1283.1	1105.6	627.3	1057	1163.3	1668.7	796.0	
2003	1187.8	1053.5	1132	966.1	1162.9	1098	1254.2	1176.5	1922.5	941.3	
2004	913.4	1004.8	1033.2	1281.8	1096.8	1081.8	1204	875.1	1876.2	982.7	
2005	1806.6	1555.1	1179	1267.8	1358	1147.4	1619.2	1067.7	1948.1	855.5	

Source: National Meteorological Agency, 2007

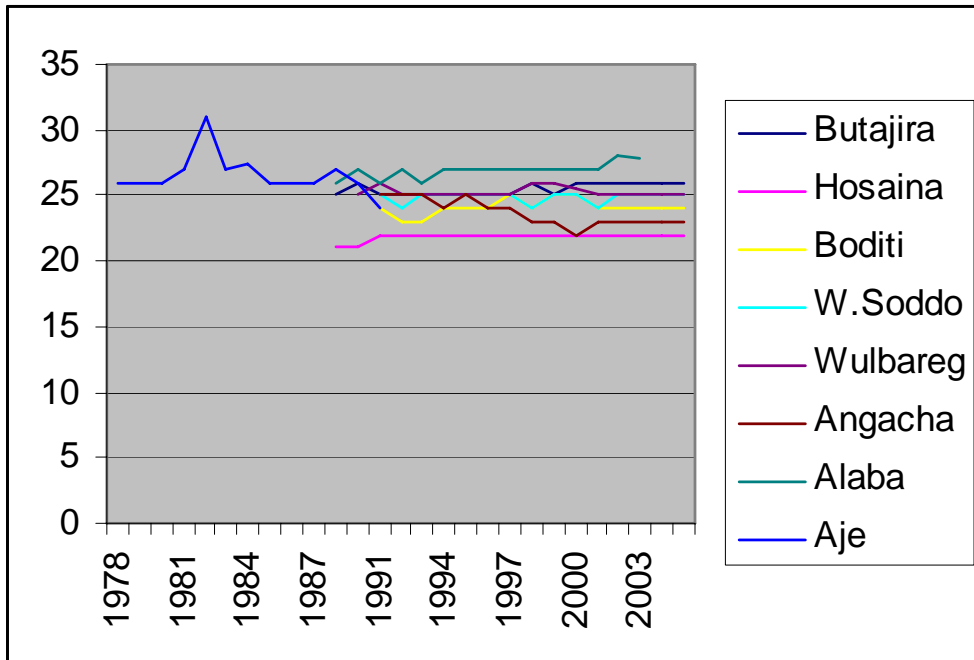


Figure-5 Maximum Average Annual Temperature of Bilate Watershed

Table-2. Maximum Annual Average Temperature of Selected Meteorological Stations of Bilate Watershed

Year	Butajira	Hosaina	Boditi	W.Soddo	Wulbareg	Angacha	Alaba	Aje
1978								26.0
1979								26.0
1990								26.0
1981								27.0
1982								31.0
1983								27.0
1984								27.4
1985								26.0
1986								26.0
1987								26.0
1989	25	21					26.0	27.0
1990	26	21			25.0		27.0	26.0
1991	25	22	24	25	26.0	25.0	26.0	24.0
1992	25	22	23	24	25.0	25.0	27.0	
1993	25	22	23	25	25.0	25.0	26.0	
1994	25	22	24	25	25.0	24.0	27.0	
1995	25	22	24	25	25.0	25.0	27.0	
1996	25	22	24	25	25.0	24.0	27.0	
1997	25	22	25	25	25.0	24.0	27.0	
1998	26	22	24	24	26.0	23.0	27.0	
1999	25	22	25	25	26.0	23.0	27.0	
2000	26	22	25	25	25.5	22.0	27.0	
2001	26	22	24	24	25.0	23.0	27.0	
2002	26	22	24	25	25.0	23.0	28.0	
2003	26	22	24	25	25.0	23.0	27.8	
2004	26	22	24	25	25.0	23.0		
2005	26	22	24	25	25.0	23.0		

Source: National Meteorological Agency, 2007

Table-3 Minimum Annual Average Temperature of Selected Meteorological Stations of Bilate Watershed

Year	Butajira	Hosaina	Boditi	W.Soddo	Wulbareg	Angacha	Alaba	Aje
1978								12.0
1979								12.0
1980								14.0
1981								12.0
1982								12.0
1983								12.7
1984								12
1985								12
1986								12
1987								12
1988								13
1989	13	10					7.0	13
1990	12	10					8.0	
1991	12	10	7	14	10.0	15.0	8.0	
1992	13	10	6	14	11.0	15.0	9.0	
1993	13	11	12	14	10.0	15.0	8.0	
1994	13	10	12	14	10.0	15.0	13.0	
1995	13	11	13	14	9.0	15.0	13.0	
1996	12	11	13	14	10.0	14.0	13.0	
1997	11	10	13	13	7.0	13.0	13.0	
1998	11	10	13	14	5.0	12.0	14.0	
1999	11	10	13	14	9.0	13.0	12.0	
2000	11	10	13	14	11.0	12.0	13.0	
2001	11	11	13	14	11.0	13.0	13.0	
2002	10	10	12	14	11.0	13.0	14.0	
2003	10	11	13	14	11.0	13.0	13.0	
2004	10	7	13	14	10.0	13.0	12.0	
2005	10	6	13	14	11.0	13.0	12.0	

Source: National Meteorological Agency, 2007

Climate Diagrams of the Bilate Watershed

Climate diagrams are brief summaries of average climate variables and time course. They are useful to acquire climatic information especially for wide range of scientific studies, industry, bio- and geo-sciences. They are used as an instrument to show the relationships between precipitation and temperature which are useful to analyse soil, vegetation and climate.

The diagram displays monthly average of temperature and rainfall over a year.

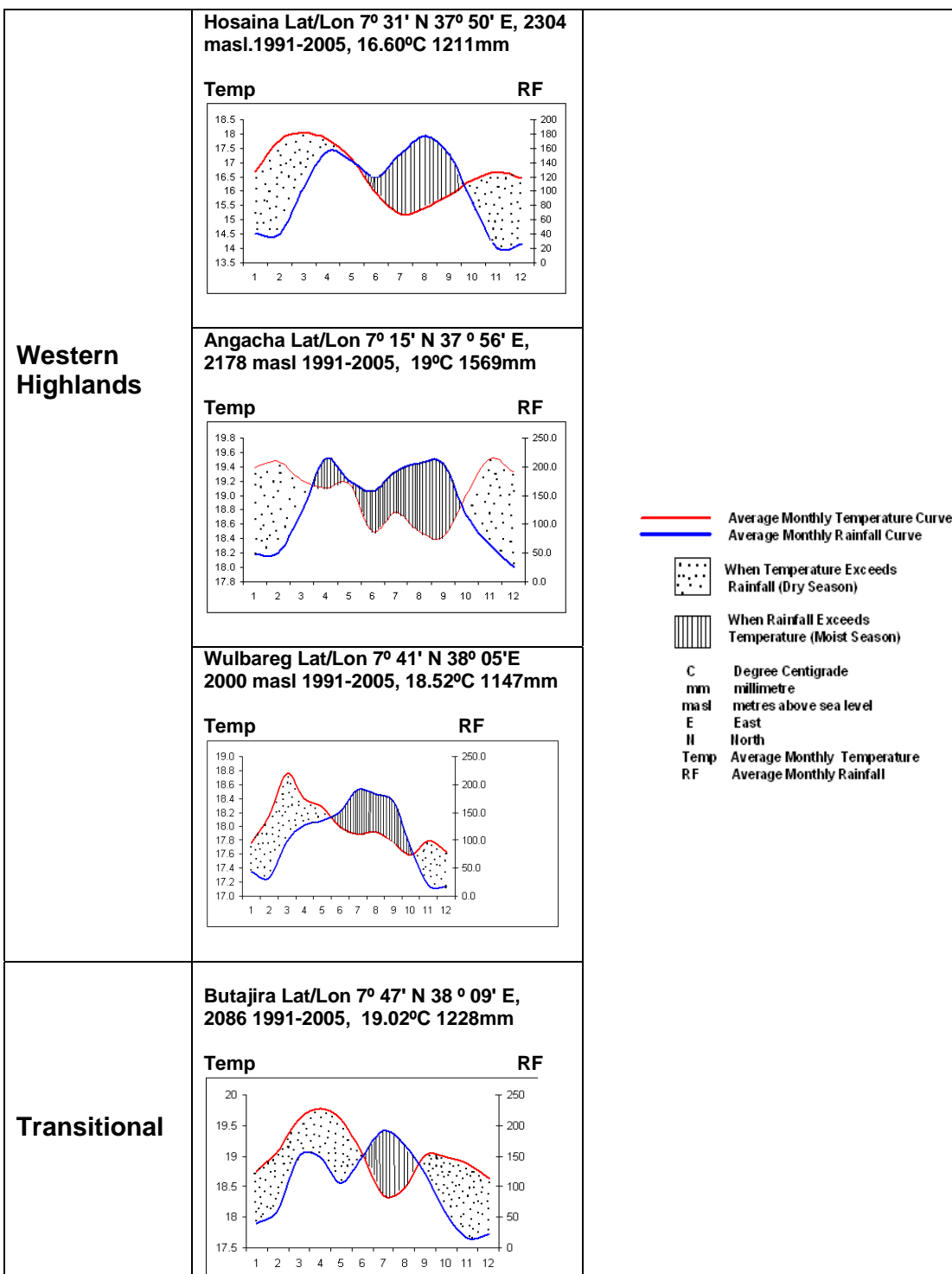
For this purpose seven meteorological stations are identified from the Bilate watershed. They are Aje, Alaba, Angacha, Boditi, Butajira, Hosaina, Wolaita Soddo and Wulbareg. The reason for selection of these towns is because of relatively available temperature and rainfall data for a certain period of time and their distribution in western highlands (Hosaina and Angacha) transitional zone (Wolayita Soddo, Boditi and Wulbareg, and the Rift Valley (Alaba and Aje).

As it is presented on Figure-6, on the diagrams the horizontal line (abscissa) indicates months starting in January in the left corner and December right corner. The left column shows an average monthly temperature and the right one is for monthly average rainfall.

The moist season for most of the selected towns and their environ is from June to September. Some of the towns such as Hossaina, Angacha and Butajira have two moist seasons starting from March to April and from June to September.

The highland areas from where most of the water comes for the Bilate watershed have higher rainfall than those areas in the Rift valley or Transitional zones.

Watershed Zone	Climate Diagram of selected Towns	Legend
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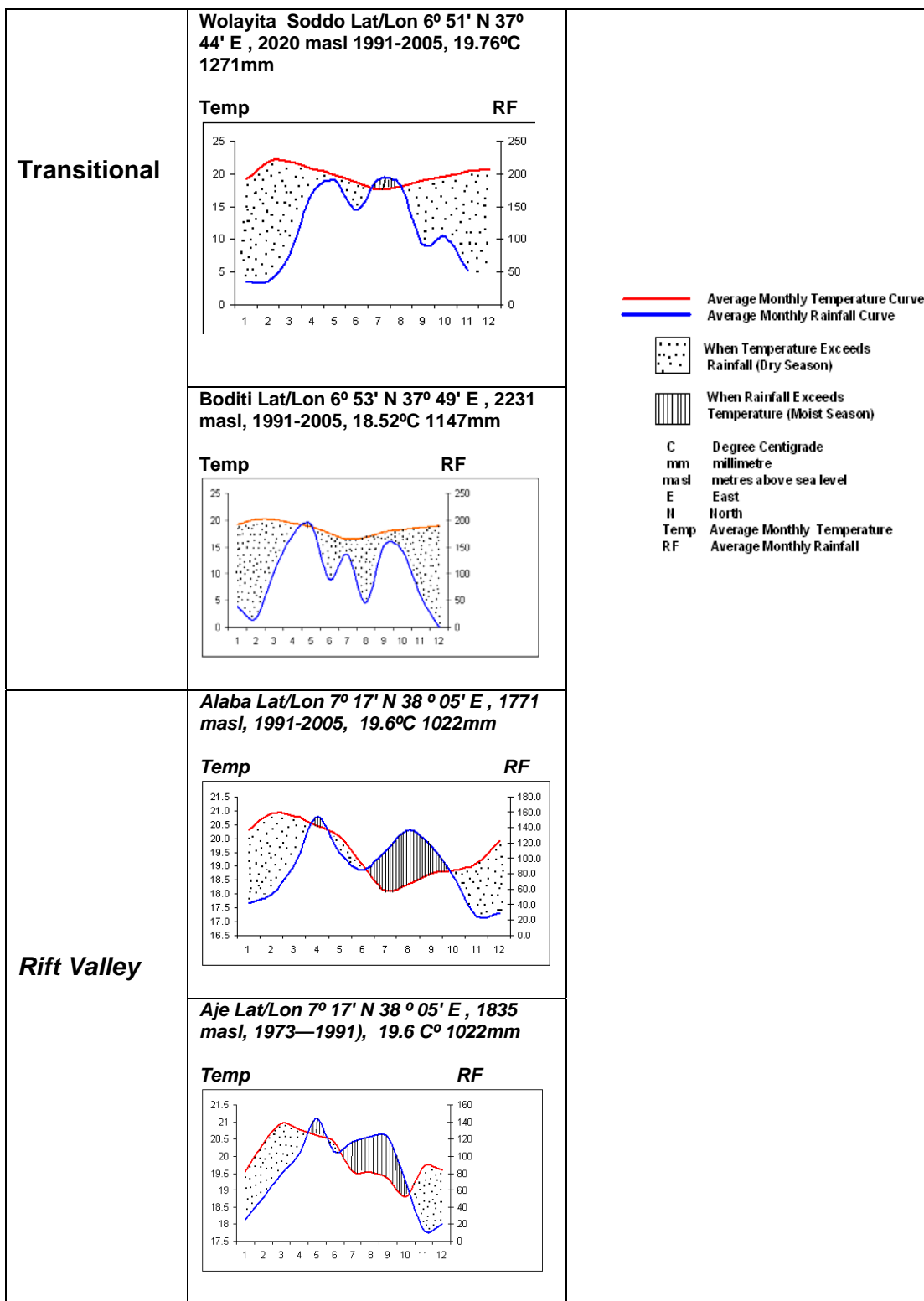


Figure-6 Climatic Diagram of Selected Towns from the Bilate Watershed
 Source: Extracted from Meteorological Data, NMA, 2007

1.6.4. Vegetation

Depending on the landscape and topography of the watershed, there are different types of indigenous vegetation existing in the area. The highlands are known for their temperate types of vegetation. In higher mountains like Mt. Ambaricho and Mt. Damot Afro-alpine is common. Besides different types of crops grow in this altitude. The remaining indigenous biomasses which are common along ridges and rivers or very few protected areas are good indicators of their degradation through time.

The transitional area between the western highlands and the Ethiopian Rift Valley are known for variety of biomass type due to favourable topographic and climatic conditions.

Within the rift valley, arid and semi arid types of biomass exist. The dominant ones here are acacia groups, scrubs and grass. In the southern part of the watershed where the temperature condition is moderate most of the trees are similar with the transitional areas. It has been observed during the fieldwork that forests, woodlands and grasslands are on the process of degradation.



Figure-7 Remnants of bamboo forest, near the spring of Bilate (Wera)

1.6.5. Agriculture

The upper and middle course areas of the Bilate watershed are known for their intensive cultivation because of high density of population, which led to almost all plots to be used. The highlands are known for growing of different types of crops such as wheat, barely, leguminous cereals and the likes. Uniquely these areas are known for Enset plantation, which is staple food in the upper course and middle course areas of the watershed (Figure-8). Agroforestry and side plantation are practiced traditionally in a smaller scale in the highland areas especially to overcome shortage of fuel wood.



Figure-8. Croplands, Grazing Areas and Settlements in transitional zones of western part of the Bilate Watershed

1.6.6. Population and Settlement

The Bilate watershed in general and its western part specifically that of transition areas are known for their high density of population. As many agree, that may be related with the suitable agro-climatic condition, soil type and availability of water resources. In these areas maximum rural population density exceeds 500person/kmSq area (Figure-9). This is the highest density in Ethiopia.

In general, the population distribution of the watershed has two characteristics:

- The first one is maximum rural population density in the upper and middle course areas of the western part of the basin.
- The second part is the eastern part that is dominantly known for agro-pastoralism and relatively sparse population distribution.

Surprisingly, the ethno-cultural distribution within the watershed is highly diversified. There are more than eight ethnic groups dwelling within the watershed. Their contribution to the environment depends also on their ethno-cultural background. For example, the Oromos and the Sidamas living near the mouth of the Bilate River or northern part of Lake Abaya are more of agro-pastoralists. On the other hand the Kambatta, Hadiya and Wolayita people living in the western part of the watershed are known for their intensive and mixed farming culture.



Figure-9 Rural population distribution in western highlands (Left) and Rift

Valley parts (Right) of the Bilate watershed

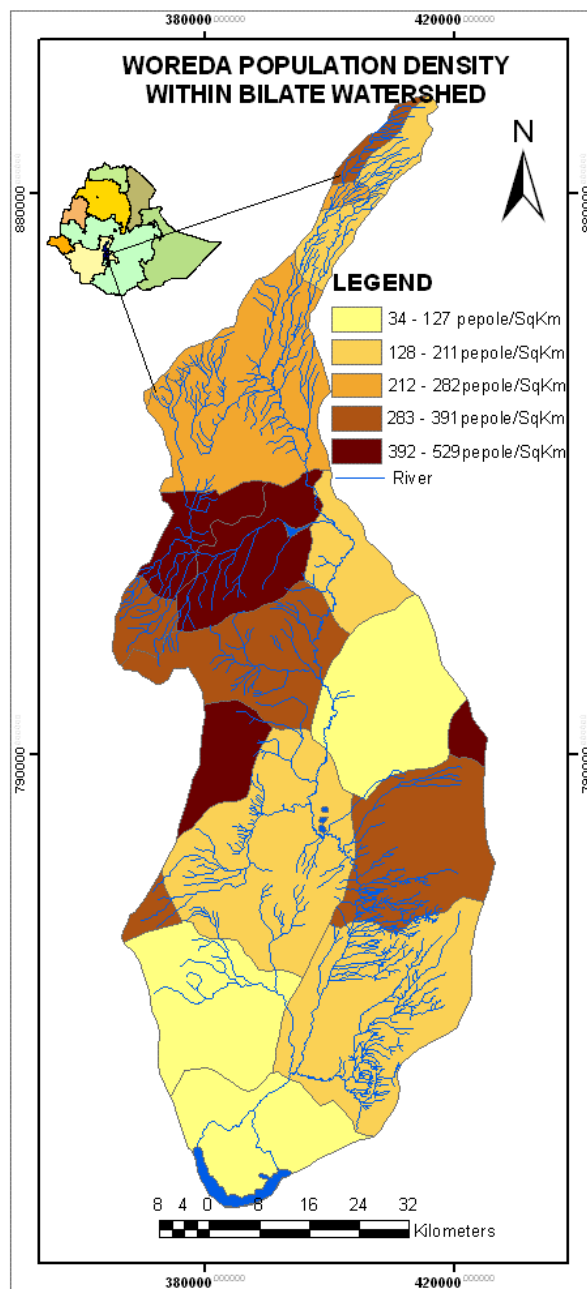


Figure-10 Population Density per Woreda within the Bilate Watershed

1.7. Objective

1.7.1 General Objective

Analysing the biomass degradation and impact on the Bilate Watershed using GIS techniques

1.7.2. Specific Objectives

- Mapping and analysing the biomass coverage of past and its current condition
- Assessing major indicators of biomass degradation of the basin
- Applying GIS as a tool for watershed level study
- Analysing factors contributing to the biomass degradation and their impact
- Identification of priority areas for conservation
- Recommending appropriate approaches, mechanisms and solutions for sustainable development of the watershed

1.8. Methods and Materials

1.8.1. Methods

Different types of methods are employed for the study. The major ones among all are discussed as follows.

- Literature reviewing of the study area in general and related studies of different areas
 - Digital image processing of multi-temporal satellite images of the study areas
 - Digitising and collection spatial data such as that of infrastructure, drainage system contour lines and the likes a from different sources
 - Building geodatabase and processing accordingly
 - Integration and analysis and modelling using GIS Techniques
 - Field data collection or ground truthing
 - Identifying priority areas for conservation
 - Technical or research report writing
-

All the above and approaches of data processing and analysis in detail are discussed in Chapter 3. In addition, the flow of the methodology is presented on Figure-11.

1.8.2. Materials

Different materials as discussed below are utilized for the research purpose.

1.8.2.1. Data

- Topographic maps of 1:50000 and 1:250000 scale
- Thematic maps of the area such as:
 - Land use land cover
 - Population distribution
 - Drainage system
 - Socio-economic infrastructure
 - Slope
 - Conservation priority areas and etc.
- Satellite images of three decades
 - Landsat MSS of 1973
 - Landsat TM of 1986
 - Landsat ETM of 2001

1.8.2.2. Hardware and Software

- Computer with different image processing and GIS software such as ERDAS Imagine 8.6, ArcGIS 9.0, Global Mapper 7, MapSource and etc.
- GPS
- Camera

Depending on the nature of the research is classified into five chapters. The first chapter deals with the general background of the research, which discusses the watershed management, biomass, condition, the study area, objective, methodology, and the likes. The second chapters discusses about the literature review. In the third chapter all the methods and techniques undertaken using GIS techniques are discussed step by step. Fourth chapter deals with Results and findings that incorporate factors for biomass degradation and their effect on the physical environment of the study area.

Finally recommendations and suggestions are presented based on the findings.

Flow Chart for the Bilate Watershed Geo-data Processing

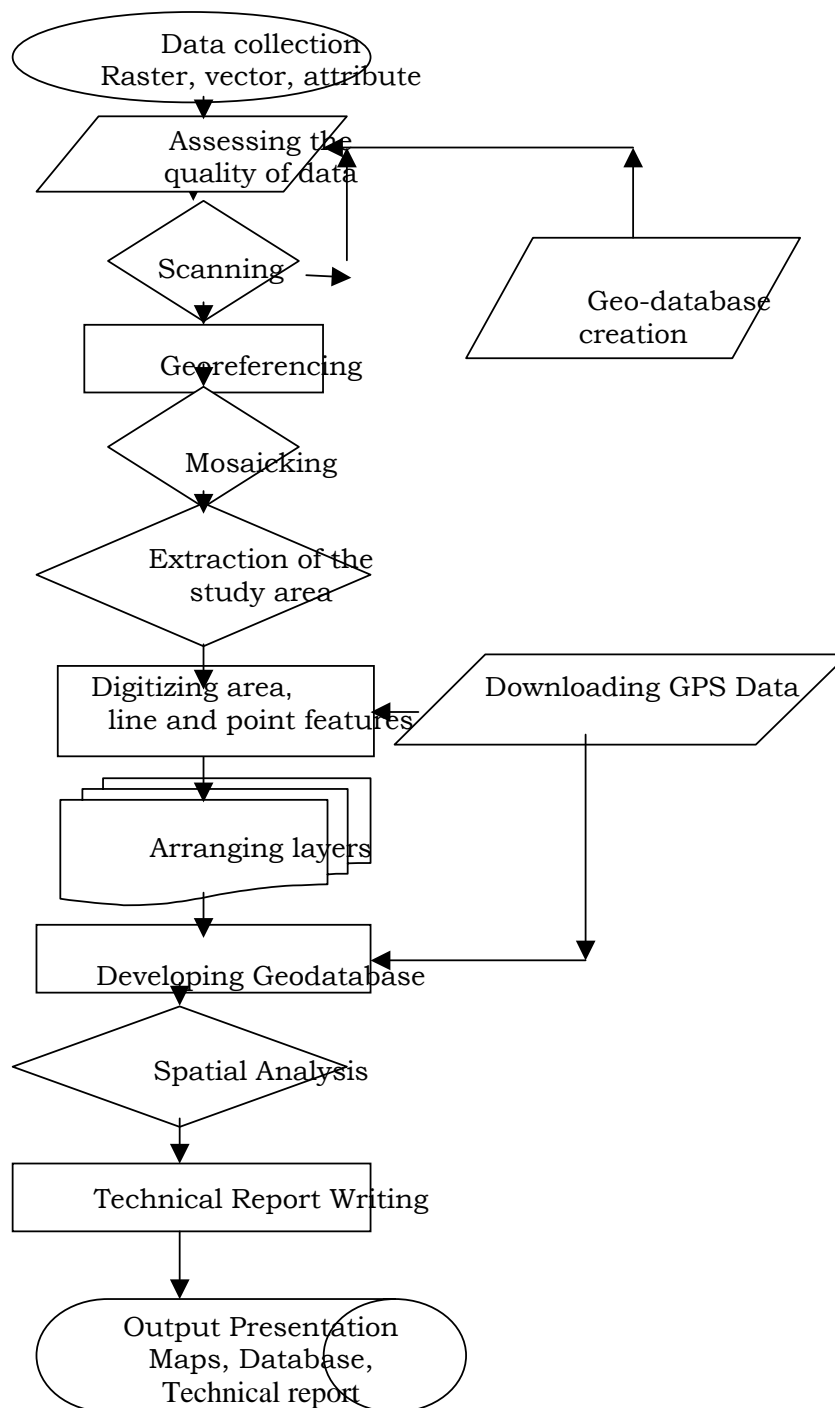


Figure-11 Flow Chart for the methodology of Biomass degradation analysis of the Bilate watershed

Chapter Two

2. Literature Review

For the analysis purpose of the Bilate watershed biomass degradation and its indication as an environmental challenge, different types of literature are reviewed. The reviewing here includes activities done in the study area as well as other areas which could be relevant baseline information. Most of the areas in this reviewing include watershed management, different aspects such as watershed management, biomass degradation, Geographic Information System, Remotely sensed data and techniques of interpretation and analysis

The topographic nature of Ethiopia made it owner of more than eight watersheds or river basins. All the larger watersheds have their own sub basins (EMA: 1988). The water number of streams and water volume depends on different factors such as geological, topographic, length of the river and the likes. Most of the studies indicate that utilization of watersheds in Ethiopia is for primary products dominantly that of crop farming and livestock production. Since the highlands which are also upper courses of most of the watersheds are suitable for human life, their settlement history is long. That is why the biomass is badly degraded over there. (EPA :2003).

Watershed management as it has been discussed above is new introduction to the Ethiopian environment. For the first time it was introduced in the Amhara Regional state to overcome the environmental degradations and promote sustainable development. (EPAA: 2004)

In addition, Woldeamlak has discussed about the importance of integrated watershed management in highlands of Ethiopia using Chemoga Watershed as a sample. In this study the highlands degradation problems are focussed on soil and related resources (Woldeamlak: 2003)

SNNPR also has started introducing the value of watershed management in relation with environmental protection. Although many efforts are going on for

sustainable development and environmental protection using watersheds as basis especially in the regional level, it is hardly possible to get a single manual or guideline either in a regional or federal level. The only approach is that of FAO guidelines prepared in the 1990s (FAO: 1997). Many efforts undertaking place in many parts of the country are based on agricultural and rural development sectors. Integrated approaches with other sectors are under introduction. (MOI: 2002).

Majority of Ethiopian population use biomass as means of energy. They use woody biomass for construction and domestic purposes. The woody biomass used by the rural communities is naturally existing and regenerated. (Dereje :2004) although plantation of trees is exercised in areas like the upper and middle courses of the Bilate watershed, still the natural biomass areas are highly exposed for degradation

According to the general assessment of the regional biomass of SNNPR, major problems related with the degradation are associated with expansion of small scale agriculture, fuelwood and the demand for energy, supply and consumption patterns of other bio-fuels, rural and urban domestic energy consumption, poverty and woody biomass harvesting for income support, forest use, poor conservation and management, land degradation and etc. (SNNPR: 2001) The studies do not incorporate the watershed and related biomass condition.

Even though it was not in the watershed level, assessment of the woody biomass of Ethiopia using remotely sensed data took place in the early 1990s. The study was focused only on general inventory of the availability of the biomass without considering the changes occurring. In other words it multi-temporal aspects; factors for degradation and their effects are not incorporated in the monitoring (WBISPP: 1994).

Concerning the soil erosion and risk of the Bilate watershed research was undertaken by Thieman (Thieman: 2007). This research is focused on soil erosion and sediment accumulation condition of the watershed using eight identified sites as a sample. He has tested a model for soil erosion as a sever problem of the watershed.

As it has been assessed and from different sources except the soil erosion there is no detailed study of the biomass change especially using GIS techniques. Even the woody biomass inventory of the 1984 is focussed on single time data of Landsat TM.

Chapter Three

Geoinformation Processing Techniques and Analysis

As it was discussed in chapter one, for the biomass analysis of the Bilate Watershed, different techniques of geoinformation data capturing, processing, modelling and analysis are applied. The techniques include data identification, collection, organization, capturing, processing and analysis. Based on these techniques, the spatial data components of data input, data management, data analysis and output are practically applied (Lo and Yeung : 2005)

Different types of data were collected and organized in the primary and secondary level. Their collection was to use them as an input to the overall geoinformation that has to be extracted. Major types of spatial data among all are topographic maps, thematic maps, satellite images and ground truth data. The secondary level data includes those which are extracted from other spatial and non spatial data like that of meteorological and population. The nature of each type of data is discussed in this chapter.

3.1. Topographic Maps

Two Types of topographic maps identified for the Bilate Watershed research are the 1:250000 and 1:50000 scale ones.

3.1.1. Topographic Maps 1:250000 scale

These types of maps are those which were prepared in the 1960s to cover the entire country. They were revised in early 1994 by the Ethiopian Mapping Agency. Such scale maps are useful for viewing the whole study area because only three maps covered the whole watershed as presented in Figure-12. All the maps are scanned and georeferenced and mosaicked in such a way that the study area can be extracted. The geoprocessing and standards are presented in 3.2.2.

NC 37-14 Addis Ababa
NB 37-2 Hosaina
NB 37-6 Arba Minch

Figure-12 1:250000 scale topographic maps Index of the Bilate Watershed.

3.1.2. Topographic maps 1: 50000 Scale

These maps are of medium scale and have better information on the topographic features of the watershed. The total number of these maps is fourteen (Table-4). The drainage system and elevation information are very clear. These maps are scanned, georeferenced and mosaicked respectively. For the purpose of georeferencing all the routine steps of digital image processing are applied using ERDAS Imagine software. During the georeferencing, data integration and compatibility with the national reference system considered are:

- Projection UTM
 - Spheroid Clark 1880
 - Datum Adindan Ethiopia
 - UTM Zone 37 North
-

Table-4 1:50000 scale topographic maps coverage of Bilate Watershed

	37° East	38° East	
07 ° North		0738A1 Dalocha	0738A2 Tora
	0737B4 Hosaina	0738A3 Welbareg	0738A4 Mito
	0737D2 Angacha	0738C1 Kulito	0738C2 Aje
	0737D4 Shone	0738C3 Ropi	
06 ° North	0637B2 Soddo	0638A1 Chericho	
	0737B4 Tebela	0638A3 Kilisa	

Source: Ethiopian Mapping Agency 2004.

3.1.3. Satellite Images

For the biomass analysis of Bilate Watershed Landsat MSS, TM and ETM images of 1973, 1986 and 2001 are applied respectively. The area is extracted from the mosaics of three Landsat TM and ETM images (Figure-13). Such images are identified for their information on the biomass condition and other resources through time.

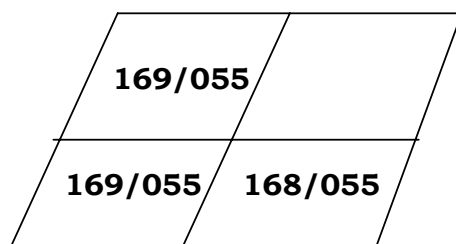


Figure-13 Path and Row of the Landsat TM/ETM Scenes

Table-5 Satellite Image-Types and Acquisition Date

Landsat Scene Path/Row	Sensor	Bands	Acquisition Date	Remark
180/055	MSS	MIR, NIR, Red, Green	21/10.1973	Distripping problem in the southern tip
168/055	TM	FIR, THIR, MIR, NIR, Red, Green Blue	21/01/1986	
169/054	TM	FIR, THIR, MIR, NIR, Red, Green Blue	22/11/1984	Cloud coverage in the northern tip
169/055	TM	FIR, THIR, MIR, NIR, Red, Green Blue	22/11/1984	
168/055	ETM	FIR, THIR1, THIR2 MIR, NIR, Red, Green Blue, Panchromatic	05/02/2001	
169/054	ETM	FIR, THIR1, THIR2 MIR, NIR, Red, Green Blue, Panchromatic	26/11/2001	
169/055	ETM	FIR, THIR1, THIR2 MIR, NIR, Red, Green Blue, Panchromatic	26/11/2001	

Source: Extracted from the header files of respective images

As it is presented on the Table-5, all the bands of each scene have good quality information. Very insignificant coverage of cloud cover is observed in the 169/054 (path/row) of 1986. In addition due to sensor problem destripping problem is found on band 4 of the MSS image. Such problems are solved through using alternative bands and running destripping program.

Tabl-6: Application of Multi spectral bands

Multispectral Band of Landsat	Intended Application
Blue	<i>Maximum penetration of water which is useful to bathymetric mapping in shallow water. Useful to distinguish soil from vegetation and deciduous from conifer.</i>
Green	<i>Matches green reflectance peak of vegetation which is useful for assessing plant vigour.</i>
Red	<i>Matches a chlorophyll absorption that is important to discriminate vegetation types.</i>
Near IR	<i>Useful for determining biomass content and for mapping shorelines.</i>
Middle IR	<i>Indicates moisture content of soil and vegetation. Good contrast between vegetation types.</i>
Thermal IR	<i>Useful for temperature analysis and estimating soil moisture.</i>
Far IR	<i>Coincides with an absorption band caused by hydroxyl ions in minerals. Useful for mapping hydrothermally altered rocks associated with mineral deposits</i>
Panchromatic	<i>Better spatial resolution (15 meters) useful for features identification and image sharpening</i>

Source: Extracted from Different Sources

3.2. Field Data /Ground Truthing

Ground truthing or field data collection within and around Bilate Watershed took place from May 27-31, 2007. The main purpose here is to compare the real world condition with the existing raw satellite images and topographic maps. The data collection is using sample points which represent features identified on the satellite images. More than 45 points are identified and as shown on Figure-14. Major observed conditions here include:

- Gully erosion conditions are more clear and contrasting
- Flooding is common due to run off and related problems effected from biomass degradation
- Spectral response of land use land cover feature variation which can be caused by crop calendar such as ploughing, weeding, and maturity stages of different types of crops and etc.

The field data collection has been undertaken from initial course of the stream of River Bilate to its mouth. In the mean time almost all the tributaries are observed. In general, the following conditions are analysed during the ground truthing.

- Indigenous vegetation in almost the whole watershed are found to be substituted by the exotic ones.
 - Ridges, mountains, and valleys including plains are exposed for biomass degradation, which is followed by soil erosion.
 - As a result of the soil erosion sedimentation filling in the flood plains is common.
 - Increase in rural population is among the major causes for the depletion of biomass in the watershed.
 - Transformation and or/conversion from one land use to another is very common especially:
 - From grazing to cropland
 - From forest to cropland
 - From woodland to barren areas
 - From any to roads
 - From nothing to gullies and gorges
-

- From sparsely populated to densely populated and etc.
- Demand for fuel and related domestic needs is very common
- When compared with the upper course the problem is less in the lower one.
- Proportionally western part is more affected than the eastern.
- In the satellite images, canopies of some of the vegetation species hide or camouflage the real soil degradation.

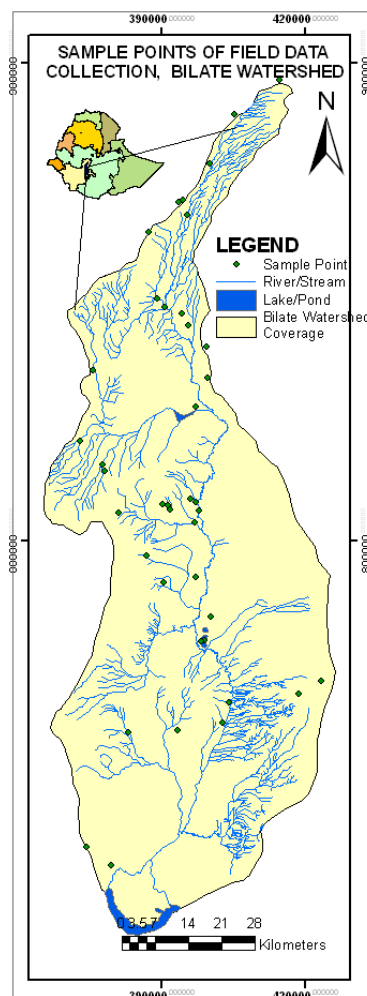


Figure-14 Sample points of field data collection using GPS

3.3. Drainage System

The drainage system of the Bilate Watershed is digitised from the topographic map of 1:50000 scale. As it is demonstrated in Figure-14, they are dense in the western part of the watershed compared to the east and the rift valley area. Their level range up to five and four in the mountainous areas.

3.4. Administrative Units and Boundaries

Although the drainage system and watershed do not consider the administrative units incorporating such information can be useful for population distribution and an overall analysis. Woreda level administrative units are extracted and digitized from the regional administrative units (Figure-10).

3.5. Climatic Data.

As discussed in chapter one, the climatic condition of the watershed is variable and depends on the topographic nature. Such a data covering the area and some of its vicinity is collected from the National Meteorological Services Agency of Ethiopia (See Table 1,2 3 and Figure-6).

3.6. Infrastructure

Infrastructure here includes mainly roads network and towns within the watershed. The reason is that the development of the infrastructure has two aspects on the biomass condition of the watershed. The first one is that due to domestic needs and construction purpose the demand of biomass can be very high. In addition during the roads construction, unless measures are taken into consideration the damage can be very damaging of the environment. The second aspect is that due to the exposure and accessibility of the degraded areas there can be conservation practices as presented on Figure-1.

3.7. Digital Image Processing

For the purpose of data restoration, quality assessment, enhancement, classification and interpretation of remotely sensed data, digital image processing is among the major steps. Band combination process also played an integral role for the identification of the most informative bands for the processing. By testing the combinations two sets of false colour composites become very informative depending on the objective of the study. Such an approach was done using the probability formula:

$$\frac{N!}{(N-R)!}$$

Where, N= number of bands for TM which is 6 because the thermal infrared was excluded and for MSS that is 4.

R= Number of band combinations using the Red Green and Blue colours which is 3.

Using this formula, it is possible to visualize 120 colour composites for TM and 34 for MSS respectively. Among the composites, the most visualized ones are identified. The best ones for this research purpose are:

- NIR, Red and Green on RGB which is known as conventional false colour composite useful for biomass analysis
- FIR, NIR and Red on RGB for drainage system identification.

Since the study area comprises of three scenes, mosaicking is compulsory. Variation of path and row led to the acquisition of data in different date which also caused spectral variations. That needs especial attention during mosaicking. To overcome the problem, band matching using average spectral values made the images similar.

Extraction of the research area is the next step which took place using the processing software. Area of Interest (AOI) was identified and extracted (Figure-15). The problem here is that in each step of value adding, there is also enhancement of the spectral values.

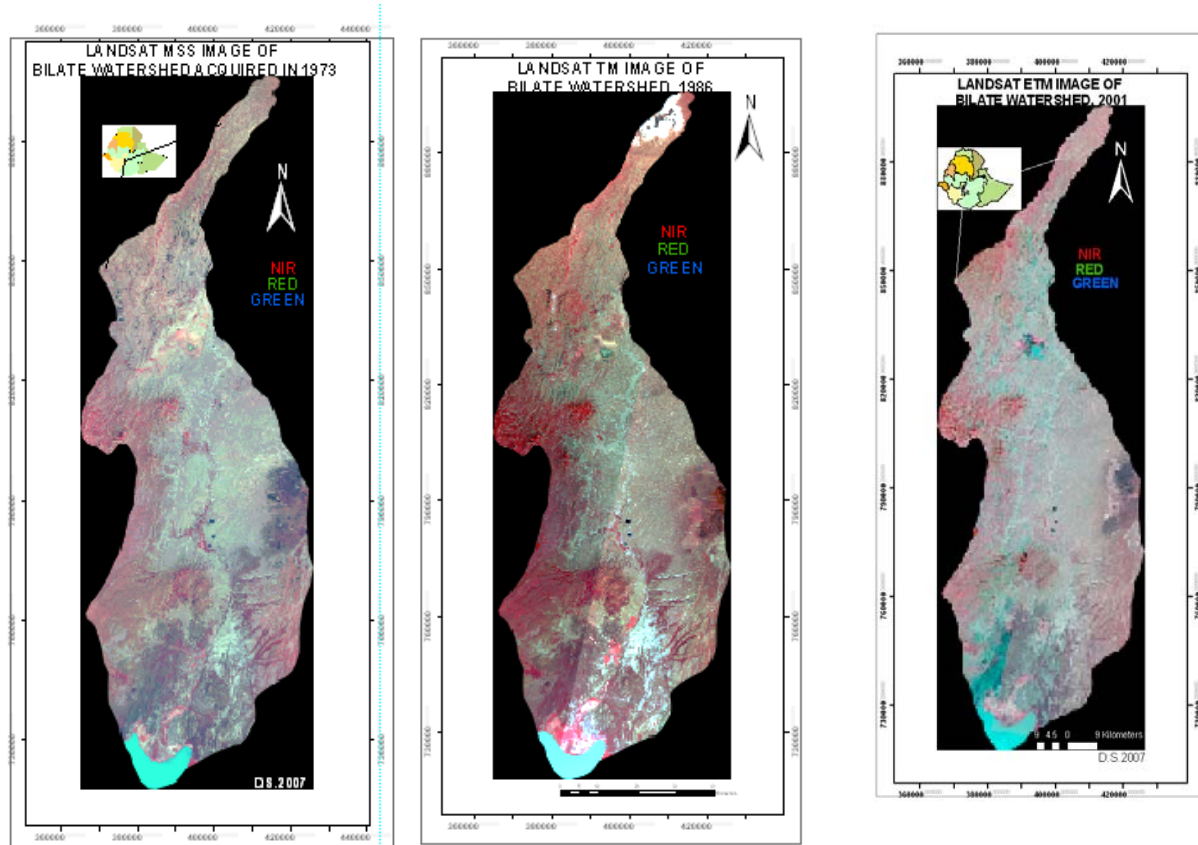


Figure 15. Conventional false colour composites of Multi-temporal (A) Landsat MSS 1973, (B) Landsat TM 1986 and (C) Landsat ETM 2001 images.

3.7.1. Pre-Processing of Remotely Sensed Data

Major types of preprocessing activities include radiometric and geometric corrections. Radiometric corrections include those which can be contributed by scene illumination, atmospheric factors, viewing geometry and instrument response characteristics. Geometric corrections include those related with variation of the flight altitude, attitude, earth curvature, velocity of the platform and the likes (Lilseland and Keifer, 2004). Most of distortions caused by the above factors are solved in the receiving station of the satellite data.

During the image processing time some of the pre-processing and image restoration activities took place. These are image enhancement and georeferencing of the images. Image enhancement in this case is that of

spectral one which is useful for more visualizing of the images. The georeferencing and mosaicking, as discussed in the previous cases are common process for both topographic maps and satellite images or aerial photographs.

3.7.2. Image Mosaicking.

This is a process which merges two or more side lapping and overlapping images or maps. Since the Bilate Watershed is composed of three TM scenes, mosaicking is processed using the available facility of the software. After major steps in pre-mosaicking here include:

- Georeferencing
- Checking the coordinate system and GCPs coinciding in relation to the features,
- Band matching

Challenge encountered during mosaicking was that of temporal variation of one of the Landsat TM/ETM scenes. Both 169/054 and 169/055 scenes were acquired on the same date. On the contrary, the remaining 168/055 scene was of different season. When mosaicking their boundary has become sharply demarcated. In addition, spectral reflectance of the same groups of features becomes different. That has created problem especially in automatic visualization and automatic classification processes. In general the problems related with temporal variation have resulted in the following challenges especially during the digital image processing.

- During supervised or unsupervised classification, similar features on the ground can be categorized to different groups because of similarity of the spectral response. A good example is that of grass and some of the crops such as barely, *teff* or wheat.
 - On the other hand features of the same group can be categorized to completely different ones due to their similar spectral response which is directly linked to seasonal variations.
 - If one tries to overcome the above and related problems through image
-

enhancement especially that of linear stretching, darker and brighter features will become darker or brighter. Such an approach causes missing of some of the features.

The last problem is partially solved through band matching, as an average value and using areas of overlapping only. Other problems are solved only by applying screen digitizing instead of supervised and unsupervised classifications.

3.8. Screen Digitizing

All the features represented on the satellite images are digitized using the screen digitizing techniques (See Maps 5, 6 and 7.). Error correction and topology building have been well considered. Snapping tolerance is also considered in such a way that topology building and minimizing the errors.

3.9. Geoinformation Extraction from images and Analysis

Geoinformation collected and organized from different sources are has different mechanisms of processing using different types of algorithms. Such a processing is basic method for the findings. This chapter in detail discusses the most applied methods for biomass degradation analysis.

3.9.1. Vegetation Index Analysis

Vegetation Index (VI) is in remote sensing is a combination of reflectance of two or more bands usually, red and Near Infrared. Vegetation index analysis is a complex phenomenon because of its variation of canopy structures, density, leaf property and phonological changes in time (Meijerink and others, 1994).

Vegetation Index analysis is very useful because is has effect on the drainage system, evapo-transpiration and protection of run off. Using such technique one can analyse the biomass extent also.

For the Bilate watershed biomass analysis the applied index is that of Normalized Vegetation Index (NDVI) as expressed below.

$$\text{NDVI} = \frac{(\text{NIR}-\text{Red})}{(\text{NIR}+\text{Red})}$$

The value of NDVI is bounded between -1 and 1. If the value is -1, it indicates that there is no vegetation or chlorophyll content and 1 shows maximum reflectance. The problem in the tropical areas is that most of the deciduous trees shed their leaves in the dry seasons. On the contrary, during the rainy seasons when the vegetation is green and the reflectance in NIR can be higher, cloud cover is the challenge. To overcome such a challenge, using images after the rainy seasons is advisable.

Through developing colour composites of NDVI 1973, 1986 and 2001 in Red, Green and Blue colours respectively the combination has become good indicator of the biomass condition in the last three decades. The outputs are presented in Table-7 and Figure-16.

From Figure-16 one can easily analyse the biomass degradation of Bilate watershed visually. The brighter tone represents presence of biomass while darker one demonstrates its absence. Vegetation Index from Landsat MSS images of 1973 which have courser spatial resolution (80 metres) is much better than that of TM or ETM of recent years. The normalized Vegetation index derived from ETM image of 2001 was acquired after the rainy seasons which are expected to have more greenness. On the contrary it is darker than that of MSS or TM indicating sever condition of degradation of biomass.

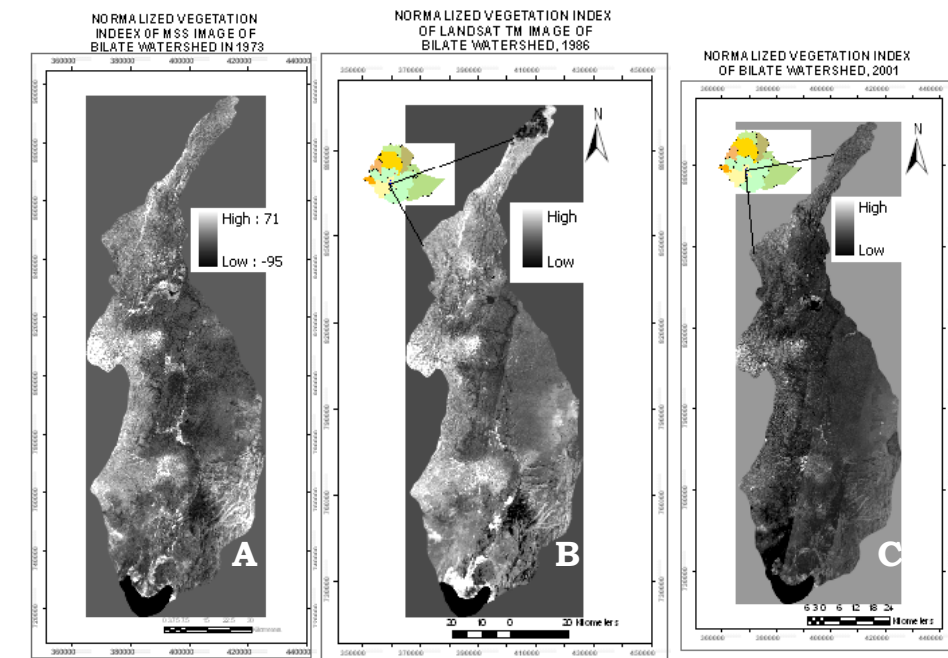


Figure-16 Vegetation Index of Bilate watershed in (A) 1973 (B) 1986 and (C) 2001



Figure-17 Multi-Temporal Colour composite of NDVI of Bilate Watershed

Table 7 NDVI as a multi-temporal colour composite and indicative situation.

NO.	Colour Composite	Indicative Information
1	White	Areas with ever green vegetation or not affected
2	Black	Areas devoid of vegetation in the three cases
3	Yellow	Areas with vegetation in 1973 and 1986
4	Cyan	Areas with Vegetation in 1986 and 2001
5	Magenta	Areas with vegetation in 1973 and 2001
6	Red	Areas with vegetation in 1973
7	Green	Areas with vegetation in 1986
8	Blue	Areas with vegetation in 1986

NDVI 1973 Red, NDVI1986 Green NDVI 2001 Blue

Source: Extracted from NDVI Processing Multi-temporal images of Bilate Watershed

3.9.2. Tasselled Cap Analysis

Tasselled cap analysis is one of the techniques for vegetation analysis especially using multi-spectral bands other than thermal Infrared. The six bands of TM are dispersed into three-dimensional space formed by two orthogonal planes and a transition zone. Vegetated areas indicated in the plane display the greenness.

Because of the capability of showing soils or on can analyse the degradation extent in the watershed. In the case of the Bilate Watershed, vegetation condition and level of degradation on the soil clearly presented especially along the river gorges.

As it is indicated in Figure 18, biomass is on the process of degradation in the past three decades. For example green colour shows the presence of biomass and red its absence. From that one can derive that biomass condition was

better in the 1973 even in course resolution of MSS when compared with that of 2001.

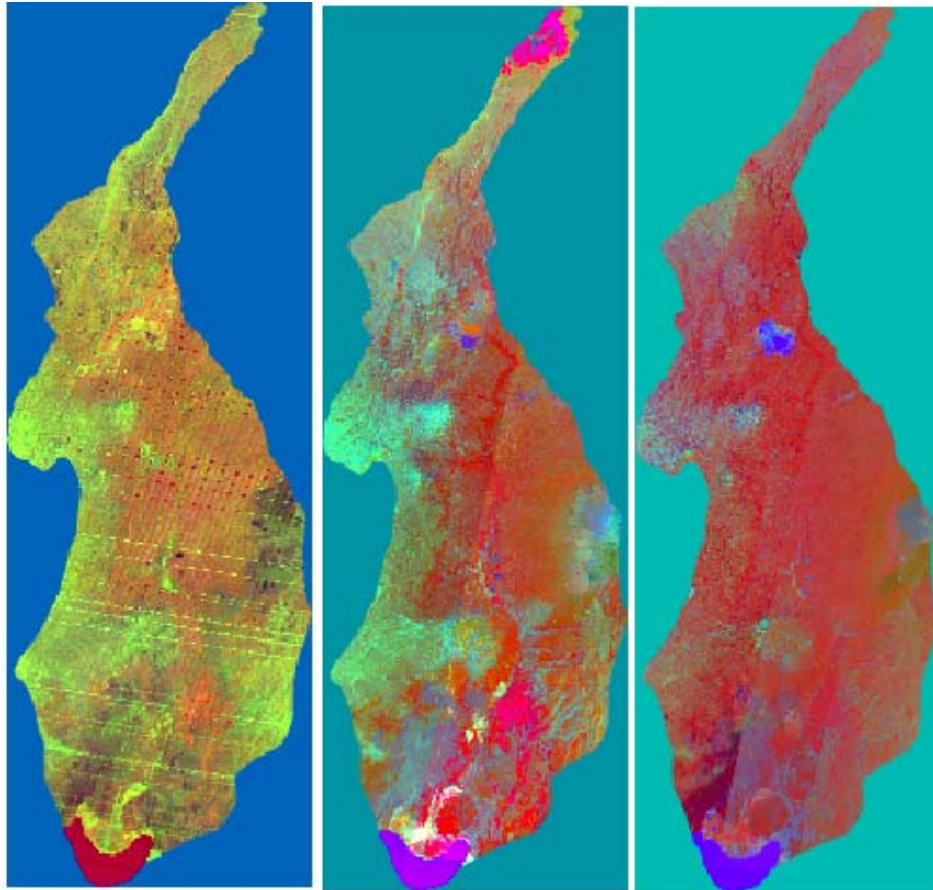


Figure 18 Tasseled Cap multi-temporal images indicating biomass of Bilate Watershed

3.10. Interpretation of Data and Multi-temporal Analysis

As it has been discussed in the previous cases, satellite images are interpreted with screen digitizing techniques of the ARCGIS 9 software facility. The rationale behind is that because of temporal variations of the satellite images, either supervised or unsupervised classifications found to be misleading. In addition, spectral similarity and difference of some of the features have affected the real presentation.

Another benefit of screen interpretation is its similarity with visual one. It is not only the spectral aspect or tone which has to be taken into consideration but also other elements of interpretation such as texture, shape, size

association and etc can be considered in one or other way. In this case most of the interpretations are generalized.

Interpretation here is also assisted with the ground truthing or data collected during the field survey. All the features existing in the area are observed and presented in terms of photographic pictures.

In the mean time the interpretation procedures of the land use cover are that of FAO. Depending on the level of detail and contrasting value of the feature, some smaller size features like hot spring sites are included All the interpretation features of the study area are presented on Figure-19, Figure-20 and Figure-21

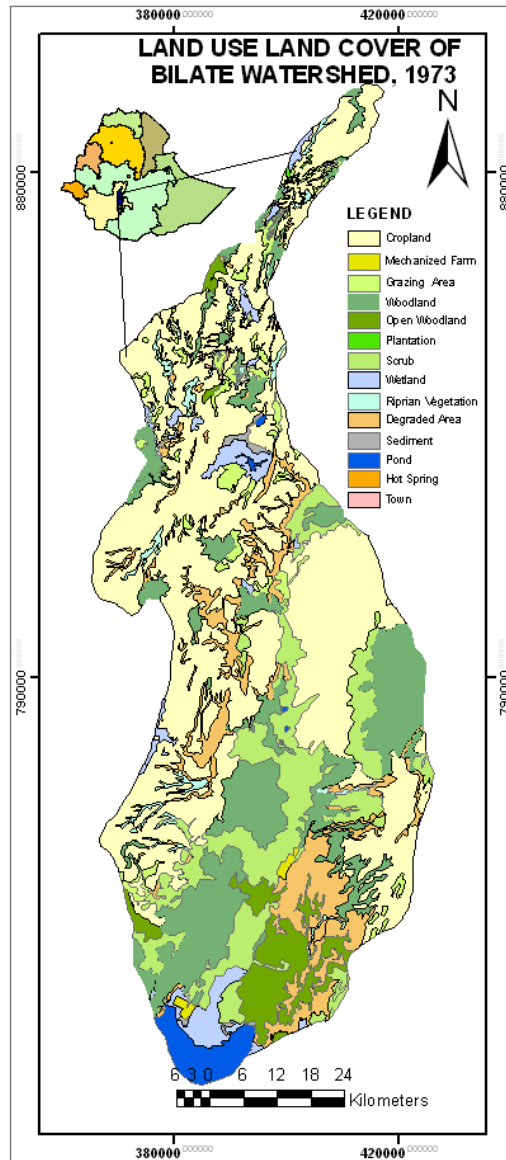


Figure-19 Land use Land cover of Bilate Watershed in 1973

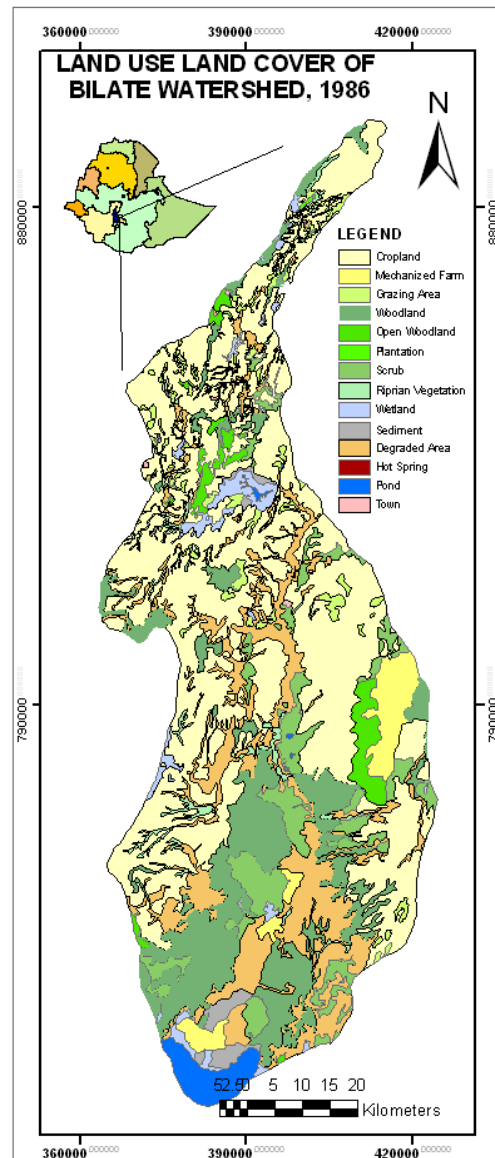


Figure-20 Land use Land cover of Bilate Watershed in 1986

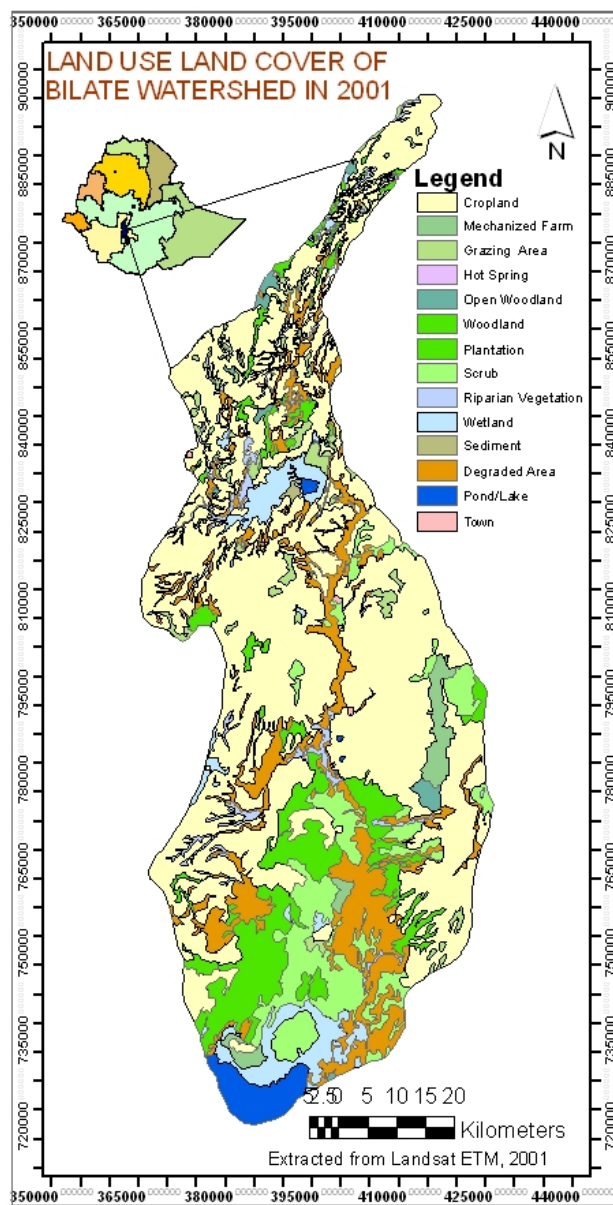


Figure-21 Land use Land cover of Bilate Watershed in 2001

3.11. Conservation Priority Area Identification Criteria Developing

Interpretation of the multi-temporal satellite images or presenting in terms of thematic maps is not an end of biomass degradation analysis. To meet the objectives further processing steps have to be done especially to facilitate the decision making. The decision making here is to identify the most affected and vulnerable areas because of biomass degradation. That can be done through integration of multiple sources. An overall process for the identification of conservation area presented on Figure-22

3.11.1. Steps for Conservation Priority Areas Analysis

For the identification of the priority areas of conservation the following geoprocessing steps are applied using ARCGIS software.

- Rasterization of the interpreted and digitized vector data.
- Raster interpolation of elevation data from contour lines for the purpose of DEM and slope generation.
- Deciding the data processing extent, cell/pixel size of the raster data and masking by the watershed boundary.
- Distance and/or buffer zoning for point and line features using spatial analysis
- Reclassification of the distance/buffer zone output.
- Assigning weight for each reclassified data and calculating the suitability condition.
- Evaluating the result.
- Identifying suitable areas conservation priority especially for planners and decision makers.

The processing steps and output maps are presented on Figures 22, 25 and 26.

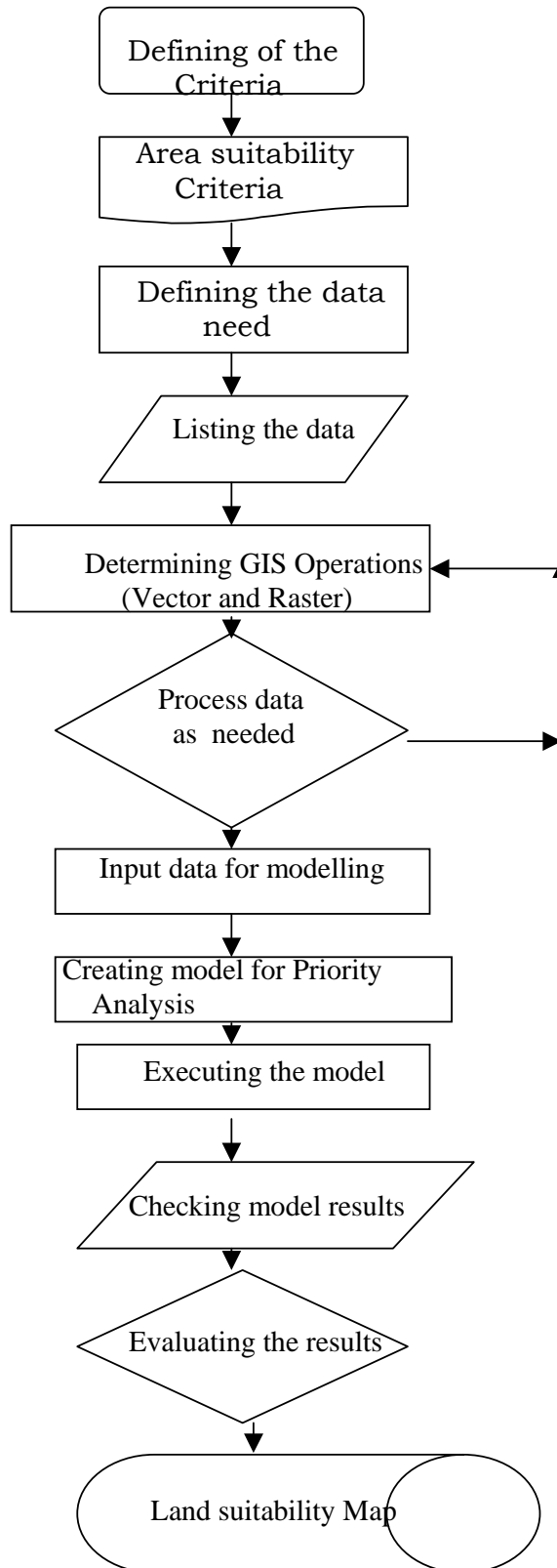
Flow Chart for Steps performed for Conservation Priority Areas Analysis

Figure-22. Flow Chart for Conservation Priority Areas Analysis of Bilate Watershed

3.11.2. Criteria for Conservation Priority Areas

After rasterization of each feature type criteria were according to their importance and based on the role which they play on the degradation process.

- **Drainage.** Areas near the rivers or streams are highly exposed for degradation due to the nature of the topography and related human factors. People in the area need such areas for wood, grazing and expansion of arable land. Therefore, such areas are highly exposed for biomass degradation. The problem is very serious in the high lands and where the population density is very high. In addition the lowland areas also have such problems mainly due to grazing related issues. Having this in mind buffer zone of 1000 metres around the rivers or streams is assumed to be exposed for high level of degradation.
 - **Land use.** In this study the land use mean areas identified as degraded areas or badlands. Although they are identified as badlands, degradation is still going on process. Therefore these areas as whole are considered as a challenges for the environment and need priority for conservation.
 - **Slope.** As it has been discussed in the previous cases, the Bilate watershed is rugged terrain especially in the western high land part. Within the Rift valley and eastern part the volcanic peaks enhance the problem. The higher the slope, the more the area can be exposed for degradation. Therefore, areas with more than 30° slope are given priority of conservation.
 - **Population Density.** As it is discussed in the first chapter population density is very high in most of the woredas within the watershed. That is directly related with high demand of fuel wood and expansion of arable land. On the other hand, such situations lead to increase in the degradation of the area. Considering these conditions areas with high
-

population density especially more than 100 people per square kilometre are assumed to be more exposed for degradation.

- **Major Roads.** As it has been observed during the field data collection, due to farming process, deforestation, ditches, ignorance during construction of roads and the likes, many areas are exposed for degradation. Gulley erosion is the most common problem till destroying the road itself (Figure-45). Therefore buffer zone of 150 meters around the road are area highly exposed for degradation mainly due to expansion of arable land, grazing area, settlements and environmentally not sounding road construction.

Table-8. Criteria assigned for conservation priority areas of Bilate Watershed

NO.	Feature Type	Criteria Assigned
1	Drainage	<i>1000 meters far from</i>
2	Land use	<i>As it is</i>
3	Slope	<i>Areas >30 degree slope</i>
4	Population	<i>More than 100 people/SqKm</i>
5	Major Roads	<i>150 meters</i>

3.11.3. Processing Steps for Implementation of the Criteria

ArcGIS software facilitates different programs and steps to process and implement the criteria. Different steps were run using two approaches namely:

- direct processing using all the programs one by one.
- building a customized model under the Tool Box.

In both cases it is the output is similar. The whole process and steps undertaken are presented on flow chart (Figures-22 and 25).

3.11.4. Pairwise comparisons method

The Pairwise comparisons method was developed in the context of the Analytical Hierarchy Process (AHP). This method involves pairwise comparisons to create a ratio matrix. As input, it takes the pairwise comparisons of the parameters and produces their relative weights as an output as demonstrated

on Table-9. The range of given weight can be from extremely less important to extremely important depending on the objective.

Table-9 Continuous Rating Scale of Pairwise Comparison

Intensity of importance	Definition
1/9	Extremely less important
1/7	Very strongly less important
1/5	Strongly less important
1/3	Moderately less important
1	equally important
3	Moderately more important
5	Strongly more important
7	Very strongly important
9	Extremely important

Source: IDRISI User Guide

Using the above approach the IDRIS data entry and editing programs are applied. The following matrix is prepared in such a way that the data can be processed. The output of Figure-22 is acceptable because the eigenvector matrix weights consistency ratio is 0.02.

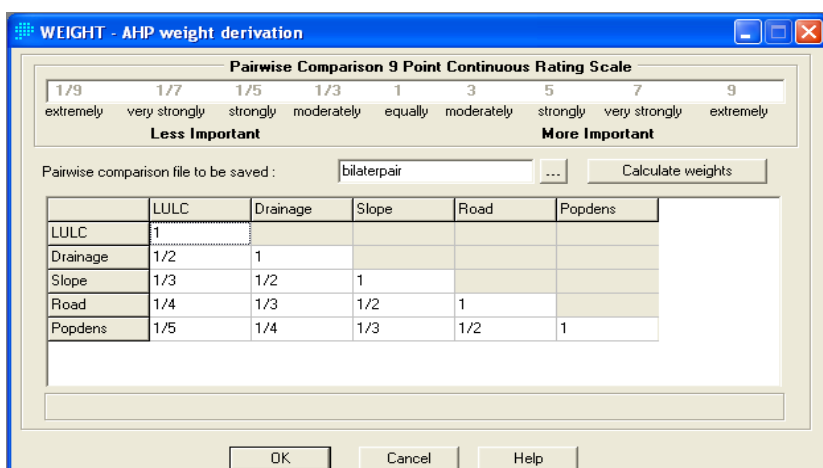


Figure-23 Matrix for Text editing using IDRISI Data Entry

Using such a technique of matrix calculating the eigenvector weight is processed as presented below

The eigenvector of weights is :

```

LULC      : 0.4185
Drainage  : 0.2625
Slope     : 0.1599
Roads     : 0.0973
Pop.density : 0.0618
Consistency ratio = 0.02
Consistency is acceptable.

```

After accepting the consistency ratio by the software its quality is tested with ArcGIS weighting the reclassified raster data calculating with respective feature types as shown on figure-24.

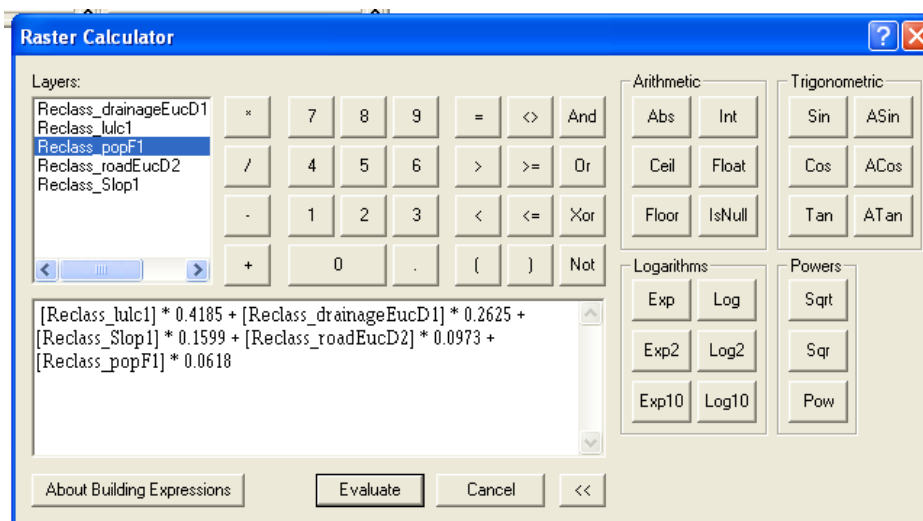


Figure 24 Calculating the reclassified data with using eigenvector weights

Using the above raster calculating approach, areas which are badly degraded within the watershed are identified as shown on Figure 26. In addition, areas which are sensitive for degradation are identified without bias. Such an approach is very useful for planners and decision makers.

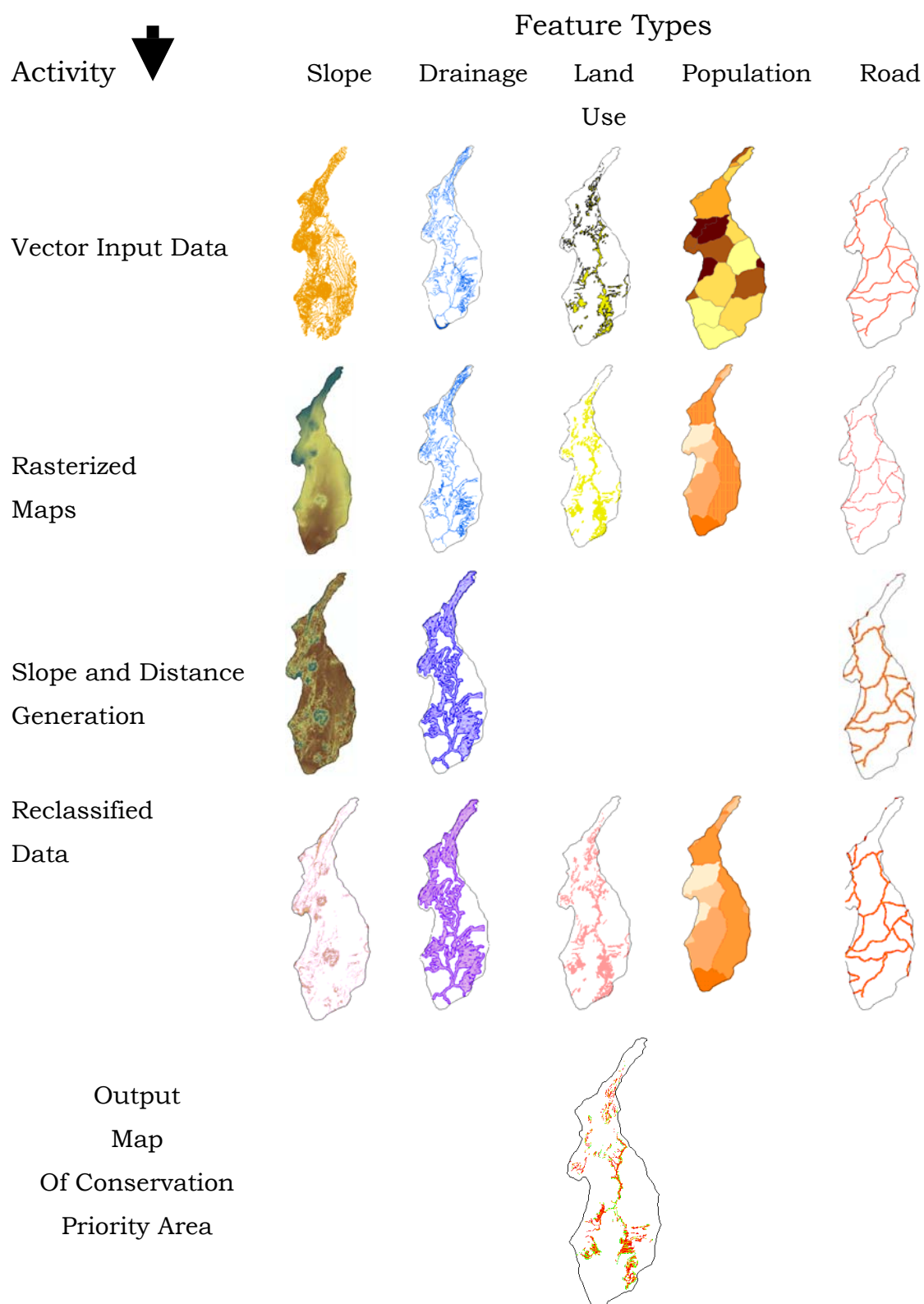


Figure-25 Conservation area analysis using GIS techniques for Bilate Watershed

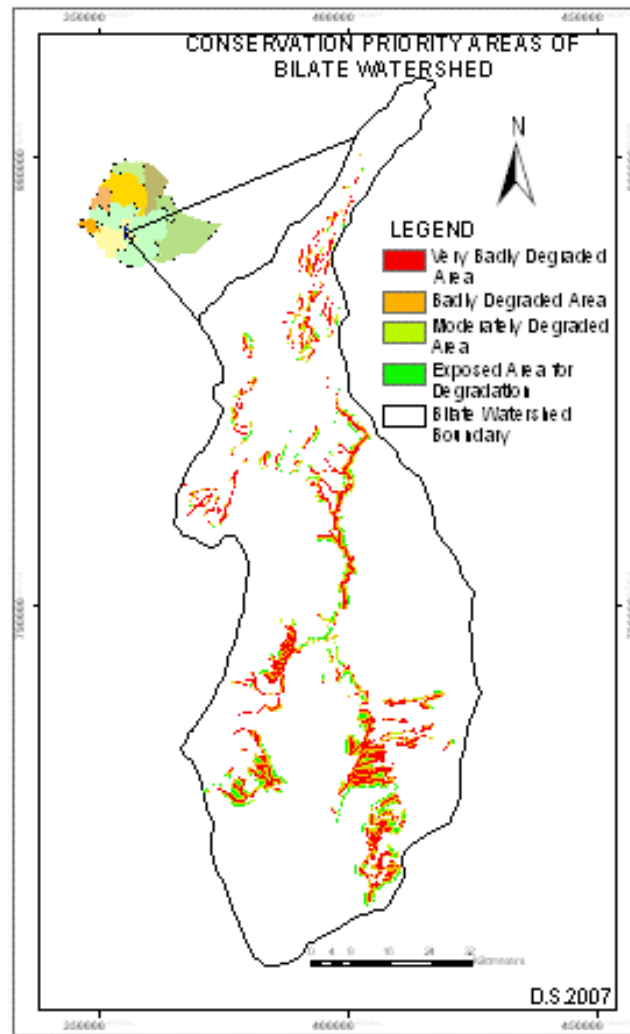


Figure-26 Conservation Priority Areas of Bilate watershed prepared using decision support system

Chapter Four

Results and Discussions

Geospatial data processing on the biomass degradation of Bilate Watershed has become an important tool to assess cause factors and their effect on the physical environment. Major causing factors as the GIS output indicates and observed during the field data collection time, include deforestation, overgrazing, expansion of arable and the likes.

4.1. Major Land Use Cover Features of and Biomass condition

With the interpretation of the Landsat images, 14 different types of features are identified. Their identification is based according to the principle which says that the feature should be familiar in the area for a certain period of time (Sabins :1990). The features general conditions are discussed as follows.

4.1.1. Cropland.

These types of features represent small scale farmlands of the Bilate Watershed. The individual ownership varies from highlands to the lowlands. In the upper courses and middle course areas of the watershed they are very dense. Because of increasing of the rural population, the total size of the farmland is expanding (See Table-10). As it is shown on Figure-27, the expansion goes to the top of mountains and deep gorges In general the expansion of cropland is good indicator of biomass degradation.



Figure-27 Expansion of Cropland land to top of mountains (Wolayita)

4.1.2. Mechanized Farm.

Few mechanized farms are found near the mouth of Bilate river known as Tena Bilate farm which is mainly used for tobacco production (Figure-28). The expansion of such farms in this area is major cause for degradation of biomass like woodland and scrub (bush land)

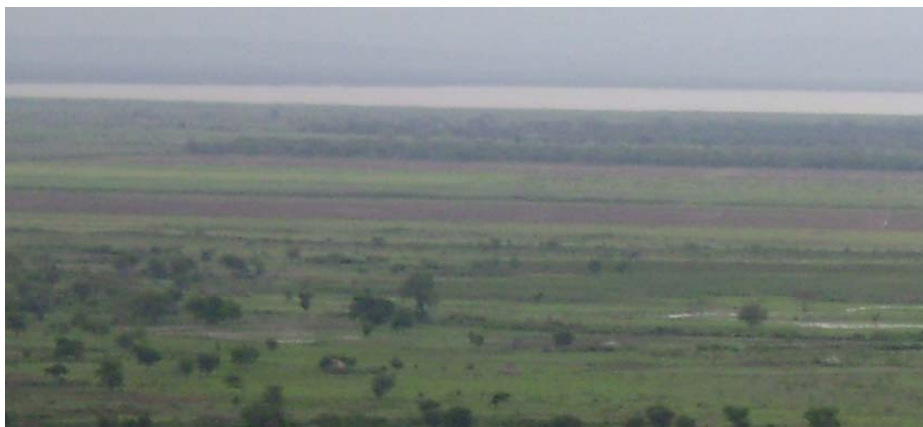


Figure-28 Mechanized farm near the mouth of Bilate River

4.1.3. Plantation.

These types of features indicate those areas covered by planted trees by the community (Figure-29) or other conservation conserved groups. Their coverage is very small. In the highlands and some of the transitional areas plantation is well practiced by individual farmers. The problem is that it is not easy to identify as a feature because in many cases plantations are like fences or agro-forests in and around farms



Figure-29 Eucalyptus [plantation around Motoqoma Peak (Kambatta)

4.1.4. Grazing Area

Since farmers in the highlands use mixed farming and those of lowland are agro-pastoralists, grazing areas are among basic needs of people living in the watershed. It is an open area without trees cover where livestock gets grass or stays during the day time. Such areas in the watershed are dominantly owned by the community (Figure-30). In some cases especially in the highlands there are very few private grazing areas. Such a private owned grazing areas are very small and cannot be distinguished from croplands in Landsat images. The size of grazing areas, as observed during the ground truthing is diminishing especially in the lowlands because of limitless expansion of croplands.



Figure-30 Community Grazing Area (Silte)

4.1.5. Riparian Vegetation.

Some types of vegetation occur around the streams only. Their range is from small grass to higher trees. In many cases they are the remnants of the indigenous tree species and are ever green. In high land areas they are almost on diminishing level due to the expansion of croplands. In addition, eucalyptus trees have already substituted the indigenous ones here (Figure-31).



Figure-31 Indigenous Riparian Vegetation along one of the tributaries, Hadiya(A) and exotic riparian vegetation along Bilate River, Silte (B).

4.1.6. Wetland.

These are marshy areas dominantly with grass cover and in some case with scattered trees. Such areas found around ponds, flood planes and the likes. Such areas are also badly affected by the expansion arable land and grazing areas.



Figure-32 Wetland North around f Lake Abaya

4.1.7 Woodland.

Woodlands are areas naturally covered by trees which are shorter when compared with high forests. Their height is not more than 4-5 meters. In many cases they are dense with undergrowth of bushes and grass. They are good habitats for wild life. In addition the variety of tree biomass species exist there. They are common in some of the highlands, transitional areas and some parts of the rift valley (Figure-33). They are endangered due to demand for fuel especially charcoal, construction, domestic needs, expansion of arable land and grazing areas.



Figure-33 Woodland North of Lake Abaya

4.1.8. Open Woodland.

The difference between woodland and open woodland is a matter of density. In the case of open woodland the trees are scattered and undergrowth is more exposed. The formation of some of the open woodlands is due to human intervention (Figure-34). They are the most endangered due to expansion of arable land and grazing.



Figure-34 Endangered open woodlands due human interventions (Wolayita)

4.1.9. Scrub (Bush land).

These types of land cover are common in the rift valley part of the watershed. Scrub, shorter acacia species, grass and the likes are common (Figure-35).. They are good source of forage for browsers. Besides they are also habitats of smaller types of wild life and birds. Their endangering is due to expansion of arable land and grazing.



Figure-35 Scrub (Bush land) at near the gorge of Bilatte river middle course

4.1.10. Degraded Area.

They are badlands which are affected by human or natural factors. Such areas are devoid of vegetation and the soils are exposed. It takes longer time for recovery. Most of them are found along the rivers banks or slope areas. Expansion of arable areas, overgrazing, roads construction, runoff and the likes are major causes for degradation. As it is presented on the maps they are expanding from time to time (Figures 19-21).



Figure-36. Degraded area along Addis Arba minch Road (A) and South Eastern part of River Bilate

4.1.11. Sediment.

Many areas within the Bilate watershed are covered by the sediments which are resulted in due to gulley erosion. Some are found on the flood plains while others exist at the Bank of rivers. For example their coverage around Lake Boyo and Lake Abaya is very significant.



Figure-37 Sedimentation and excavated sand from Tributaries of Bilate River

4.1.12 Hot Spring

In the transitional zones and within the rift valley parts of the Bilate Watershed many hot springs exist. They cover significant area. Their utilization is very traditional.



Figure 38 Arto Hot Spring West of River Bilate

4.1.13. Town/settlement.

Many towns are flourishing in and around the watershed. They are dependent on the natural resources of the area. Their impact on the biomass as well as the whole ecological system is significant.

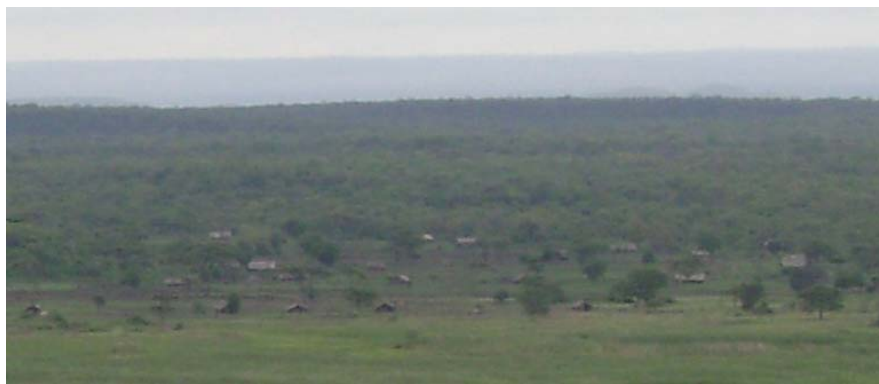


Figure-39 Expansion of settlement in woodland area of the Bilate Watershed

4.1.14. Pond/Lake

One of the characteristics of the Bilate watershed is existence of ponds and lakes. They are found in the high lands as well as the rift valley. Some like Lake

Boyo depend on the water which comes from the streams while others are volcanic.



Figure-40 Volcanic ponds east of River Bilate south of Ropi

4.2 Analysis of the Biomass Degradation

Based on the interpretation of the land use land cover of the Bilate watershed it is possible to analyse the trend of biomass degradation. That can be analysed through evaluating the area covered by feature types which can induce biomass degradation. The major ones here are cropland, grazing area, sediment, settlements and etc. As it is demonstrated on Table-9 and Figure-37, there is significant increment of such features. The exceptional one is that of cropland which has increased from 45% to 55%. On the other hand, grazing area, woodland, open woodland and scrub coverage significantly has decreased mainly due to expansion of cropland. All these imply that the biomass of the watershed is badly exposed for degradation.

Table-10 Land Use Cover Changes occurred in the Bilate Watershed 1973-2001 from Landsat MSS and ETM Images

NO	Feature Type	Area in SqKm in the Years					
		1973	%	1986	%	2006	%
1	Cropland	2667	45.5	2636	46.41	3129	55.09
2	Degraded Area	548	9.35	925	16.29	775	13.64
3	Grazing Area	170	2.90	141	2.48	152	2.68
4	Hot Spring	0.12	0.002	0.12	0.04	0.12	0.04
5	Mechanized Farm	16	0.27	187	3.29	101	1.78
6	Open Woodland	281	4.95	149	2.62	43	0.76
7	Plantation	2	0.04	2	.04	3	0.05
8	Pond/Lake	123	2.17	113	2.00	120	2.11
9	Riparian Vegetation	111	1.95	122	1.45	145	2.55
10	Scrub	722	12.71	447	7.78	494	8.70
11	Sediment	18	0.32	63	1.11	9	1.58
12	Town	1	0.02	5	0.09	6	0.11
13	Wetland	182	3.20	127	2.24	256	4.51
14	Woodland	1005	17.69	943	16.60	624	10.99
Total		5860	100	5860	100	5860	100

Source: Extracted from Land use Land cover classification

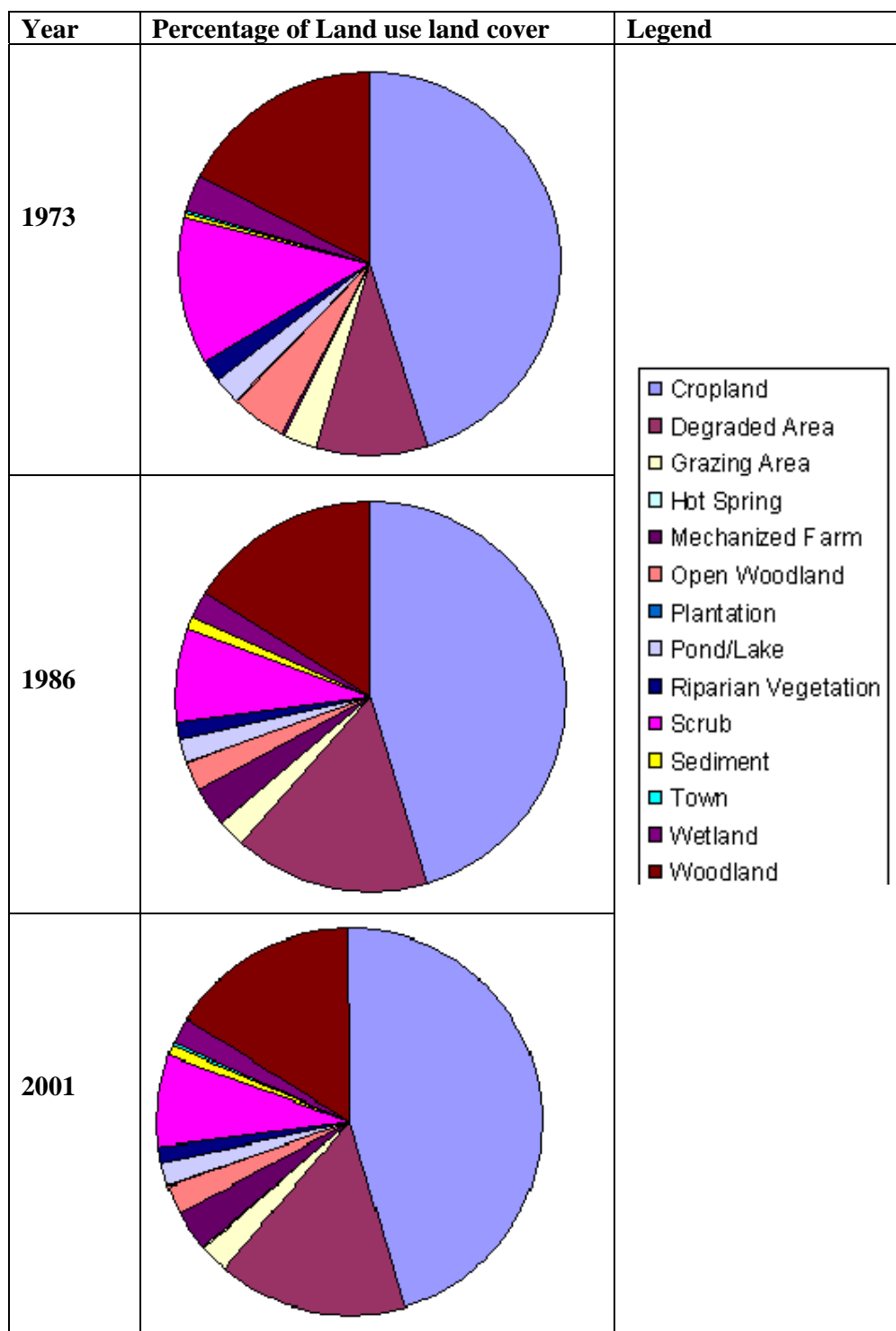


Figure-41 Land use Land cover of Bilate Watershed in terms of percentage in 1973, 1986 and 2001

4.2. Factors affecting the watershed Biomass

4.2.1. Deforestation

When comparing natural vegetation area of the 1973 with that of 1986 and 2001, the change is significant (See Table-4) It is directly related with the rural population increase.

As it observed especially the western highlands and transitional areas forests are in the level of extinction. That can easily be analysed from the remnant vegetation types and few forest areas. In fact these days the forests are transformed to croplands and/or grazing areas. The problem as indicated is directly related with increasing human population especially in the rural areas.



Figure-42 Biomass degradation, expansion of arable land and overgrazing (Silte Zone)

Some of the high forests especially within the rift valley are on transformation to bush lands and grazing areas. Neither game reserves nor protected areas are observed in the watershed. In such undulating topography, deep gorges and steep slopes and the likes, utilization of natural resources without deforestation and conservation practice can damage the whole system and indicates real future challenge.

4.2.2. Overgrazing

Residents of the watershed mostly depend on livestock production side by side with their crop farming. For that purpose they need grazing and browsing areas. In the highlands some communal grazing areas are culturally reserved. If the grass is not enough, farmers may be forced to use forests, woodlands and bush lands as source of fodder supplying areas.

Once cattle feeding in the woodlands or forest areas started, the consequence will be cutting of trees, using fire and the likes. Finally the area can be fully exposed becomes open grazing area or cropland.



Figure-43 Overgrazing and its effect

4.2.3. Expansion of arable lands

Increasing in rural population and expansion of cropland are directly related. For that purpose forests woodlands or bush lands have to be cleared. Recent problems developed in the area are that of expansion of croplands to the higher altitude where the remaining afro-alpine vegetation exists.

The more the expansion of arable areas, the more will be degradation of biomass. As it is observed and interpreted from the satellite images in the western part of the watershed the expansion of arable land is in its climax level.



Figure-44 New settlement areas in the eastern part of the Bilate Watershed

4.2.4 Roads Construction

Although roads construction is among mans of infrastructure development and its indicator, construction without considering, side effect on the biomass can affect the physical environment. Currently many roads are under construction by the Federal Government and regionally responsible organizations. Besides many communities are developing local network infrastructure The problem occurs when constructing earth and/ or gravel roads. Such a challenge has dual effects. The first one is unplanned clearing of biomass and the second one is leaving the sides for gulley erosion (See Figure-45).



Figure-45 Effects of road construction along Alaba- Angacha- Hosaina road

4.3. Effect on the Physical Environment

Environmental challenges caused by vegetation degradation are increasing spatially and temporally. Once the biomass is degraded, the soil can be depleted, fertility of the soil can be reduced, runoff increases, erosion can be enhanced and so on. Similarly many challenges of physical environment are increasing within the Bilate Watershed. The major ones as observed and interpreted are discussed below.

4.3.1. Loss of Indigenous vegetation and substitution of by emotive

Especially in the western part of the watershed indigenous vegetation is in the extent of distinction. Indigenous trees which are of temperate and tropical groups like juniper, locals like Wanza, Zigba, Bisana, pine tree and the likes which are very useful for domestic and industrial use are among the most endangered ones. The remnants can be observed at culturally protected areas such as cemeteries and grazing areas. Dominantly substituting exotic one are eucalyptus and pine trees (Figure-46).



Figure-46 Substitution of indigenous biomass species by exotic at the very upper course of Bilate River

4.3.2. Soil Erosion

Soil erosion has become among major problem of the area. That is directly the effect of vegetation degradation and can be easily understood and can be considered as major indicator.

Most of the areas are practically observed as badlands and flood plans and/or sediments are results of erosion. Erosion process in the watershed mainly can be observed in channels, gorges, gullies, badlands, along roads and so on. In general here are to types of erosion known as gulley and sheet erosion. Although there are many traditional and modern approaches of conservation are taking place in many parts, overcoming such a challenge will be very serious task.

Gulley Erosion

Gulley erosion can easily be observed in many parts of the watershed. Both natural and anthropogenic factors have severely induced such any erosion. The gullies in many cases are V-shaped. Depending on the run off, soil types and altitude, their depth ranges from one metre to 8 meters width and unto 5 meters depth (See Figure-47) In general, the most endangered areas are he western pars of the watershed when compared with the eastern.

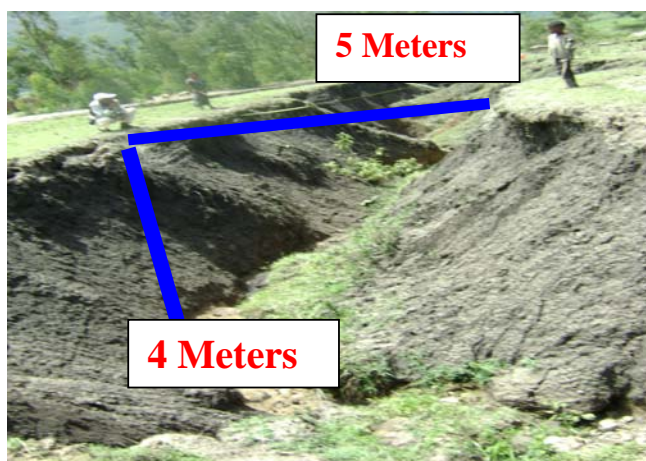


Figure-47 Gulley Erosion in North of Bonosha

Sheet Erosion

This type of erosion is very common in the rift valley area. Since there is no wind break due to deforestation, expansion of farming, roads construction and related problems, it is becoming major problem especially in dry seasons.

4.3.3. Land Sliding

Land sliding in many areas is related with geological formation. In the western high lands and transitional areas it is becoming common problem. As some interviewed people had said it was not a problem when there were forest or other vegetation cover. Currently it is becoming serious problem. (See Figure 48)



Figure-48 Landslide problems in Bilate watershed

4.3.4 Sedimentation

Many areas around the mouths of rivers, confluences of streams and their curvatures show significant amount of sedimentation. Sedimentation as discussed in the above cases is result of degradation followed by gulley erosion and run off. In Bilate watershed it is reflected by sand, mudflow, debris of rocks and he likes. It has been affecting croplands, fills stream beds, ponds and lakes and expands flood plains. Such challenges are identified around Lake Abaya, Lake Boyo and other low lands (Figure-49). As farmers living in these areas informed during the rainy they suffer.



Figure-49 Sedimentations and their effects in Bilate Watershed

4.3.5. Expansion of Degraded Areas

As it has been discussed in different parts of this paper, the degraded areas have been expanding for the past three decades. Unless measures are taken in one or other way, it will be continuous process of the Bilate watershed. In 1973 the coverage of degraded area or bad land was 548 Square Kilo metres and it became 775 in 1986. In addition its coverage was expanded to 925 Square Kilo meters in 2001. That means within three decades its area coverage is almost doubled. Its expansion has also direct relation with that of cropland.

Chapter Five

Conclusion and Recommendations

Biomass degradation and its impact analysis using GIS techniques is undertaken in Bilate Watershed. The study took place in the area, which represents most of the Ethiopian Watersheds in general, and specifically those, which found around the rift valley and its vicinity. The geological, topographical and landscape are among many factors for the diversity of the biomass resources of the study area.

As it has been observed during the field data collection, analysed from topographic maps and satellite images core cause for degradation of biomass of the watershed is directly related with the increase of human population. That is because expansion o cropland, construction, settlement, overgrazing and similar activities are those which are badly affection the biomass over there.

For the analysis part of the biomass trend of the watershed GIS techniques are intensively applied. Satellite images of the 1973, 1986, and 2001 were utilized. For extraction of more features such as drainage, contour lines, infrastructure and the likes digitization was done from topographic maps of 1:50000 and 1:250000.

The GIS activities of the watershed processed are using the multi-source data integration and analysis. Such integration in GIS is useful to analyse the process from different angles in such a way that on can evaluate causes and effects of the biomass degradation as well as decision supporting.

Depending on the type of the study, different levels of digital image processing took place. That includes Normalized Difference Vegetation Index and Tasselled Cap analysis which have practically have shown the trend of biomass

degradation. The second one is through interpretation of land use land cover of the three times independently.

According to the interpretation the expansion of degraded areas have been significantly increased from 1973 to 2001. For example the total coverage of degraded areas in 1973 for the whole watershed was 9.35% and that has become 13.09. In addition, the cropland and sediment have increased from 45.5% to 55.09 and 0.32% to 1.58 respectively.

On the other hand, woodland, open wood land and scrub (Bush land) decreases from 17.69% to 10.99%, 4.95% to 0.76% and 12.71% to 8.70% respectively.

In general, increase in some features and decrease in others is clear indication of the level of biomass degradation in the watershed. Major factors for such process are directly related with expansion of arable land, overgrazing, unplanned construction of mainly roads, land sliding, demand for fuel wood and the likes.

Biomass degradation has effect mainly on soil erosion, loss of soil fertility, micro climatic changes, land sliding, and increase in run off accumulation of sedimentation. The problem is not left only for the upland areas only but also it has been expanding up to the mouth of Bilate River.

In general watershed based biomass degradation using GIS techniques is found to be useful for the analysis of the level of degradation, major cause factors, effects on the physical environment and so on in short period of time compared with the conventional techniques.

Based on the above discussions the writer of this research would like to recommend the following points:

- The Bilate watershed, as discussed in different parts of the paper is badly exposed for biomass degradation. Unless measures are taken by the concerned institutions the whole ecological system can be exposed for more environmental challenge and danger.
 - Degradation of biomass can be minimized mainly through awareness developing among the communities their participation.
 - Conservation of soil, water and vegetation needs especial attention by all concerned groups.
 - Areas identified for priority of conservation in this study really need special attention by all concerned groups.
 - Multi-temporal remotely sensed data with medium and higher resolution can be more informative for such and similar study. Therefore within a year time different seasonal or decadal data can be more relevant.
 - Shortage of time, limitations of resources especially that of finance and data have determined the scope of the study to focus only on the biomass and scale of map to be medium.
 - Since the core sources of biomass degradation are identified, it is possible for further studies in larger scale, more detailed approaches and diversified approaches including the socio-economic activities.
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