The Federal Democratic Republic of Ethiopia

Regional State of Tigray Bureau of Water Resource Development

Ruba Chemit Pump Irrigation Project

Watershed Management Study Final Feasibility Report

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Executive summary

The overall objective of the watershed management study is to ensure efficient utilization of land for sustainable socio-economic development and to promote sustainability of natural resources.

Our region Tigrai has encountered an excessive natural resource depletion and hence land degradation which has caused very severe erosion process for a long period of time which resulted in higher reduction of soil fertility and hence higher reduction in agricultural productivity, and together with backward agricultural production system and many other reasons, these have been the main sources of food insecurity and poverty.

Similarly, the natural resources of this particular study area are clearly seen excessively depleted where especially the natural vegetation have been extremely destructed, as a result of the long period deforestation activity and expansion of agricultural practice, as a factor of the over increasing growth of population; both human and livestock, there is very limited and declining tree or bush cover and there is very limited area of grassland, rather very large area of the study area is presently under extensive cultivation and where even steep slope areas have been also put under cultivation.

As a result the land degradation has been aggravated from time to time, which has greatly affected the overall agricultural productivity. Generally the land degradation process has resulted in ecological imbalance and economic insecurity.

Hence, the need for proper planning, implementation, and development of watershed management aiming at the protection of the process of soil erosion and land degradation and hence improvement of soil fertility and land productivity is very crucial.

This particular study area, Ruba Chemit is found in Tigray region, Central zone, Werie Leke wereda and within the Tabia of Adi Hedem. It has a total area of 130.95 km^2 (13,095 ha). The study area is largely characterized by plain and gently sloping (51.4%), and considerably with hilly to mountainous (48.6%) land features. And it lies within Dry Weyna Dega agro climatic zone.

The major problems with in this particular study area are erosion as a result of the long time deforestation activity, absence of proper types and required amount of conservation measures, recurrent drought, and shortage of grazing land and hence very serious shortage of feed.

This particular watershed area has three major land use types, namely; cultivated land (75.166%), forests / bush land (23.836%), and miscellaneous land (0.998%) out of the total 130.95 km^2 watershed area.

The development strategy is prepared as per the direction given from the client , where a total area of four times the net command area to be considered as a micro-watershed for soil and water conservation purpose and it is planned one third (1/3) for the command area and two third within the adjacent watershed area. So much so that the net command area for this scheme is 97hectare (0.97km^2) and hence a total of 291 hectare (2.91km^2) micro-watershed is considered for soil and water conservation purpose.

Hence, Based on the soil and water conservation requirement classes different soil and water conservation measures are recommended as a set of integrated physical and biological measures, which includes stone bund, bench terrace, micro basins, check dam, gabion structure, tree planting, area closure and various agronomy practices, with the aim of rehabilitating the degraded environmental condition and increase the overall functionality the aimed pump irrigation project.

1. Introduction

1.1 Project Background

Our country Ethiopia in general and our region in particular have been greatly affected by the burgeoning population growth, both in human and livestock, which has resulted excessive natural resource depletion and hence land degradation. This has caused very severe erosion process for a long period of time which in turn resulted in higher reduction of soil fertility and hence higher reduction in agricultural productivity, together with backward agricultural production system and many other reasons, which have been the main sources of food insecurity and poverty. Presently, the Government of Ethiopia has properly outlined various and broad policies and strategies in order to deter the various problems of land degradation and hence to improve and bring about a rapid change and growth in agricultural productivity aiming at attaining food security and sustaining the overall economic development of our country, among which strengthening natural resource management and community based approaches to watershed management are the key elements, through which very promising changes and growth have been achieved.

With regard to this particular study area, the natural resources in the study area are clearly seen excessively depleted where especially the natural vegetation have been extremely destructed as a result of the expansion of agriculture, cutting of trees for various reasons such as house construction, fuel wood, for making agricultural implements and to fulfill other human needs. Hence, as a result of the long period deforestation activity and expansion of agricultural practice, as a factor of the over increasing growth of population; both human and livestock, there is very limited and declining tree or bush cover and there is very limited area of grassland, rather very large area of the study area is presently under extensive cultivation and where even steep slope areas have been also put under cultivation.

Due to this reason, the area is presently clearly seen highly bare and exposed to the direct action of raindrops.

Far from this, the acceleration of erosion as a result of the long time deforestation, mismanaged use of land and lack of proper types and required amount of conservation measures within the study area, which has aggravated the land degradation from time to time, has greatly affected the overall agricultural productivity. Generally the land degradation process has resulted in ecological imbalance and economic insecurity.

Hence, the need for proper planning, implementation, and development of watershed management aiming at the protection of the process of soil erosion and land degradation and hence improvement of soil fertility and land productivity is very crucial.

This particular study area, Ruba Chemit is found in Tigray region, Central zone, Werie Leke wereda and within the Tabia of Adi Hedem. It is found North West of Edaga Arbi, about 33km through the all weather road leading to Nebelet . It has a total area of 130.95 km^2 (13,095 ha). But the development strategy is prepared as per the direction given from the client, where a total area of four times the net command area to be considered as a micro-watershed for soil and water conservation purpose and it is planned one third (1/3) for the command area and two third within the adjacent watershed area. So much so that the net command area for this scheme is 97hectare (0.97km^2) and hence a total of 291 hectare (2.91km^2) micro-watershed is considered for soil and water conservation purpose.

The study area is largely characterized by plain and gently sloping (51.4%), and considerably with hilly to mountainous (48.6%) land features. It is found within 1719m – 2750m above sea level altitudinal range. It has 776.25mm annual rainfall and the mean minimum temperature is 6.5 ^oc in Dec to 14.6^oc in August and the mean maximum temperature is 23.2^oc in August to 30.1^oc in April, and hence, it is found within the Dry Weyna Dega agro climatic zone.

Based on the assessment of the present land use situation of the study area, three major land use types are identified. These are: cultivated land (75.166%), forests / bush land (23.836%), and miscellaneous land (0.998%). According to the interviews and discussions made with the local people and field observations, the major

problems with in this particular study area are erosion as a result of the long time deforestation activity, absence of proper types and required amount of conservation measures, recurrent drought, and shortage of grazing land and hence very serious shortage of feed.

1.2 Objective of the study

Due to the long period deforestation activity resulted from the over increasing question for land and other human needs as a factor of the population increment, the study area is exposed to the direct action of rain drops, therefore, watershed management study, which has the following main objectives, is very important.

The major objectives of the study are:-

- The study will contribute to the better understanding of soil and water conservation and conservation objectives.
- To rehabilitate the highly degraded environmental condition and hence increase the productivity of the land within the study area through the practice of conservation measure, and increase the overall functionality of the aimed pump irrigation project.

1.3 Justification

Within this watershed area, there is higher land degradation due to the long period deforestation activity, which has resulted from the high question for agricultural land and other human needs such as agricultural implements, wood for constructing houses, fuel wood etc, mismanaged use of land, and lack of proper types and required amount of conservation measures.

The soil erosion process has greatly affected the productivity of the cultivable land there by reducing the fertility of the top soil, and the increased runoff from steep areas, due to the lack of protecting vegetation cover, has created many rills and deep gullies on the lower agricultural lands and grazing lands which reduces their respective area from time to time. Hence, the decrease in the productivity and area of the agricultural and grazing land has great effect on the economic aspect of the society of the local community.

Therefore, watershed management program with the aim of rehabilitating the degraded environmental condition and increase the productivity of the land through the practice of proper conservation measures is very essential.

2. Materials and methods

Materials used during the study are GPS, Topo maps, Spot image, software like Ilwis30, Global Mapper 11and Arc GIS 9.3.

GPS is used to identify the geographical location of the project area and taking readings for the overall land use identification activities.

2.1 Methodology

The major approaches and procedures used during the feasibility study were review of previous documents, field observations, local people and woreda expert discussions, area delineation and over all mapping works, land capability classification, and outlining and designing of the soil and water development strategies in order to undertake the following activities.

2.1.1 Office work

Review of previous studies and reports in the project area is carried out. Area delineation of the study area, determination of drainage order, and slope classification of the watershed area is carried out using Ilwis and ArcGis through the help of DEM30 in order to prepare the base map for field work.

2.1.2 Field Work

Thorough field survey was undertaken in order to assess and collect data on

- the current major land use of the project area,
- Major factors for undertaking the land capability classification process, which includes soil depth, slope class, soil texture, past erosion, surface stoniness, infiltration, and water logging.
- the overall soil erosion and land degradation situation of the study area,
- the types and distribution of Vegetation cover of the study area
- The major problems of the study area through interviews and discussions with the local people in the study area in order to address their view points.
- past conservation efforts made on the study area, and
- Socio-economic conditions of the study area through discussions with local people and woreda experts.

2.1.3 Data compilation, analysis and interpretation

Major lands use types are digitized which are further sub-divided in to their sub-units on the basis of the slope classes with the help of Global Mapper. Furthermore, the mapping works of the major land use types, and their respective sub units are carried out using the Arc GIS 9.3. The identified major land use types are cultivated land, forest/bushes land, and miscellaneous land.

The land capability classification has been carried using the USDA land capability classification method modified to Ethiopian condition to have identified the soil and water conservation requirement class using the Arc GIS 9.3. The land classification process was employed using the two categories in the land classification system. The soil conservation requirement classes (SCRC), represent the major category of the system, which is determined by the most limiting condition permitted in a range of characteristics for each land feature. The other category is the land class unit (LCU), which is the lowest category of the system, and it is determined by the major limiting factor affecting the use of land. The limiting factors could be one or two of the following land features: Slope (L), Soil depth (D), Past erosion (E), Water logging (W), Infiltration (I), Texture (T), and Stoniness. And finally, required types and amount of physical and biological soil and water conservation measures are recommended for each land class unit.

Field survey findings regarding the overall land use, conservation, development opportunities and constraints, and other relevant issues related to the land use system in the project area, results of community and expert level discussions, and secondary data are interpreted and included in the study.

3. General Description of the Watershed Area

3.1 Location

This particular study area, Ruba Chemit is found in Tigray region, Central zone, Werie Leke wereda and within the Tabia of Adi Hedem. It is found South East of Edaga arbi, which is about 33km through the all weather road driving from the town of Edaga arbi leading to Nebelet. The watershed area is found within the range of 14°00′41″ – 14°11′22′′N Latitude and 39°09′43′′ – 39°17′16′′E longitudinal range.

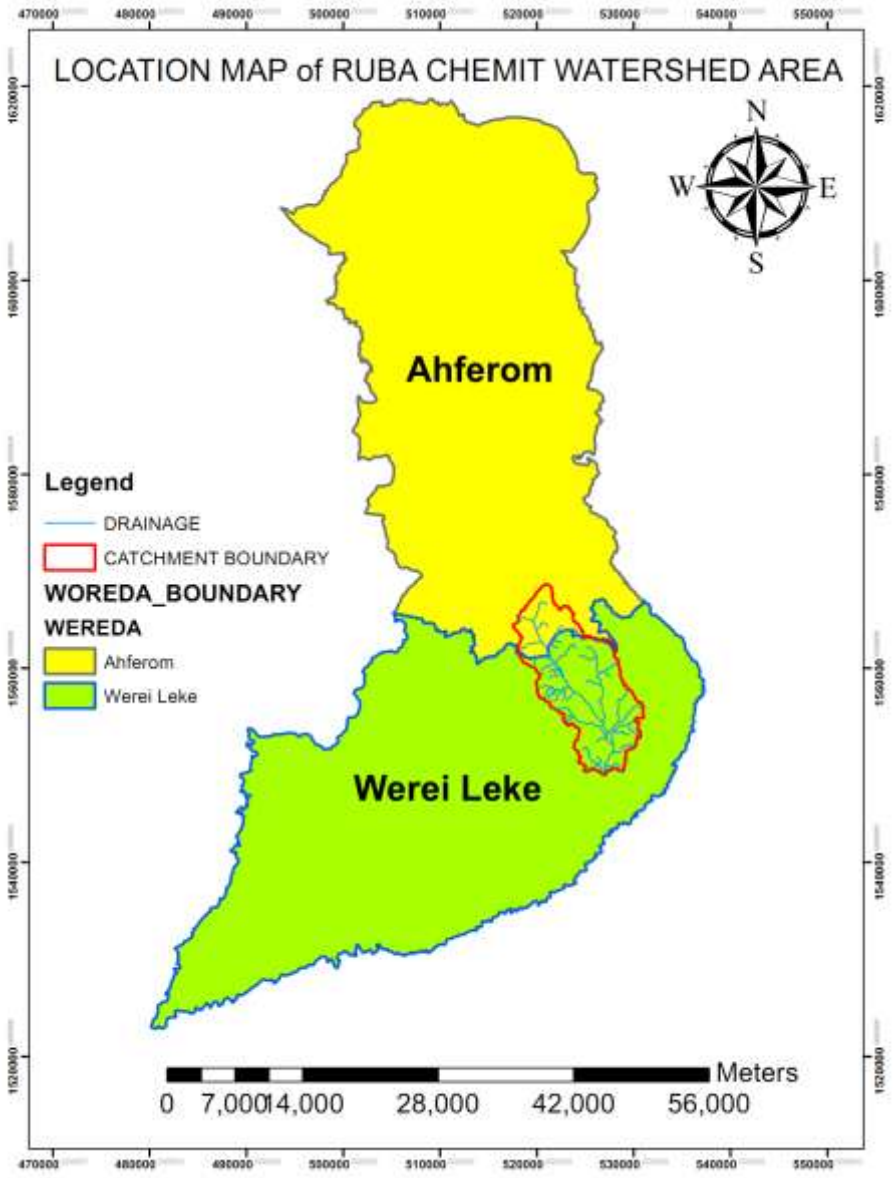

Figure 1 : Location Base Map of the Watershed Area

3.2 Topography

The study area is largely characterized by plain and gently sloping (51.4%), and considerably with hilly to mountainous (48.6%) land features. The plain and gently sloping land has good deep soil and it is presently under extensive cultivation.

The steep land has shallow soil depth and with considerable rock out crops, seen with very scattered bushes or scrubs, and where severe erosion is causing higher land degradation. But the steep slope areas are also put under extensive cultivation which is aggravating from time to time which has resulted from the population pressure in the area. The altitudinal range of the catchments area is 1719m – 2750m above sea level.

Table 1 : Slope Class and Area Proportion of the Watershed Area

S/N	Slope Class	Area in Km^2	Percentage (%)
1	2-8%	38.8911	29.69919817
2	8-15%	28.4206	21.70339824
3	15-30%	37.0186	28.26926308
4	30-50%	14.2929	10.91477663
5	>50%	12.3268	9.413363879
		130.95	100

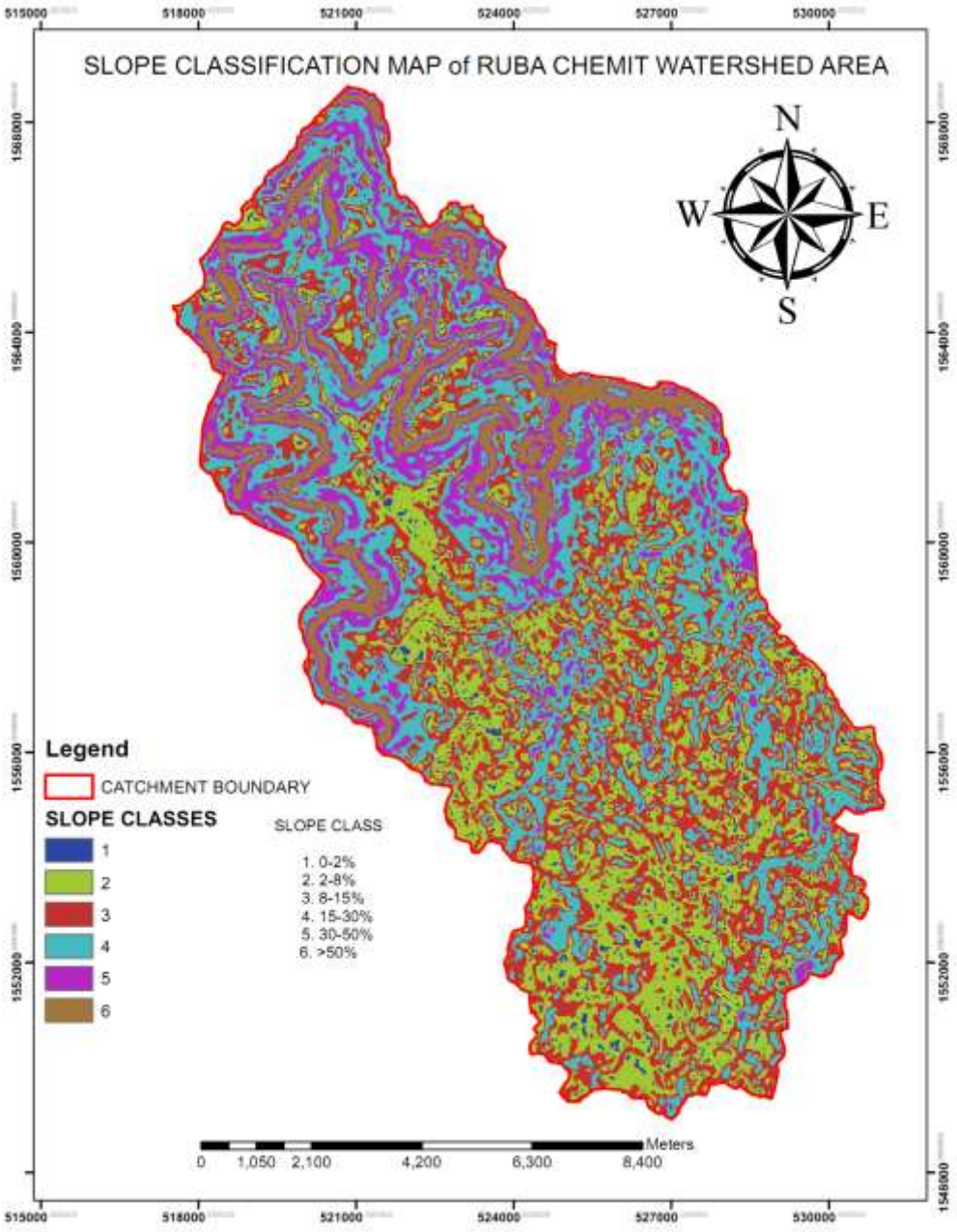

Figure 2 : Slope Class Map of the Watershed Area

3.3 Climate

The mean annual rainfall of the study area is 776.25mm.The mean minimum temperature is 13.3^{o}c in Jan to 16.6^{o}c in November and the mean maximum temperature is 27.6^{o}c in August to 35.3^{o}c in April. The rainfall data is taken from Edaga-arbi Metrological station, while the temperature data is derived using New_LocClim 1.10. Hence, based on the data described above, the agro climatic zone of this particular study area is within Dry Weyna Dega agro climatic zone.

3.4 Soil

The soil type of the catchment area is clearly seen varying in the texture, depth, and color, which differs with in a piece of land of the same land use and slope range.

Relatively good soil depth observed on the plain and gentle slope land feature, which is under extensive cultivation practice. The steep land feature which is also considerably under extensive cultivation practice is seen with very scattered bushes or scrubs, has shallow soil depth.

The soil texture in determined by making different shapes of a moisten soil from the different land use types. The dominant soil textures in the study area are silt loam and loamy sand, and considerably loam, light clay, and clay loam soils. Detail information about soil type with respect to the major land use types and their respective sub units is presented in table-5.

3.5 Vegetation

With regard to vegetation cover this particular study area is seen with very scattered trees/bushes or scrubs in which the high forests are destructed for a long period of time even if there is scattered to good vegetation cover in some locations especially in the upper part of the watershed area. Even these remaining bushes or scrubs are presently under exploitation for many reasons. Small patches of ruminants of high forest trees are also seen within and around church compounds. There also scattered to good vegetation cover in some locations within the cultivated land.

The major tree species found within the watershed area includes, Acacia etbaica, Acacia tortilis, Acacia seyal, Acacia, sieberiana, Balanites aegyptiaca, Rumex nervosus, Capparis micrantha, Euclea schimperi, Dichrostachys cinearea, Dodonia angustifolia, , Carrisa edulis, Cassia singueanea, Aconkanthera shimperi, Combretum molle, , Euphorbia abyssinica, Ficus sycomorous, Grewia bicolor, Maytenus senegalensis, Boscia salicifolia, Faidherbia albida, ziziphus spina-christi, Embelia schmperi, Ormocurpum pubescens, Syzygium guineense, buddleja polystachysAgave sisalanaand remenants of Cordia Africana, and Olea europea var Africana, whereas, the vast cultivated land is clearly seen bare with almost no tree cover.

Far from this, As a result of the long period over grazing activity and due to the pressure from the higher expansion of the agricultural practice, there is no grass land area in which there is imbalance in the number of livestock to graze and the availability of feed and hence it has become a source of additional pressure on the tree feed source. The forest land constitute 23.836% of the total catchment area.

4. Socio- economic conditions of the Watershed Area

The total human population number found within the watershed area (project area), which is living within tabia Adi Hedem, is 5,268 out of which 2,579 representing 48.96% of the total population are male and the rest 2,689 are female representing 51.04% of the total population.

There are 1,006 household leaders with in the tabia out of which 355 are female headed households and the rest 651 are male headed households. Hence, in accordance to the ratio of the total population and the existing household leaders the average family size of the study area is 5.24.

With regard to the existing labor availability within the project area, with a total of 5,268 population, 2,654 persons are said to be active man power representing 50.38% of the total population indicating a dependency ratio of around 1:1.98 where about two persons are dependent on one active man/women.

The livelihood of most of the farmers of the study area is mainly dependent on agriculture i.e. they rely on both crop production and animal rearing (Livestock production). Agriculture is conducted by small scale farmers and is largely subsistent oriented. By and large, the farming system is manual agriculture with few or no inputs used. The major crops grown in the study area are **Teff,** Sorghum, and maize.

Table 2 : Active Man Power Within the Watershed Area

Tabia Name	Availability of Man Power		
	Population	**Man Power**	**Man Power in %**
Adi Hedem	5268	2654	0.5038
Azmera	3873	1903	0.49135
Arena	6340	3197	0.50426
Seguh	8151	4080	0.50055
Tseftsef	4175	2097	0.50228
Total	**27807**	**13931**	**0.50099**

5. Present land use situation

As per as the present land use situation of the study area is considered, three major land use types are identified. These are: cultivated land, forests / bush land, and miscellaneous land.

Out of the identified land use types the cultivated land constitutes 75.166%, the forest land constitutes 23.836%, and the miscellaneous land which includes homesteads, dam reservoir, and rock out crop covers 0.998% out of the total watershed area.

Table 3: Present Land Use Situation of The Study Area

S/N	Major land use type	Total area in Km^2	Area in prop %	Remark
1	Cultivated land	98.43	75.16609393	
2	Forest / bush land	31.2137	23.83634975	includes bushes, plantation & other natural vegetation areas
3	Miscellaneous	1.3063	0.997556319	
	Grand Total	130.95	100	

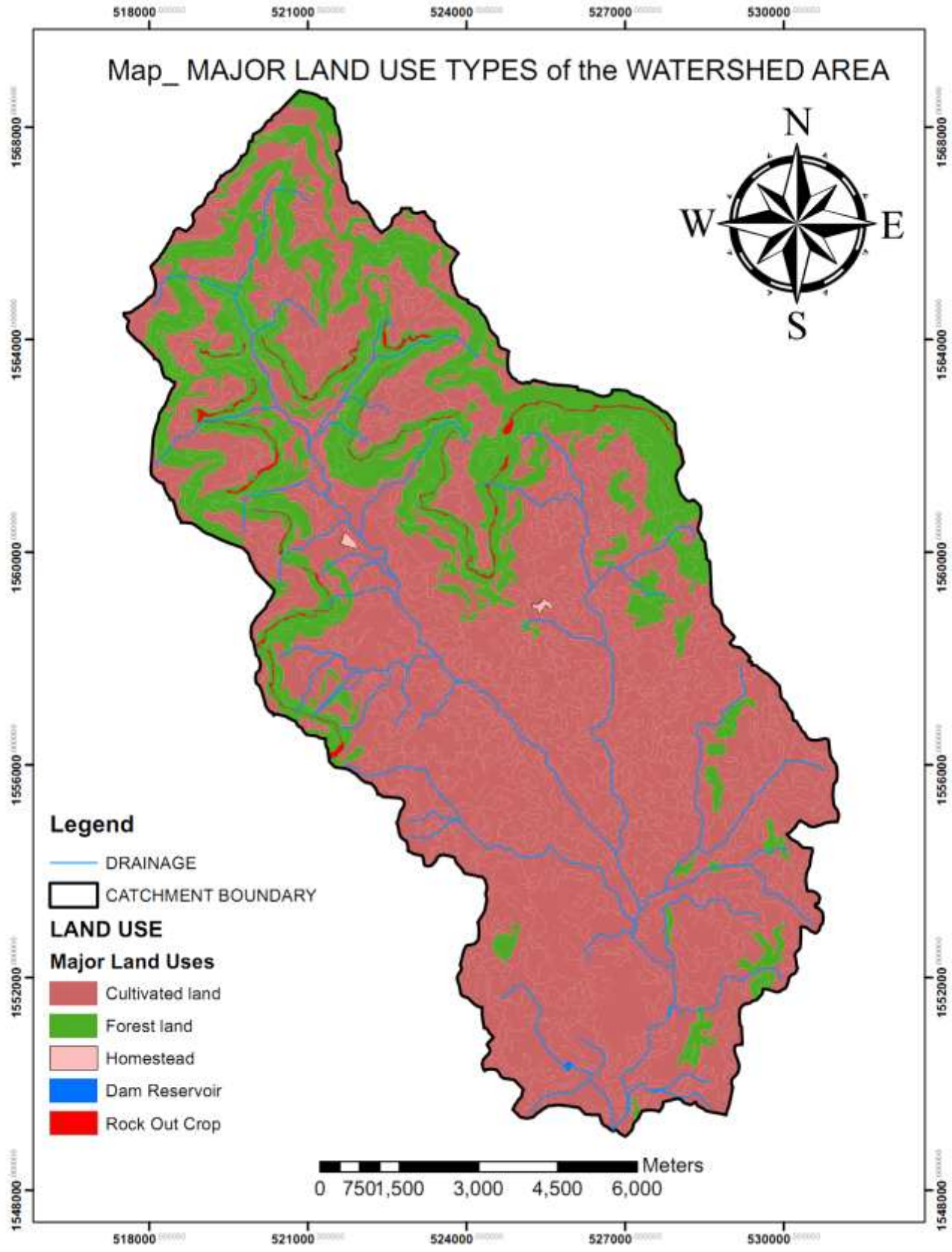

Figure 3 : Present Major Land Use Types of the Watershed Area

6. Sub – units of major land use types

The above major land use types are further sub divided into different sub-units on the basis of definite slope classes.

The following table shows the different sub-units of the identified major land use types within the catchments area.

Table 4 : Sub Units of The Major Land Use Types of The Study Area

S/N	Land Use Type	Sub Unit	Slope in %	Area in Km^2	% Proportion out of total Area
1	**Cultivated Land**	CL2	2-8%	**38.63**	29.49980909
		CL3	8-15%	**28.0908**	21.45154639
		CL4	15-30%	**30.4586**	23.25971745
		CL5	30-50%	**1.2506**	0.955021
	TOTAL AREA			**98.43**	**75.16609393**
2	**Forest Land**	FL2	2-8%	**0.1357**	0.103627339
		FL3	8-15%	**0.3298**	0.251851852
		FL4	15-30%	**6.56**	5.009545628
		FL5	30-50%	**13.0423**	9.959755632
		FL6	>50%	**11.1459**	8.511569301
	TOTAL AREA			**31.2137**	**23.83634975**
3	**Miscellaneous**	Homestead		**0.1024**	0.078197785
		Dam Reservoir		**0.023**	0.017563956
		Rock out crop		**1.1809**	0.901794578
	TOTAL AREA			**1.3063**	**0.997556319**
	GRAND TOTAL AREA			**130.95**	**100**

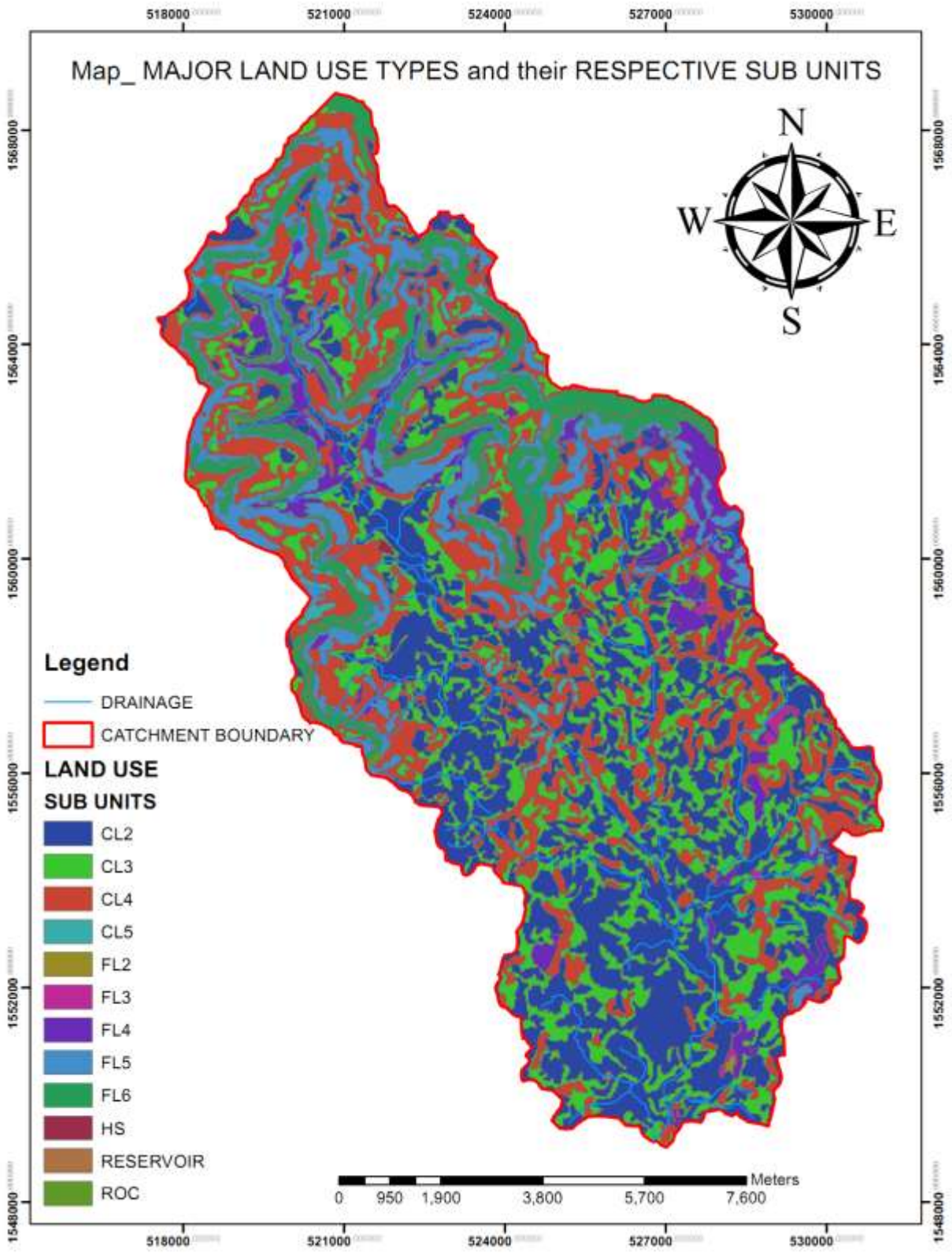

Figure 4 : Major Land Use Types and their Sub Units Map of the Watershed Area

Table 5 : Major Land Use Types, and Their Respective Sub units and Soil Types

S/N	Land Use Type	Sub Unit	Area in Km^2	Slope in %	Soil Texture
1	Cultivated Land	CL2	5.8041	2-8%	clay loam
		CL2	2.923	2-8%	light clay
		CL2	1.9722	2-8%	loam
		CL2	10.8873	2-8%	loamy sand
		CL2	17.0434	2-8%	silt loam
		CL3	2.5171	8-15%	clay loam
		CL3	3.0801	8-15%	light clay
		CL3	2.1577	8-15%	loam
		CL3	6.658	8-15%	loamy sand
		CL3	13.6779	8-15%	silt loam
		CL4	0.467	15-30%	clay loam
		CL4	3.3056	15-30%	light clay
		CL4	4.0865	15-30%	loam
		CL4	9.6131	15-30%	loamy sand
		CL4	12.9864	15-30%	silt loam
		CL5	0.0608	30-50%	light clay
		CL5	0.2688	30-50%	loam
		CL5	0.4007	30-50%	loamy sand
		CL5	0.5203	30-50%	silt loam
2	Forest Land	FL2	0.0356	2-8%	light clay
		FL2	0.058	2-8%	loamy sand
		FL2	0.0421	2-8%	silt loam
		FL3	0.0636	2-8%	light clay
		FL3	0.2662	2-8%	silt loam
		FL4	0.069	15-30%	clay loam
		FL4	0.7821	15-30%	light clay
		FL4	0.6377	15-30%	loam
		FL4	2.731	15-30%	loamy sand
		FL4	2.3402	15-30%	silt loam
		FL5	2.1749	30-50%	light clay
		FL5	2.6316	30-50%	loam
		FL5	5.7788	30-50%	loamy sand
		FL5	2.457	30-50%	silt loam
		FL6	1.5659	>50%	light clay
		FL6	2.6277	>50%	loam
		FL6	4.8048	>50%	loamy sand
		FL6	2.1475	>50%	silt loam
3	Miscellaneous		1.3063		
	TOTAL AREA		**130.95**		

7. Determination of Runoff Coefficient

Based on the assessment of the major land use types, slope and soil type of each of the sub units, the determined runoff coefficient is summarized in the following table.

Table 6 : Determination of runoff coefficient

S/N	Land Use Type	Sub Unit	Area in Km²	Slope in %	Soil Texture	C (Runoff Coefficient)	Weighted C
1	**Cultivated Land**	CL2	5.8041	2-8%	clay loam	0.3	0.013430888
		CL2	2.923	2-8%	light clay	0.3	0.006763923
		CL2	1.9722	2-8%	loam	0.3	0.004563739
		CL2	10.8873	2-8%	loamy sand	0.25	0.020994657
		CL2	17.0434	2-8%	silt loam	0.25	0.032865847
		CL3	2.5171	8-15%	clay loam	0.35	0.006795432
		CL3	3.0801	8-15%	light clay	0.35	0.008315367
		CL3	2.1577	8-15%	loam	0.35	0.005825158
		CL3	6.658	8-15%	loamy sand	0.3	0.015406842
		CL3	13.6779	8-15%	silt loam	0.3	0.031651133
		CL4	0.467	15-30%	clay loam	0.4	0.001440872
		CL4	3.3056	15-30%	light clay	0.4	0.01019903
		CL4	4.0865	15-30%	loam	0.4	0.012608403
		CL4	9.6131	15-30%	loamy sand	0.35	0.025952553
		CL4	12.9864	15-30%	silt loam	0.35	0.035059475
		CL5	0.0608	30-50%	light clay	0.45	0.00021104
		CL5	0.2688	30-50%	loam	0.45	0.000933019
		CL5	0.4007	30-50%	loamy sand	0.4	0.001236312
		CL5	0.5203	30-50%	silt loam	0.4	0.001605323
2	**Forest Land**	FL2	0.0356	2-8%	light clay	0.25	6.86497E-05
		FL2	0.058	2-8%	loamy sand	0.2	8.9476E-05
		FL2	0.0421	2-8%	silt loam	0.2	6.49472E-05
		FL3	0.0636	2-8%	light clay	0.3	0.000147173
		FL3	0.2662	2-8%	silt loam	0.25	0.00051333
		FL4	0.069	15-30%	clay loam	0.35	0.00018628
		FL4	0.7821	15-30%	light clay	0.35	0.002111441
		FL4	0.6377	15-30%	loam	0.35	0.001721603
		FL4	2.731	15-30%	loamy sand	0.3	0.006319628
		FL4	2.3402	15-30%	silt loam	0.3	0.005415304
		FL5	2.1749	30-50%	light clay	0.4	0.006710392
		FL5	2.6316	30-50%	loam	0.4	0.008119484
		FL5	5.7788	30-50%	loamy sand	0.35	0.015601067
		FL5	2.457	30-50%	silt loam	0.35	0.00663318
		FL6	1.5659	>50%	light clay	0.45	0.00543532
		FL6	2.6277	>50%	loam	0.45	0.009120883
		FL6	4.8048	>50%	loamy sand	0.4	0.014824631
		FL6	2.1475	>50%	silt loam	0.4	0.006625852
3	**Miscellaneous**		1.3063				
	TOTAL AREA		**130.95**				**0.325567652**

Table 7 : Main River With its Elevation Difference

Main River Length and Elevation at Main Reaches

Length (m)	Altitude (m a.s.l)
0+00	1719
0+1787	1750
0+6840	1800
0+9658	1850
0+10571	1900
0+14126	1950
0+17157	2000
0+19002	2050
0+20213	2100
0+21261	2150
0+21422	2200
0+22978	2250
0+23689	2300
0+24018	2350
0+24139	2400
0+24657	2450
0+24808	2500
0+24975	2550
0+25214	2600
0+25389	2650
0+25479	2700
0+25565	2750

8. Past Conservation Efforts made in the Watershed Area

It is very clearly known that vast, popular and model soil and water conservation activities have been executed by the Government of the National Regional State of Tigray. With regard to this particular study area, generally, the carried out soil and water conservation activities are unsatisfactory, where large part of the study area, especially the vast cultivated land, is clearly seen with no or negligible conservation measures and in the areas where some conservation measures are carried out there are technical problems of implementation and lack of maintenance and hence as a result part of the conservation measures are seen collapsed and/or overtopped.

There are also few areas which has good soil and water conservation activities. There are different types of soil and water conservation activities carried out within the watershed area. Some of the conservation measures that have been carried out within the watershed include hill side terrace, soil bund, stone bund, gabion, and stone check dam.

Large part of the hillside terraces constructed at the forest areas of the watershed area is not properly spaced and some part of the terraces are seen collapsed. At the limited part of the vast cultivated land there are trials of soil and stone bunds which have technical problems in spacing and size of the bunds in that they do not have proper width and height, and moreover due to human and livestock interferences they are seen collapsed and left with no maintenance work. Moreover, the cultivated lands in the steep slope areas are seen treated with technically poorly constructed hillside terraces which should be rather bench terraces which can properly support the cultivation practice besides to the conservation objective.

Most of the gullies found in the watershed are not treated. There are few loose check dams constructed in the gullies. But these have also very clear technical problems during construction. Particularly, the structures have no key to both sides of the gully. There are also some check dams which are overtopped being filled with silt.

Moreover, higher emphasis has been given to physical soil and water conservation measures. Regarding to biological conservation measure, there are no clear considerably successful works seen at the watershed area.

Generally, the watershed area is not well treated with proper types and required amounts of both physical and biological soil and water conservation measures which is aggravating the soil erosion and land degradation process. Therefore, due attention must be given to reduce and mitigate these problems and hence to improve the fertility and productivity of the watershed area through the implementation of the proposed conservation measures.

9. Major problems of the watershed area

Interviews and discussions are made with the local people to collected data on major problems in the study area to obtain the community major viewpoints in addition to the field observations.

The major problems with in this particular study area are erosion as a result of the long time deforestation activity, absence of proper types and required amount of conservation measures, recurrent drought, and higher shortage of grazing land and hence very serious shortage of feed source.

Within this particular study area there has been practiced the process of deforestation activity by the local people for a long of time, which has left the area bare and exposed to the direct action of rain drops, due to the main reason of the question for agricultural land as per the over increasing population growth with in this area, presently, it is only seen with scattered bushes or scrubs with in a limited area which cannot prevent the land degradation process satisfactorily.

In addition to the deforested and bare conditions the area is not treated with effective type and amount of conservation measures, which has aggravated the land degradation. And hence, generally the above conditions have resulted in excessive erosion process.

Hence, due to the severe erosion and high land degradation resulting in low fertility and productivity together with the erratic distribution of rainfall in the area recurrent drought has been prevailing widely.

Far from this, As a result of the long period over grazing activity and due to the pressure from the higher expansion of the agricultural practice, there is no grass land area, in which there is imbalance in the number of livestock to graze and the availability of feed which is highly affecting the overall livestock production due to serious shortage of feed source and hence it has become a source of additional pressure on the tree feed source moreover there are no alternative feed source introduced to the local community which can substitute the scarce grass resource.

10. Land Capability Classification

Land classification is a main tool enabling the diagnosis of main problems affecting the land and providing guidance for identifying sustainable range of rational uses of natural resources as well as productive conservation technologies. The land classification is an interpretative system, the purpose of which is to group and classify areas of land with the same capability to support sustained agriculture without resulting in land degradation.

The Land classification is primarily meant for soil conservation purposes and it is done mainly on the basis of limitations in relation to water erosion. The limiting factors could be one or two of the following land features: Slope (L), Soil Depth (D), Past erosion (E), Water logging (W), Infiltration(I), Soil texture(T) and Stoniness(S).

Hence, based on this the land capability classification process is properly carried out and the overall information is presented in a table and represented with a map.

Table 8 : Land Capability Classification for the Micro-Watershed Area

Cultivated land	**98.43**
CL2	**38.63**
IIIE	38.63
CL3	**28.0908**
IIILE	28.0908
CL4	**30.4586**
IVDE	6.8486
IVLE	23.61
CL5	**1.2506**
VIIDE	0.4905
VLD	0.7601
Forest land	**31.2137**
FL2	**0.1357**
IVD	0.0356
IVDE	0.058
VID	0.0421
FL3	**0.3298**
VID	0.3298
FL4	**6.56**
IVDE	2.8421
VIIDE	3.7179
FL5	**13.0423**
VIIDE	8.9815
VIIIDE	4.0608
FL6	**11.1459**
VIIDE	2.6504
VIIIDE	8.4955
Homestead	**0.1024**
HS	**0.1024**
RESERVIOUR	**0.023**
RES	0.023
Rock	**1.1809**
ROC	**1.1809**
Grand Total	**130.95**

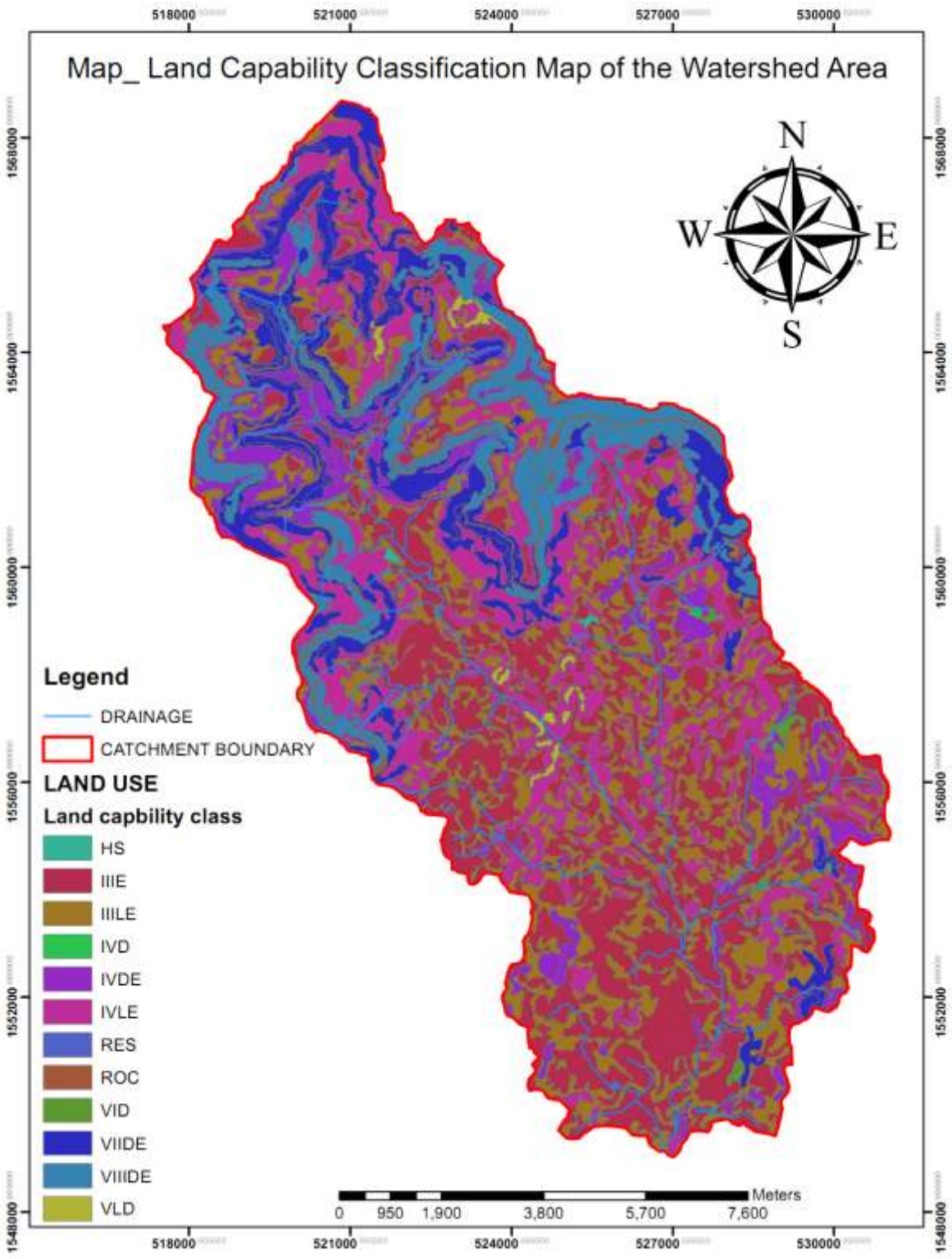

Figure 5 : Land Capability Classification Map of the Watershed Area

Table 9 : Land Capability Classification for the Micro-Watershed Area

1	**Command Area**	**Cultivated and**	**0.97**
		CL2	**0.78**
		IIIE	0.78
		CL3	**0.19**
		IIILE	0.24
2	**Watershed Area**	**Cultivated and**	**2.5222**
		CL3	**1.8686**
		IIILE	1.781
		CL4	**0.6536**
		IVDE	0.2522
		IVLE	0.279
		Forest land	**0.3878**
		FL2	**0.0421**
		VID	0.0421
		FL3	**0.0732**
		VID	0.0732
		FL4	**0.2725**
		IVDE	0.0399
		VIIDE	0.2326
	Grand Total		**3.88**

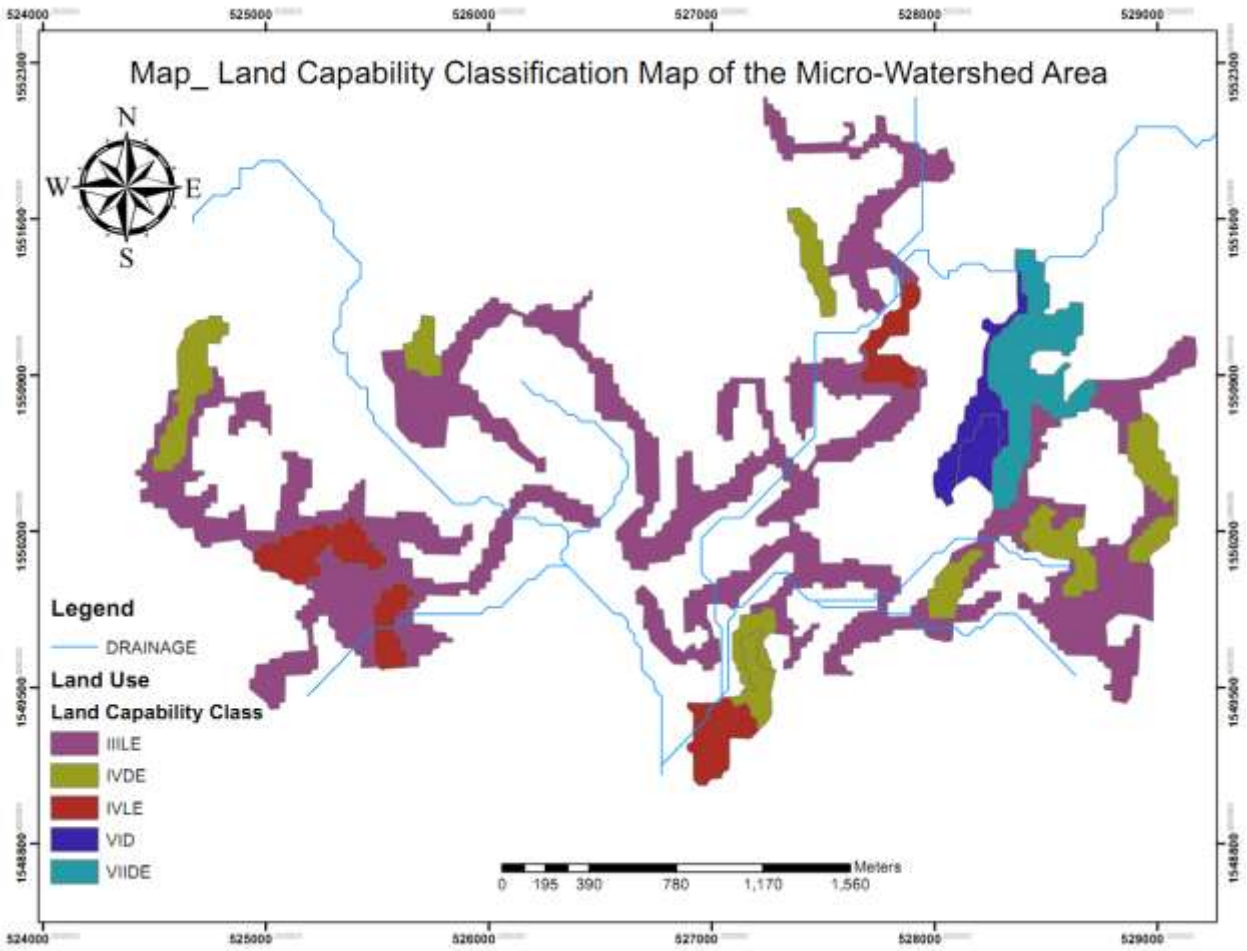

Figure 6 : Land Capability Classification Map for Soil and Water Conservation

11. Soil Loss Estimation of the Watershed Area

The universal soil loss equation (USLE) is used to compute the total average annual soil loss from sheet and rill erosion within a particular watershed. The USLE is a complex method for effective use to determine soil loss in all countries but based upon soil and water conservation research plots data, a modified universal soil loss Equation (USLE) was adopted to Ethiopian condition by Hurni (1985).

Parameter of the USLE can be easily estimated was simple field data. The equation was estimated parameter I. The six parameters of the USLE are estimated for each land mapping unit within the watershed using the land resources data's an input. This equation was validated by comparison was the plot measurement in Ethiopia and showed a high correlation of 0.90, explaining 80% of the measured simple Hurni, 1986). Soil erodibility, slope length, average slope, land use /covered and management factors have to be determined for each mapping unit. The estimate yields average annual soil loss as per mapping unit. Thus, the total sum of soil loss from all mapping units within watershed estimate the total soil loss from a given watershed.

The weighted annual soil loss from each land unit for the watershed of was computed using the USLE adapted to Ethiopia using the field data of the six factors through the outlined methodologies.

The weighted annual soil loss computed for the Ruba Chemit watershed area, excluding the miscellaneous land is 36.66tone/ha/year. Hence based on the (Hurni and Perich, 1992), the soil loss range of a normal and protected watershed has a tolerable soil loss range of 5-11 tone/ha/year. As per the soil loss condition from this specific watershed area it highly exceeds the tolerable range of soil loss of a protected catchment.

Hence, the need for proper planning, implementation, and development of the recommended watershed management activities aiming at the protection of the process of soil erosion and land degradation and hence improvement of soil fertility and land productivity is very crucial.

The numerical values and factors used in the USLE adopted to Ethiopian conditions are:

Equation A = R*K*L*S*C*P (Tone/ha/year)

R = Rain fall erosivity

Annual rainfall (mm)	100	200	400	800	1200	1600	2000
Annual factor R	48	104	217	441	666	890	1115

K = Soil erodability

Soil color	Black	Brown	Red	Yellow
Factor k	0.15	0.2	0.25	0.3

L = Slope length

Length (m)	5	10	20	40	80	160	240	320
Factor L	0.5	0.7	1	1.4	1.9	2.7	3.2	3.8

S = Slope gradient

Slope (%)	5	10	15	20	30	40	50	60
Factor S	0.4	1	1.6	2.2	3	3.8	4.3	4.8

C = Land cover

Dense forest	0.001	Degraded grass	0 .05	Bad land hard	0.05
Other forests see grasses		Dense grass	0.01	Bad land soft	0.4
Fallow hard	0.05	Sorghum, maize	0.01	Ethiopia teff	0.25
Fallow ploughed	0.6	Cereals, pulses	0.15	Continuous fallow	1

P = Management factors

Plough up and down	1	Stripe cropping	0.8	Applying mulch	0.6
Stone cover 80%	0.5	Plough on contour	0.9	Stone cover 40%	0.8
Inter cropping	0.8	Dense inter cropping	0.7		

Source: Wischmeier and Smith, 1978

Adoptions: R correction, Hurni, 1985

K value from bono and seiler, 1983, 1984; and Welgal, 1985

Table 10: Weighted Annual Soil Loss of the Watershed Area

S/N	Major Land Use	Sub Unit	Area in Ha	Ave. Dom Slope %	Rainfall erosivity-R	Soil erodibility-K	Slope length-L	Slope gradient_S	Land cover-C	Land Mgt factor-P	Erosion Rate (tonnes/ha/year	Total Soil Loss (tonnes/ha/year)
1	Cultivated Land	Cl2	3863	5	428	0.25	3.2	0.4	0.15	0.9	18.4896	71425.3248
		Cl3	2809.08	12	428	0.25	2.7	1.2	0.15	0.9	46.8018	131470.0003
		Cl4	3045.86	22	428	0.2	1.9	2.42	0.15	0.9	53.134488	161840.2116
		Cl5	125.06	40	428	0.2	1.9	3.8	0.15	0.9	83.43432	10434.29606
2	Forest Land	Fl2	13.57	5	428	0.25	1.9	0.4	0.05	0.8	3.2528	44.140496
		Fl3	32.98	12	428	0.25	1.9	1.2	0.05	0.8	9.7584	321.832032
		Fl4	656	22	428	0.25	1.4	2.42	0.05	0.8	14.50064	9512.41984
		Fl5	1304.23	40	428	0.2	2.4	3.8	0.05	0.8	31.22688	40727.0337
		Fl6	1114.59	70	428	0.2	2.7	4.8	0.05	0.8	44.37504	49459.97583
	TOTAL		**12964.37**									475235.2347
											Average Weighted Soil Loss	**36.65702496**

12.Development Strategy

The development strategy is prepared as per the direction given from the client , where a total area of four times the net command area to be considered for soil and water conservation purpose and the development strategy should be prepared one third (1/3) for the command area and two third within the watershed area . So much so that the net command area for this scheme is 97hectare (0.97km^2) and hence a total of 388 hectare (3.88km^2) is considered for soil and water conservation purpose, where in this case, 129.33ha in the command area and 258.67ha in the upper watershed area must have been considered, but since there is 97ha net command area the remaining 32.33ha is included to the watershed area, hence 291ha of it is considered.

Depending on the agro climatic zone, local situation (slope and soil range), land class unit and upon additional field experience the following physical and biological soil and water conservation measures are proposed for each major land use types with respect to their definite land class units.

12.1. Description and Technical Specification of the Recommended Conservation Measures

As a result of the long time deforestation and hence high expansion of cultivation together with mismanagement of land, the watershed area clearly seen highly exposed to severe soil erosion. Hence, implementation of proper types and amount of soil and water conservation measures is unquestionable in order to minimize the soil erosion and land degradation process in the watershed area.

Soil and water conservation in its wider significance includes soil fertility and moisture management, as well as runoff and erosion control through an entire set of integrated physical and biological measures. Besides, soil and water conservation is mostly water harvesting based if arid and semi arid areas are considered.

This particular watershed area has three major land use types, namely; Cultivated land, Forest land, and Miscellaneous land. Based on the soil and water conservation requirement classes different soil and water conservation measures are recommended

as a set of integrated physical and biological measures which are specifically described as follows.

1. Physical soil and water conservation

The physical soil and water conservation measures have the prime purpose of controlling runoff velocity and erosion.

These measures are meant to make the best use of available rainfall, relaying on the fact that the amount of water and nutrients loss by surface runoff is a main limiting factor in the overall production activity. These conservation measures help to divide the natural length of the slope in to shorter sections which limits the volume and velocity of runoff that each structure must contain. The reduction of slope length reduces the chance of runoff gathering into constricted flow lines and so reduces the probability of rills and gullies forming.

Stone bund

A stone bund is an embankment made of stone constructed along the contours(points of the same elevation) across sloping lands, without a collection channel or basin at its upper side. Soil which is eroded between two bands is deposited behind the lower band. Stone bunds are either impermeable structure if their upstream side is sealed with soil or semi permeable if not. Whenever the bund has trapped enough sediment, the bund should be raised. In this way, a bench terrace will develop in the course of years. The main function of stone bund is to reduce the velocity of runoff and hence reduces the soil erosion process.

The stone bunds should have a bottom width of 1-1.5meter, a top width of 30-50cm and a height of 50-75cm. Care should be taken in the selection of stones, their placing and provision of a stable foundation. A layer of soil should be placed on the top and upper side of the bund which will reduce the flow of runoff through the bund and encourage the growth of grass.

Bench Terraces

Bench terraces are conservation structures along the contours, where a slope is converted into a series of level or nearly level steps or benches. Maximum control of

runoff and erosion can be achieved when an entire hill slope is terraced and cropped. They are used mainly to support the growth of perennial crops or highly valuable crops.

Bench terraces are level along the contour in dry to moist agro-climatic zones, whereas in moist to wet agro-climatic zones, they are graded to drain excess runoff sideways to the next river or waterway. Bench terraces must be spaced with a vertical interval of two and a half times (2.5) the depth of the reworkable soil. The width of cultivated area on a bench terrace is determined by the slope gradient and the soil depth. Bench terraces are constructed by cutting and filling as well as riser stabilization with grass or stones.

Micro-basin

A micro basin is a small structure with the shape of half or a full circle, excavated to obtain a small basin for planting a tree. Micro-basins have sizes according to their designation to conserve water, being small in moist (1m diameter) and large in dry (2m diameter) agro-climatic zones.

Check Dam

A check dam is an obstruction wall across the bottom of a gully or a small river, which reduces the velocity of runoff and prevents the deepening and widening of the gully. Excess runoff move to the next structure downstream through a spill way.

Sediments are deposited behind the check dams so that the slope gradient of the gully is also reduced.

The vertical interval between check dams is equal to the height of a check dam. The check dams should be extended at least up to one meter (1m) inside the gully sides. Check dams should be constructed with a minimum base width of one meter (1m) and should have an apron at least 50 centimeter wider on both sides of spillway fall and length towards water flow of minimum one meter (1m).

Gabion Check dam

A gabion check dam is an obstruction wall across the bottom of a gully or a small river which consists of galvanized iron steel wire cages, usually 2m*1m*1m size, filled with loose rocks/stones. The cages are placed close together and tightly tied with wire. Gabion check dams require stable soils or sub soils for proper anchorage. Gabion check dam reduces the velocity of runoff and prevents the deepening and widening of the gully. Excess runoff move to the next structure downstream through a spillway. Sediments are deposited behind the gabion check dams so that the slope gradient of the gully is also reduced.

A good gabion check dam should have a proper key, an adequate spillway, and an apron. An apron extending 1.5-2m times the spillway height is necessary and should have an apron at least 50 centimeter wider on both sides of spillway fall. A key trench, 1m deep and as wide as the width of the dam should be dug in the underlying soil. The key trench should extend at least 1m into the abutment wall, right up to the height of the dam.

The vertical interval between gabion check dams is equal to the height of the dam. The gabio check dams should be extended (Key) at least up to one meter (1m) inside the gully sides. Gabion check dams should be constructed with a minimum base width of two meter (2m).

2. Biological soil and water conservation measures

Tree Planting

Tree planting for soil conservation is an activity to improve the vegetative cover of the ground, thereby reducing runoff and soil erosion and producing wood products (fuel wood, construction wood, etc). Tree planting supports many other conservation activities if combined with them. Tree planting by itself is a soil conservation measure because the tree roots stabilize the soil and the tree protects the ground from direct impact of rain drops. On the other hand trees improve infiltration, provide mulch and organic matter, recycle nutrients and provide high protein animal feed.

For a better implementation of tree planting, pits should be properly prepared with a width of 25-45cm and a depth of 40cm and they have to be kept open for 3-12 months before planting in order to support soil formation around them. Care has to be given for species selection that seedlings must be raised in accordance to the specific agro-climatic zones and tree species which can bring additional income to the farmers should have to be given the priority. Transport of tree seedlings must be very careful and they must be transported in boxes or tins. After plantation trees must be protected from weed competition and insect damage, and the planting site must be protected from any human and livestock interference.

The tree planting activity will be undertaken on the cultivated land, forest land, and along the sides of the gullies and roads.

12.2. Recommended Conservation Measures

Cultivated land

The cultivated land as a major land use type to be considered has a total area of 349.22ha, where the command area comprises 97ha and the rest 252.22ha is within the watershed area.

Depending on the general condition of the land class units the following conservation measures are proposed.

A. Command Area

1 Cultivated Land Use two (CL2)

1.1. Land Class Unit IIIE

This land class unit has a total area of 78ha and an average dominant slope of 5%. The land class unit is mainly characterized by dominantly silt loam soil, a soil depth of largely >150cm, slight past erosion, good infiltration, largely slightly stony, and with no water logging conditions. It is classified under soil requirement class III, having slight past erosion as the major limiting factor.

Recommended Conservation Measures

A. Physical Conservation Measure: Stone Bund

B. Biological Conservation Measure: Tree Planting

C. Agronomy Practices (Measure)

Stone Bund

Total area = 78ha

Average slope = 5%

Vertical interval = 1m

Horizontal interval = 20m

Proposed measure = stone bund

Hence, stone bund per hectare = 5x100m=500m/ha

Total length of stone bund = 78ha x 500m/ha

= 39,000 m

= 39 km

Work norm = 250pd/km

Total required pd = 39 km x 250pd/km

= 9,750Pd

Tree Planting

The tree planting activity is aimed in order to improve soil fertility in addition to the soil and water conservation purpose.

Recommended Spacing: 10m between trees and 20m between rows, which is 50trees per ha. Hence, the total number of seedlings required will be 78ha*50 trees/ha= 3,900 Seedlings.

Work Norms and required amount of Pd:

Seedling Production: 3,900 seedlings * 15pd/1000 seedlings= 59pd

Pitting: 3,900 seedlings *1pd/15pits= 260pd

Tree planting: 3,900 seedlings*1pd/50 seedlings= 78pd

Total Pd for Tree Planting On farm= 397Pd

2. Cultivated land Use Three (CL3)

2.1. Land Class Unit IIILE

This land class unit has a total area of 19ha and an average dominant slope of 12%. The land class unit is mainly characterized by silt loam soil, a soil depth of >150cm, slight past erosion, good infiltration, slightly stony, and with no water logging conditions. It is classified under soil requirement class III, having slight past erosion and its slope as the major limiting factor.

Recommended Conservation Measures

A. Physical Conservation Measure: Stone Bund
B. Biological Conservation Measure: Tree Planting
C. Agronomy Practices (Measure)

Stone Bund

Total area = 19ha

Average slope = 12%

Vertical interval = 1m

Horizontal interval = 8.3m

Hence, stone bund per hectare = 12x100m = 1200m/ha

Total length of stone bund = 19ha x 1200m/ha

= 22,800m

= 22.8km

Work norm = 250pd/km

Total required pd = 22.8km x 250pd/km

= 5,700Pd

Tree Planting

The tree planting activity is aimed in order to improve soil fertility in addition to the soil and water conservation purpose.

Recommended Spacing: 10m between trees and 20m between rows, which is 50trees per ha. Hence, the total number of seedlings required will be 19ha *50 trees/ha= 950Seedlings.

Work Norms and required amount of Pd:

Seedling Production: 950seedlings * 15pd/1000 seedlings= 15pd

Pitting: 950seedlings *1pd/15 seedlings= 64pd

Tree planting: 950seedlings*1pd/50 seedlings= 19pd

Total Pd for Tree Planting On farm= 98Pd

3. Watershed Area

1. Cultivated land Use Three (CL3)

1.1. Land Class Unit IIILE

This land class unit has a total area of 186.86ha and an average dominant slope of 12%. The land class unit is mainly characterized by silt loam soil, a soil depth of >150cm, slight past erosion, good infiltration, slightly stony, and with no water logging conditions. It is classified under soil requirement class III, having slight past erosion and its slope as the major limiting factor.

Recommended Conservation Measures

D. Physical Conservation Measure: Stone Bund
E. Biological Conservation Measure: Tree Planting
F. Agronomy Practices (Measure)

Stone Bund

Total area = 186.86ha

Average slope = 12%

Vertical interval = 1m

Horizontal interval = 8.3m

Hence, stone bund per hectare = 12x100m = 1200m/ha

Total length of stone bund = 186.86ha x 1200m/ha

= 224,232m

= 224.232km

Work norm = 250pd/km

Total required pd = 224.232km x 250pd/km

= 56,058Pd

Tree Planting

The tree planting activity is aimed in order to improve soil fertility in addition to the soil and water conservation purpose.

Recommended Spacing: 10m between trees and 20m between rows, which is 50trees per ha. Hence, the total number of seedlings required will be 186.86ha *50 trees/ha= 8,905Seedlings.

Work Norms and required amount of Pd:

Seedling Production: 8,905seedlings * 15pd/1000 seedlings= 140pd

Pitting: 8,905seedlings *1pd/15 seedlings= 623pd

Tree planting: 8,905seedlings*1pd/50 seedlings= 187pd

Total Pd for Tree Planting On farm= 950Pd

2. Cultivated Land Use Four (CL4)

2.1. Land Class Unit CIVDE

This land class unit has a total area of 37.46ha and an average dominant slope of 22%. The land class unit is mainly characterized by silt loam soil, a soil depth of largely 50-100cm, moderate past erosion, good infiltration, largely moderately stony, and with no water logging conditions. It is classified under soil requirement class IV, having moderate past erosion its soil depth as the major limiting factor.

Recommended Conservation Measures

A. Physical Conservation Measure: Bench Terrace
B. Biological Conservation Measure: Tree Planting
C. Agronomy Practices (Measure)

Bench Terrace

Total area = 37.46ha

Average slope = 22%

Vertical interval = 2.5 x workable soil depth (0.75m)

= 1.875m

Horizontal interval = 8.52

Hence, Bench terrace per hectare = 11.74 x100m = 1174m/ha

Total length of Bench terrace = 37.46ha x 1174m/ha

= 43,978.04m

= 43.97804km

Work norm = 5000pd/km

Total required pd = 43.97804km x 500pd/km

= 14,804pd

Tree Planting

The tree planting activity is aimed in order to improve soil fertility in addition to the soil and water conservation purpose.

Recommended Spacing: 10m between trees and 20m between rows, which is 50trees per ha. Hence, the total number of seedlings required will be 37.46ha*50 trees/ha= 1,873Seedlings.

Work Norms and required amount of Pd:

Seedling Production: 1,873seedlings * 15pd/1000 seedlings= 28pd

Pitting: 1,873seedlings *1pd/15 seedlings= 128pd

Tree planting: 1,873seedlings*1pd/50 seedlings= 38pd

Total Pd for Tree Planting On farm= 194Pd

2.2. Land Class Unit CIVLE

This land class unit has a total area of 27.9ha and an average dominant slope of 22%. The land class unit is mainly characterized by silt loam and considerably clay loam soils, a soil depth of 100-150cm, moderate past erosion, good infiltration, largely slightly stony, and with no water logging conditions. It is classified under soil requirement class IV, moderate past erosion and 15-30% slope as the major limiting factors.

Recommended Conservation Measures

A. Physical Conservation Measure: Bench Terrace
B. Biological Conservation Measure: Tree Planting
C. Agronomy Practices (Measure)

Bench Terrace

Total area = 27.9ha
Average slope = 22%

Vertical interval = 2.5 x workable soil depth (1.25m)

= 3.125m

Horizontal interval = 14.2m

Hence, Bench terrace per hectare = 7.04 x100m = 704m/ha

Total length of Bench terrace = 27.9ha x 704m/ha

= 19,641.6m

= 19.6416km

Work norm = 500pd/km

Total required pd = 19.6416km x 500pd/km

= 9,821pd

Tree Planting

The tree planting activity is aimed in order to improve soil fertility in addition to the soil and water conservation purpose.

Recommended Spacing: 10m between trees and 20m between rows, which is 50trees per ha. Hence, the total number of seedlings required will be 27.9ha *50 trees/ha= 1,395Seedlings.

Work Norms and required amount of Pd:

Seedling Production: 1,395seedlings * 15pd/1000 seedlings= 21pd

Pitting: 1,395seedlings *1pd/15 seedlings (Pits) = 93pd

Tree planting: 1,395seedlings*1pd/50 seedlings= 28pd

Total Pd for Tree Planting On farm=142Pd

C. Agronomy Practices (measures)

For all the cultivated land use types the following agronomy practices (measures) are proposed.

Contour ploughing

Contour ploughing is a practice of ploughing along a contour line as opposed to along the slope. Contour ploughing increases the contact time between water and soil by checking the flow of water. By modifying the surface conditions it contributes to slow down runoff and reduce erosion.

Greater shortage of water and more effective erosion control can be achieved by connecting the ridges with cross ties, thereby forming a series of rectangular depressions which fill with water during rain. It is normally used on well drained soils. If excess moisture is expected on poorly drained soils, the contours should be graded to drain excess moisture to water ways.

Crop rotation

Crop rotation is an oldest practice for fertility restoration and pest/disease control and it consists of growing different crops one after another on the same piece of land. Plants of the same crop develop their roots at the same depth of soil profile and thus the proliferation of the root systems in the same depth results in a strong competition for moisture and nutrients. Therefore, if the same crop is grown on the same land year after year, the soil nutrient in that stratum decreases sharply and the crop yield consequently declines.

On the other hand, if different crops are rotated, the depletion of soil nutrients and decline of crop yields are not as serious as when the same crop is grown year after year. Different crops have different characteristics that enable them to exploit the soil at different depths.

In addition to fertility restoration, crop rotation is a popular practice of controlling diseases, pests and weed infestation. It is well known that different crops are not equally susceptible to the same kind of pests, diseases and weed infestation.

Mulching

Mulching is the covering of the soil with crop residues such as straws, maize/sorghum stalks. The cover protects the soil from rain drops, drastically reduces splash erosion and velocity of runoff. It then minimizes erosion, increases infiltration, prevents the formation of hard crusts and contribute to improve fertility. It also encourages insects and warms to make holes into the ground, thus increasing the permeability of the soil.

Mulching has great potential for sustaining productivity. The plant material going back to the soil has a potential of increasing/maintaining soil organic matter. It also helps in reducing evaporation and maintaining soil moisture.

Compost Making

Composting is the process of decomposition or break down of organic waste by a mixed population of microorganisms in a warm, moist, and aerated environment. The final product of this process is called compost. Compost is a natural product which consists a partially decomposed mixture of organic residues: crop residues, weeds, waste vegetable material, usually mixed with animal dung and some soil. It is used for fertilizing and conditioning the soil.

Good compost contains a proper mixture of available nutrients for the crops and well decomposed materials which would release nutrients, gradually during the entire crop cycle and bind soil particles into stable aggregates. The application of compost would improve soil fertility, water storage, and reduces runoff.

Efficient use of Fertilizer

The rational application of fertilizers is necessary to support and enhance a balanced growth of crops. An excess application of fertilizer, particularly Nitrogen fertilizers like Urea and Nitrates, can affect the growth of the crops if levels of soil moisture are not sufficient to regulate the ion exchange mechanisms occurring into the soil. Excess of ions concentration in the exchange complex would drag out moisture from crops in order to dilute the high concentration of solutes(Osmotic pressure) and thus burn the

young plants in a very short period of time. Hence, care should have to be taken to avoid this risk.

Forest / bush land

The forest / bush land, as a major land use type, to be considered has a total area of 38.78ha, which is within the watershed area.

Depending on the general condition of the sub-units the following conservation measures are proposed.

1. Forest Land Use Two (FL2)

1.1. Land Class Unit VID

This land class unit has a total area of 4.21ha and an average dominant slope of 5%. The land class unit is characterized by dominantly silt loam soil, a soil depth of 25-50cm, moderate past erosion, good infiltration, stony, and with no water logging conditions. It is classified under soil requirement class VI, having a soil depth of 25-50cm as the major limiting factor.

Total area = 4.21ha

Proposed measures

1. Micro basin
2. Tree planting
3. Area closure

1. Micro basin

- Spacing used = 2m x 2m
- Micro basin per ha = 625mb/ha
- Total number of micro basin = 4.21ha x 625mb/ha

  = 2,631mb

  Work norm = 1pd/5mb
- Hence total required pd= 2,631mb x 1pd/5mb

  =526pd

2. Tree planting

The number of seedlings to be planted is equal to the number of micro basins to be constructed.

Hence, the total required number of seedlings is 2,631 seedlings

Work norms and required amount of Pd:

Seed ling production 2,631 seedlings *15pd/1000 seedlings=40Pd

Pitting: 2,631 seedlings *1pd/15pits=176Pd

Planting: 2,631seedlings *1pd/50seedlings=53Pd

Therefore; a total of 269Pd is required for Tree planting activity

2. Forest Land Use Three (FL3)

2.1. Land Class Unit VID

This land class unit has a total area of 7.32ha and an average dominant slope of 12%. The land class unit is mainly characterized by dominantly silt loam soil, a soil depth of 25-50cm, moderate past erosion, good infiltration, stony, and with no water logging conditions. It is classified under soil requirement class VI, having 25-50cm soil depth as the major limiting factor.

Total area = 7.32ha

Proposed measures

1. Micro basin
2. Tree planting
3. Area closure

1. Micro basin

- Spacing used = 2m x 2m
- Micro basin per ha = 625mb/ha
- Total number of micro basin = 7.32ha x 625mb/ha
  = 4,575mb

Work norm = 1pd/5mb

Hence total required pd= 4,575mb x 1pd/5mb

=915pd

2. Tree planting

The number of seedlings to be planted is equal to the number of micro basins to be constructed.

Hence, the total required number of seedlings is 4,575 seedlings

Work norms and required amount of Pd:

Seed ling production 4,575 seedlings *15pd/1000 seedlings=69Pd

Pitting: 4,575 seedlings *1pd/15pits=305Pd

Planting: 4,575seedlings *1pd/50seedlings=92Pd

Therefore; a total of 466Pd is required for Tree planting activity.

3. Forest Land Use Four (FL4)

3.1. Land Class Unit IVDE

This land class unit has a total area of 3.99ha and an average dominant slope of 22%. The land class unit is mainly characterized by dominantly silt loam soil, a soil depth of 50-100cm, moderate past erosion, good infiltration, stony, and with no water logging conditions. It is classified under soil requirement class IV, having 50-100cm soil depth and moderate past erosion as the major limiting factors.

Total area = 3.99ha

Proposed measures

1. Micro basin
2. Tree planting

3- Area closure

1. Micro basin

- Spacing used = 2m x 2m
- Micro basin per ha = 625mb/ha
- Total number of micro basin = 3.99ha x 625mb/ha
  = 2,494mb

  Work norm = 1pd/5mb
- Hence total required pd= 2,494mb x 1pd/5mb
  =499pd

2. Tree planting

The number of seedlings to be planted is equal to the number of micro basins to be constructed.

Hence, the total required number of seedlings is 2,494seedlings

Work norms and required amount of Pd:

Seed ling production 2,494 seedlings *15pd/1000 seedlings=38Pd

Pitting: 2,494 seedlings *1pd/15pits=166Pd

Planting: 2,494 seedlings *1pd/50seedlings=50Pd

Therefore; a total of 254Pd is required for Tree planting activity.

3.2. Land Class Unit FVIIDE

This land class unit has a total area of 23.26ha and an average dominant slope of 22%. The land class unit is mainly characterized by dominantly silt loam soil, a soil depth of 25-50cm, severe past erosion, good infiltration, stony, and with no water logging conditions. It is classified under soil requirement class VII, having 25-50cm soil depth and severe past erosion as the major limiting factor.

Total area = 23.26ha

Proposed measures

1. Micro basin
2. Tree planting
3. Area closure

1. Micro basin

- Spacing used = 2m x 2m
- Micro basin per ha = 625mb/ha
- Total number of micro basin = 23.26ha x 625mb/ha

  = 14,538mb

  Work norm = 1pd/5mb
- Hence total required pd= 14,538mb x 1pd/5mb

  =2,908pd

2. Tree planting

The number of seedlings to be planted is equal to the number of micro basins to be constructed.

Hence, the total required number of seedlings is 14,538 seedlings

Work norms and required amount of Pd:

Seed ling production 14,538 seedlings *15pd/1000 seedlings=218Pd

Pitting: 14,538 seedlings *1pd/15pits=969Pd

Planting: 14,538seedlings *1pd/50seedlings=291Pd

Therefore; a total of 1,478Pd is required for Tree planting activity.

3. Area closure (for all Forest land use types)

Area closure is a biological conservation measure, which improves the land, which has degraded vegetation and / or soil.

No livestock is allowed to graze, and no human interference tolerated until a satisfactory cover is reached. Area closure has to be decided in combination with the agreement of the peasant association in the way to increase the productivity of the land while maintaining the conservation measure.

Gully Treatment

The conservation measures recommended for the gullies are: check dam, gabion check dam, and gully side plantation.

1. Check dam construction

Total gully length = 3.669km
Average width of gully (length of check dam) =6m
Height of check dam= 1m
Width of check dam= 3m
Average slope = 5%
Vertical = 1m
Horizontal interval = 20m

$$\text{Number of check dam} = \frac{\text{total gully length}}{\text{Horizontal interval}} = \frac{3{,}669\text{m}}{20\text{m}} = 183 \text{ check dams}$$

Volume of one check dam= L*W*H
= (6m+1m key)*3m*1m
=7m*3m*1m
= 21m^3

Total volume of check dam=183 check dams*21 m^3

=3,843m^3

Work norm = 0.5 m^3/ Pd

Total requires Pd = 3,843 m3*1pd/0.5 m^3

=7,686 Pd

2. Gabion Check dam construction

Total gully length = 3,224km

Average width of gully (length of Gabion check dam) =8m

Height of Gabion check dam= 1m

Width of check dam= 2m

Average slope = 5%

Vertical = 1m

Horizontal interval = 20m

Number of check dam = total gully length = 3,224m

Horizontal interval 20m

= 161 Gabion check dams

Volume of one check dam= L*W*H

= (8m+1m key)*2m*1m

=9m*2m*1m

= 18m^3

Total volume of Gabion check dam=161 Gabion check dams *18 m^3

=2,898 m^3

Work norm = 0.25 m^3/ Pd

Total requires Pd = 2,898 m^3*1pd/0.25 m^3

=11,592 Pd

3. Gully side plantation

Gully side plantation is a tree planting activity on both sides of the gully

Total length = 6.893km

- Spacing = 2m

Total number of seedlings = Total Length*2/ Spacing

Required

= 6,893m*2/2m

= 6,893seedlings

Work Norms and required amount of Pd:

Seedling Production 6,893 seedlings * 10pd/1000 seedlings= 69pd

Pitting: 6,893seedlings *50pd/1000 seedlings= 345Pd

Tree planting: 6,893 seedlings *15pd/1000 seedlings= 104pd

Total Pd for Tree Planting On farm= 518Pd

Table 11: Recommended Conservation Measures and Cost of Implementation

S/N	Major land use type	Sub Unit	Land class unit	Area in ha	Slope range (%)	Dominant average slope (%)	Recommended Conservation measure	Unit	Qty per ha	Total	Norm	Required person day (pd)	Cost of implementation (15Br/pd)
1	Cultivated land	CL2	IIIE	78	2-8%	5%	Stone bound	km	0.5	39	250pd/km	9,750	146250
							Tree planting (Prod., Planting, Pitting)	No	50	3,900	15pd/1000sdlgs,1pd/50sdlgs,1pd/15pits	397	5955
		CL3	IIILE	205.86	8-15%	12%	Stone bound	km	1.2	247.032	250pd/km	61,758	926370
							Tree planting	No	50	10,293	15pd/1000sdlgs,1pd/50sdlgs,1pd/15pits	1,048	15720
		CL4	IVDE	37.46	15-30%	22%	Bench terrace	km	1.174	43.97804	500pd/km	21,289	319335
							Tree planting	No	50	1,873	15pd/1000sdlgs,1pd/50sdlgs,1pd/15pits	194	2910
			IVLE	27.9	15-30%	22%	Bench terrace	Km	0.704	19.6416	500pd/Km	9,821	147315
							Tree planting	No	50	1,395	15pd/1000sdlgs,1pd/50sdlgs,1pd/15pits	142	2130
2	Forest/ bush land	FL2	VID	4.21	2-8%	5%	Micro basin	No	625	2,631	1pd/5mb	526	7890
							Tree planting	No	625	2,631	15pd/1000sdlgs,1pd/50sdlgs,1pd/15pits	269	4035
		FL3	VID	7.32	8-15%	12%	Micro basin	No	625	4,575	1pd/5mb	915	13725
							Tree planting	No	625	4,575	15pd/1000sdlgs,1pd/50sdlgs,1pd/15pits	466	6990
		FL4	IVDE	3.99	15-30%	22%	Micro basin	No	625	2,494	1pd/5mb	499	7485
							Tree planting	No	625	2,494	15pd/1000sdlgs,1pd/50sdlgs,1pd/15pits	254	3810
			VIIDE	23.26	15-30%	22%	Micro basin	No	625	14,538	1pd/5mb	2,908	43620
							Tree planting	No	625	14,538	15pd/1000sdlgs,1pd/50sdlgs,1pd/15pits	1,478	22170
		All	All	7,539.39			Area closure	-	-	-	-	-	0
3	Gully Treatment				0-10%	5%	Check dam	M^3	-	3,843	0.5 m^3/ Pd	7,686	115290
							Gabion Check dam	M^3	-	2,898	0.25 m^3/ Pd	11,592	173880
							Gully side plantation	No	-	6,893	15pd/1000sdlgs,1pd/50sdlgs,1pd/15pits	518	7770
	Total											**131,510**	**1,972,650**

13.Training, Monitoring and Evaluation, and Maintenance Costs for the Watershed Management Activity

13.1. Training Costs:

One of the important components of watershed management is building the capacity of stakeholders through relevant training programs, which can upgrade their overall knowledge, skill, and attitude that enables them to properly accomplish the watershed management activities, and hence to attain sustainable community based development. Detail cost breakdown is displayed in Table_12 and 13 below.

Table 12:Training Materials cost

S/N	Types of materials	Unit	Quantity	Unit cost(Birr)	Total cost
1	Stationary	No.	50	20	1000
2	Scotch	No.	10	35	350
3	White board	No.	3	1400	4200
4	Flip chart	No.	6	120	720
5	White board marker	pack	6	110	660
6	Flip chart marker	pack	6	130	780
7	Tape meter (50m)	No.	5	120	600
8	Plastic Rope (200m)	Roll	4	100	400
9	Preparation of domenstartion area (field practice)	No.	10	100	1000
10	Digging hoe	No.	10	100	1000
11	spade	No.	10	80	800
12	water leveling	No.	10	250	2500
13	poles	pair	5	120	600
	Total cost				**14610**

Table 13: Trainees and trainer costs

S/N	Trainees and trainer	Unit	Quantity	Average Perdium per person	Days/year	Total cost
1	**Trainees**					
a	Tabia Development agents	No.	5	120	10	6000
b	Formans	No.	10	120	10	12000
c	Technicians	No.	5	120	10	6000
d	Tabia adminstration	No.	5	120	10	6000
e	local farmers	No.	25	120	10	30000
2	**Trainer**					
a	Wereda/regional Agricultural and irrigation expert	No.	2	200	10	4000
b	Wereda/regional soil and water conservation expert	No.	2	200	10	4000
c	Wereda/regional livestock mangement expert	No.	1	200	10	2000
	Total		55			**70,000**

13.2. Monitoring and Evaluation Cost:

Purposive and regular supervision and controlling of activities, which includes collection of relevant data so as to properly assess and judge the level of success and failure visa visa-vis the planned activities, is very crucial at every step of implementation of the watershed management development program. Detail cost breakdown is displayed in Table_14 below.

Table 14: Monitoring and Evaluation Cost

S/N	Types	Unit	Quantity	Unit cost in birr	Days/ year	Total cost
1	**Supervision and controlling activities**					
a	Assessment by professions	No.	5	250	60	75,000
b	Technicians and selected local farmers	No.	20	120	60	144,000
2	**Materials for data collection and measurement**					
a	Stationary	No.	25	20	_	500
b	A4 papers	pack	5	150		750
c	A3 papers	pack	5	350		1,750
d	Sampling equipments	No.	10	80	_	800
e	Digging materials	No.	10	100	_	1,000
f	Beam balance	No.	3	800	_	2,400
3	**Labour**	No.	15	100	_	1,500
	Total					**225,950**

13.3. Maintenance Cost

As per the Maintenance costs, costs related to maintenance of the soil and water conservation works and tools, and store for equipments and tools are mainly considered. As far as the maintenance cost for the soil and water conservation works is considered, 5% of the total labor cost is assumed, and a maintenance unit cost is used for the equipment and tools. Detail cost breakdown is displayed in Table_15 below.

Table 15: Maintenance Cost

S/N	Types of maintenance	Unit	Quantity	Unit cost	Total cost
1	Selected Soil and water conservation measures	Pd	6576	15Birr/pd	95,055
2	Soil and water conservation Tools				
a	Pick axe	No.	488	20	9760
b	Shovel	No.	366	10	3660
c	hammer	No.	61	38	2318
3	Stores for equiment and tools	No.	1	20000	20000
4	White board	No.	3	100	300
					131,093

14.Equipment and Manpower Requirement

The total required person days to undertake the overall development activities in this study area is 131,510Pd. Subtracting the person days for seedling production, which is 628Pd, we will have 130,882Pd to undertake the conservation activities. Assuming there are 18 working days per month and 6 working months per year, there will be 108 working days per year. Considering this, we need to have around 1,212Pd per day to accomplish the work. Taking into account that one group consists 20 people, we will have about 61 groups. Hence, based on this the equipment requirements to undertake the conservation activities are summarized in the following table.

Table 16: Required Equipments for Undertaking the Conservation Activities

S/N	Type of Equipment	Unit	Quantity per Group	Total	Unit Price (Birr)	Total Price (Birr)
1	Hammer	No.	1	61	150	9150
2	Shovel	No.	6	366	40	14640
3	Craw Bar	No.	1	61	150	9150
4	Line Level	No.	2	122	50	6100
5	Pole(2m Long)	No.	2	122	50	6100
6	Measuring Tape	No.	1	61	150	9150
7	String	Roll	1	61	50	3050
8	Pick Axe	No.	8	488	60	29280
	Total					86620

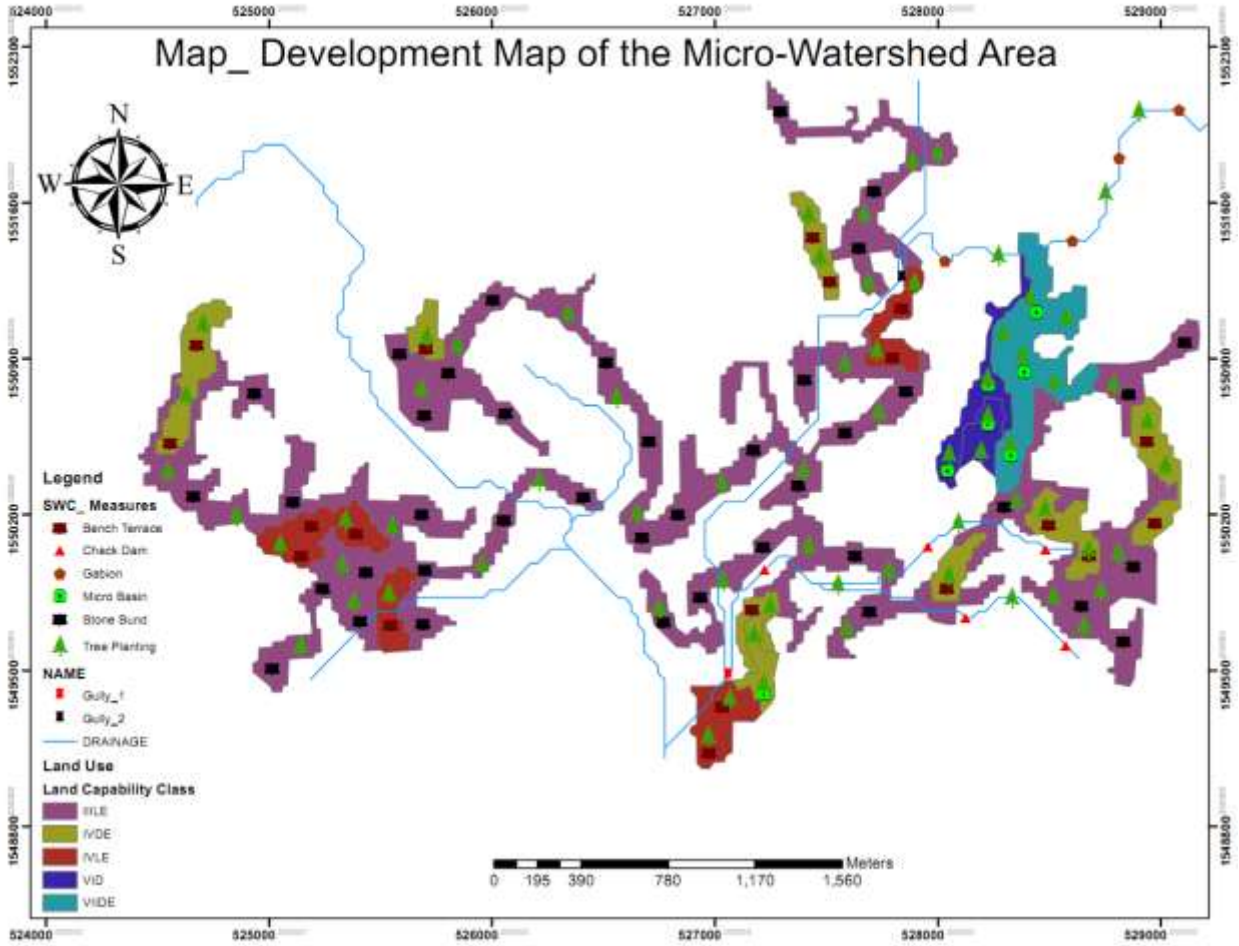

Figure 7 : Development Map for Soil and Water Conservation

15.Summary of Soil and Water Conservation Activities and Operational Calendar

The soil and water conservation measures proposed for this particular watershed area summarized in table_17 below which are aimed to be accomplished with in few months or less than a one years of implementation period taking in to account the technical requirements of each specific type of conservation measure and the available active man power in the watershed area.

Due attention must be given to the follow up of the basic technical specifications and implementation procedures of the recommended soil and water conservation measures, and in order to attain the maximum advantage of the watershed management activities, the physical conservation measures must be implemented in integration with the respective biological conservation measures.

Moreover, Due attention must be given to the selection of tree species which suits to the specific agro-climatic zone of the study area, and the tree planting activity should be carried out at the beginning of the rainy season and after a good reliable rain shower. Furthermore, activities like beating up, weeding and cultivation, maintenance of soil and water conservation activities must be given due attention.

Table 17 : Summary of Activities during the Year of Implementation

Type	unit	plan	pd	cost
Stone bund	km	286.032	71,508	1072620
Bench terrace	km	63.6196	31,110	466650
Micro basin	No	24,238	4,848	72720
Check dam	m3	3,843	7,686	115290
Gabion	m3	2,898	11,592	173880
Tree planting	No	48,592	4,766	71490
Total			**131,510**	**1972650**

Table 18 : Operational calendar for watershed development activities

Type of activity	Months of the Year											
	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar	Apr.	May	Jun.	Jul.	Aug.
Purchase of Goods												
Field Lay out												
Seedling production												
Pit preparation												
Seedling planting												
Weeding and Cultivation												
Beating Up												
Stone bund												
Bench terrace												
Micro basin												
Area Closure												
Check dam												
Gabion												
Maintenance												

16.Summary of Costs

The summary of costs for undertaking the soil and water conservation activities, training, monitoring and evaluation, maintenance, and purchase of equipments and materials together with 5% contingency of the total cost is displayed in table_19 below.

Table 19 : Summary of Costs

S/N	Type of Activity	Total Cost(Birr)	Remark
1	Soil and Water Conservation Labor Cost	1,972,650	
2	Training Cost	77,610	Includes cost of Training materials, and perdiem of Trainees and trainers
3	Monitoring and Evaluation Cost	225,930	
4	Maintenance Cost	131,093	
5	Equipments and Materials Cost	86,620	
	Total Cost	2,493,903	
	5% Contingency	124695.15	
	Grand TOTAL COST	2,618,598	

17.Conclusion and Recommendation

As it is repeatedly described above, this particular study area is characterized by long period deforestation activity and expansion of agricultural practice, as a factor of the over increasing growth of population; both human and livestock, which has resulted in very negligible and scattered tree or bush cover and very limited area of grassland which is under great pressure, rather very large area of the study area is presently put under extensive cultivation. Due to this reason, the area is presently clearly seen bare and exposed to the direct action of raindrops.

Far from this, the acceleration of erosion as a result of the long time deforestation, mismanaged use of land and lack of proper types and required amount of conservation measures within the study area, which has aggravated the land degradation from time to time, has greatly affected the overall agricultural productivity. Generally the land degradation process has resulted in ecological imbalance and economic insecurity.

Hence, the need for proper planning, implementation, and development of watershed management aiming at the protection of the process of soil erosion and land degradation and hence improvement of soil fertility and land productivity which will bring about sustainable agricultural development and a key element in attaining food secured society is very crucial.

For the proper implementation of the watershed management activity the following main viewpoints must be given due attention.

- The watershed management activities must be planned, implemented and developed in a community based approach,
- Due attention must be given to the adequate participation of women in the overall watershed management development activities
- Due attention must be given to the follow up of the basic technical specifications and implantation procedures of the recommended soil and water conservation measures,

- Due attention must be given to the selection of tree species which suits to the specific agro-climatic zone of the study area,
- In order to attain the maximum advantage of the watershed management activities, the physical conservation measures must be implemented in integration with the respective biological conservation measures,
- Due attention must be given to the education, technical support, and awareness creation programs to the local community on the overall objectives of watershed management and protection and maintenance of implemented conservation measures,
- Due attention must be given to the introduction of alternative energy sources in order to solve the fuel wood problem of the society and to minimize the pressure on the remaining trees or bushes found in the watershed area,
- Due attention must be given to bring about additional feed sources in order to solve the scarcity of feed and to minimize the pressure all tree resource.
- The implementation of the watershed management activities must be carried out ahead or side by side with the construction of the irrigation structures in order to attain the advantage of the overall proper functionality of the aimed pump irrigation project.

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