VETIVER IN THE REHABILITATION OF THE DEGRADED ZEGZEG WATERSHED IN ETHIOPIA

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Abstract

The Zegzeg watershed is located 180 km north of Addis Ababa. Geographically it is bounded by latitudes 10^{o} 02^{1} 03^{11} and 10^{o} 10^{1} N and longitudes 30^{o} 57^{1} 22^{11} and 39^{o} 03^{0} E, while altitude ranges from 1300 m to 2600 m. The total area of the watershed is about 7 568 ha and it has an estimated population of 4 012 people and 4 983 livestock. The Zegzeg stream has a length of about 14 km and a stream gradient of 7 %, which results in a highly erosive flow and seasonal flooding. Landforms vary across the watershed, consisting of steep mountains, escarpments and flood-prone plains. The predominant proportion of the watershed is degraded mountains and hilly areas. Using the universal soil loss equation modified to Ethiopian conditions, the total soil loss is about 126 390 t/year. In addition, yearly about 50 ha of land is lost forever due to riverbank erosion. At present, increased emphasis is being laid on the rehabilitation of the watershed. Among the measures that are showing promising results is vetiver hedgerows. Vetiver has shown its effectiveness as a buffer zone to halt runoff from steep mountains, as a riverbank stabilizer and for inter-bund management. Besides, vetiver is socially appreciated due to its value as thatching material.

Introduction

Ethiopia has experienced severe forest destruction for decades. The forest area has decreased from 40% (4 508 000 ha) in the early decades of the 20th century to less than 3% at present. The destruction of the vegetal cover has resulted in severe soil erosion and land degradation. It is estimated that over 200 million t of soil are lost from the highlands of Ethiopia. These soils are productive top soils and are for all practical purposes lost forever as it takes many years to generate a ton of top soil. Thus Ethiopian highlands are one of the largest areas of ecological degradation in Africa. This ecological degradation threatens not only millions of Ethiopians today, but more millions of Ethiopians as yet unborn.

The Blue Nile and its tributaries drain the greater part of the Central Highlands of Ethiopia. The Zegzed River flows into the Jemma River, which is one of the tributaries of the Blue Nile. Natural resource degradation in the Jemma watershed is one of the worst in the Blue Nile basin. Intensive cultivation, overgrazing, deforestation and land shortage have exerted enormous pressure on the natural resource base of the watershed. They have resulted in severe loss of soil and vegetation cover and in a decline of crop and livestock production. Under such conditions, poor farmers who struggle for survival may not be expected to pay heed to development works, unless their needs for food and fuel are met.

The aim of the rehabilitation project is to restore the deteriorated physical and environmental conditions of the watershed through integrated watershed management. Thus to bring about sustainable production and ecological stabilization, possible development interventions that suit the environmental and socio-economic conditions have been identified. Creating vetiver hedgerows is one of them.

Objectives

The broad objective of the programme is conservation, development, utilization and management of the resource basis (soil, water and vegetation) as well as reduction of runoff and flood hazards and improvement of the socio-economic environment in the watershed. The specific objectives are:

- Appraisal of erosion problems and conservation of soil and water resources under different land uses; and
- Reduction of runoff hazards over the entire topological sequences of the watershed, leading to the improvement of small-scale irrigation schemes down the slopes.

Methodology

Topographic Transect Walk

The rapid rural appraisal technique of the topographic transect walk method was employed for its effectiveness, especially for the assessment of the natural resource base of the watershed. Although there is a relatively high degree of homogeneity within the watershed, in order to obtain as much information as possible, the transect walk was applied in two directions, east to west and south to north. In both cases, the transect walk started at the top edge of the watershed and went all the way across to the other end. During the transect walk, observations and estimates of the vegetation density and erosion hazard classes were recorded. These were followed by recording land-use types, slope gradient, slope length, soil colour and depth, and drainage class over a distance of 0.5 to 1 km. Although the main objective of the walk was to assess the natural resource base of the watershed, it also provided an opportunity for informal discussions with farmers working on their plots.

Slope Capability Classification

Information collected from the field assessment was used for the diagnosis characterization of the physical and socio-economic environment of the watershed and to classify the watershed into seven slope capability classes using a 1:50 000 topographic map. The description of the slope capability classifications is as follows (Table 1):

Table 1. Parameters of land classification

No	Land form	Slope range (%)	Slope capability class
1	Flat almost flat	< 2	I
2	Undulation plain	2 - 8	II
3	Rolling to undulating	8 - 15	III
4	Hill to rolling	15 - 30	IV
5	Flat land	< 2	V
6	Steep	30 - 50	VI
7	Very steep escarpment	> 50	VII

Soil Loss Estimation

To assess rill and gully erosion, the universal soil loss equation, which was developed by Wishmir and Smith (1957) and modified to Ethiopian conditions by Hans Hurni (1985), is used.

Result and Discussion

Watershed Characterization

Soil and vegetation resources

The main soil types are cambisols on undulating plains and rolling land, lithosols on hilly and steep lands and vertisols are predominant on flat plateau plains while fluvisols are dominant on flood-prone lowland plains. The vegetation in general is sparse and has been overexploited for a long time and consists of shrubs and bushes of little economic value.

Table 2. The universal soil loss equation modified for Ethiopia

Equation A*R*K*S*P

1. R = Rainfall erosivity

Annual rainfall	100	200	400	800	1600	2000	2400
Factor R	48	104	217	441	666	890	1340

2. K = Soil factor

Soil colour	Black	Brown	Red	Yellow
Factor K	0.15	0.20	0.25	0.30

3. L = Slope length

Length (m)	5	10	20	40	80	160	240	320	
Factor L		0.5	0.7	1.0	1.4	1.9	2.7	3.2	3.8

4. S = Slope gradient

Slope (%)	5	10	15	20	40	50	60	
Factor S		0.4	1.0	1.6	2.2	3.0	4.3	4.8

5. C = Land cover

Dense forest	0.001	Dense grass	0.01
Other forest	0.01	Degraded grass	0.05
Bad land hard	0.05	Fallow hard	0.05
Bad land soft	0.04	Fallow ploughed	0.60
Sorghum, maize	0.10	Ethiopian teff	0.25
& pulse	0.15	Continuous fallow	1.00

6. P = Management factor

Ploughing up and down	1.00	Ploughing on contour	0.90
Strip cropping	0.80	Intercropping	0.80
Applying mulch	0.40	Dense intercropping	0.70
Stone cover (90%)	0.50	Stone cover (40%)	0.80

Source: Wishmir & Smith, 1957, Hurni, 1985
S Correlation, Hurni, 1985
K Values from Bomo & Seler, 1983, 1984 and Wegel, 1985
S Extrapolation, Hurni, 1982

Climate

There is a meteorological station in Alem Ketema. A seven-year data analysis indicates that the main *meher* rain (June-September) is dominant and *belg* rain (February-April) is also substantial and important for long-cycle crops. The details of the climatic components are indicated in Table 3.

Table 3. Climatic data

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean max temp °C	25.7	27	27	27.7	26.1	21.1	20.9	22.5	22.5	24.6	25	25.2	**25**
Mean min temp °C	12.1	12.9	13.6	13.7	14	13.8	11.9	12	12.8	12.7	11.4	11.5	**12.7**
Mean temp °C	18.9	20	20.2	20.7	20.6	19.5	16.5	16.5	17.7	18.7	18.2	18.4	**18.8**
Rel. humidity (%)	50	49	49	56	52	65	77	79	72	54	51	49	**59**
Wind speed at 2m m/s	1.9	2	2	1.9	2	1.3	1.2	1.2	1.4	2.3	2.2	2.1	**1.8**
Sunshine %	68	77	51	55	65	47	28	26	40	54	86	77	**57**
Precipitation (mm)	5	31	52	26	65	98	369	325	156	27	0	4	**1158**
PET (mm)	110	120	126	123	136	97	72	71	84	117	117	111	**1284**

Source: LIPRD/FAO, 1984

As the above table shows, the relative humidity varies from 49% in December, March and April to 79% in August. The wind speeds are low to moderate, varying from 4.3 km/hr in July and August to 8.3

km/hr in October. The range of actual sunshine hours in the area is of the order of 3 hr (July) to 9 hr (November). The mean annual evaporation is 1 284 mm with the highest in May, 136 mm and the lowest, 71 mm, in August. The annual mean precipitation amounts to 1 158 mm and the growing period lasts 163 days. This is when moisture from precipitation and from the soil is available for plant growth; crops with a maturing period of less than 165 days will grow successfully.

Land use

Land use in the watershed has not been studied systematically, but according to the information of the agricultural office, the total combined land area is 7 567.5 ha. The distribution of the various land uses is shown in Table 4.

Table 4. Land use and land cover

Land use	Area	
	ha	%
Annual crop land	3145.5	42
Perennial cropland	27	0.4
Irrigated cropland	475	6
Grazing	230	3
Forest & bush land	356	5
Built-up	337	4
Other	2 997	39.6
Total	**7 567**	**100**

Population, household size and landholding

The total population of the watershed was of 4 012 in 1998, as shown in Table 5.

Table 5. Population

Social group	Population
Male household head	707
Female household head	51
Female dependant	1 789
Male dependant	1 366
Total	**4 012**

As the above table shows, 7% of the farming households are headed by women. Average family size is 5 and 46% of the population is female. The population density of the watershed is about 53 persons per km^2. There are 758 families in the watershed out of which 682 are farming families and 76 landless. Most farming families have less than one hectare of land, as shown below.

Table 6. Landholding

Landholding (ha)	Household	
	Number	%
0-0,5	200	26.3
0.5-1	412	54.4
> 1	70	9.3
Landless	76	10

Current Farming System

The general farming system here refers to a broad target area that is homogenous to all slope capability classes, in terms of crop production practice and livestock production. Thus, the farming system is principally crop oriented. Sorghum and wheat account for approximately 75% of all crops grown. Other crops such as maize, pulses, oilseeds and teff are also important crops in the farming system. Although livestock rearing is an integral part of the farming system, the number of livestock in the watershed area is severely reduced by sales and death due to a shortage of animal feed. The present stocking rate of 21 livestock per hectare is above the carrying capacity. Farmers are well aware of this critical condition and practise seasonal livestock grazing migration to the lowlands (< 1500 m). Cattle are kept mainly for drought power and milking, goat and sheep are kept for live sale, and equine for transportation. The livestock population of the watershed is as follows.

Table 7. Livestock resource

Type	Population
Cattle	3 488
Goat	940
Sheep	84
Donkey	304
Mule	22
Total	**4 838**

Slope Capability Classes

On the basis of slope classification and field survey results, the watershed is divided into seven capability classes and the area extent of each slope capability class measured planometrically is shown as follows.

Table 8. Area of slope capability classes

	Physiography	Land unit	Area	
			ha	%
1	Flat or almost flat	I	487	6
2	Undulating plain	II	1 737.5	24
3	Rolling land	III	1535	20
4	Hilly lands	IV	1 612.5	21
5	Flat, flood-prone area	V	1 287.5	17
6	Steep mountain	VI	607.5	8
7	Escarpment	VII	300.0	4
Total			**7 567.5**	**100**

As the above table indicates, the watershed predominantly consists of hilly to rolling landforms. The plain areas are found on the plateau and along the river courses, and steep slopes (land units IV & VI) in the southern upper reaches of the watershed. The soils of steep lands are less than 20 cm thick over the parent materials. Generally the soil material has been eroded following the destruction of the original vegetation cover. Though farmers are aware of its marginal agricultural value, they use it for crop production and unproductive areas as degraded grazing resources. Four percent of the total area is escarpment which is extremely steep, with slope gradients of more than 50% and reaching up to 100%. This land unit is the main runoff-contributing area to down-slope lands. Flatland soils are deep with vertic property; poor drainage and sheet erosion and to some extent animal trampling are the major limitations of the land unit. The general characteristics of the land units are summarized as follows.

Table 9. Summary of the characteristics of slope capability classes (land units)

No	Parameter	Slope capability class (land unit)						
		I	II	III	IV	V	VI	VII
1	Slope (%)	<2	2-8	8-15	15-30	<2	30-50	100
2	Soil texture	Clay	Sandy loam	Sandy	Sandy	Loam	Sand	Nil
3	Soil depth	Deep	Moderately	Shallow	Very	Very	Extremely	Nil
4	Soil colour	Very dark	Reddish	Reddish	Brownish	Yellowish	Light	Nil
5	Drainage	Poor	Well	Well	Extremely	Poorly	Extremely	Nil
6	Local soil name	Merera	Boda	Tabita	Tebita	Boda	Dingay	Nil
7	Stoniness	Nil	<15%	15-40%	40-90%	Nil	>90%	Nil
8	Land use	Cultivated	Cultivated	Cultivated	Bush	Irrigated	Rock out	Nil
9	Soil erosion hazard	Sheet	Rill	Gully	Gully	Flood	Nil	Nil

Soil Erosion

Sheet and rill erosion

The need for fuel wood and construction poles as well as farmland has led to the final destruction of the remnant hillside forests and bushes, with increasing evidence of destabilized steep slopes and increased runoff rate, which leads to gully erosion. Mountainside overgrazing also worsened the erosion situation. Since animal dung and crop residues are burnt as fuel substitutes, the soil structure and fertility are steadily depleted. This in turn accelerates the erosion process in the watershed. Using the modified soil loss equation, the soil loss of each slope capability class was estimated as follows.

Table 10. Estimated soil loss

No.	Slope capability class	Soil loss	
		ton/ha	mm*/yr
1	I	0.80	0.06
2	II	6.50	2.34
3	III	32.50	2.60
4	IV	27.30	2.18
5	V	0.50	0.04
6	VI	26.0	2.08
	Average	15.60	1.25

** Assuming soil bulk density of 1.2 gm/cm^3*

As the above table shows, the highest rate of soil loss is in slope capability class III. This is due to the fact that the land unit is intensively cultivated, whereas class IV has an over 40-% stone cover which can retain the impact of the kinetic energy of raindrops and also serve as mulch (stone mulch) and decrease runoff effects. Class V is dominated by rock outcrops with 90-% stone cover of 30-75 cm diameter, so the soil loss is not too much when one takes into account the slope gradient. On the other hand, if the erosion process continues, the ensuing crop yield decline on the other land unit will place more pressure on the extensive use of land in Class II, which will lead to a higher soil loss rate. Based on these soil loss rates, the total soil loss of the watershed is estimated to be about 126 387 tons per year. This is illustrated for each land unit as follows.

Table 11. Annual soil loss by rill & gully erosion

Land unit	Physiography	Main type of erosion	Soil loss (t)
I	Flat	Sheet erosion	389.6
II	Undulating	Sheet & rill	11 293.75
III	Rolling	Rill & gully	49 887.5
IV	Hilly	Gully	49 021.25
V	Flat & flood prone	Stream bank erosion*	*52 ha/yr**
VI	Mountainous	Sever gully	15 795.0
VII	Escarpment	Rock outcrop	Nil
Total			**126 387.1**

** Source: Farmers, a total of 0.04% of the land is lost every year due to stream cutting*

As the above table shows, land degradation by rill and gully erosion is spreading with increasing evidence. If we convert the annual soil loss to a fertile land area of 1 m soil depth, annually the watershed looses 9 ha of very fertile land.

Gully erosion

Gullies represent a severe erosion hazard and are indicative of an advanced stage of erosion. Due to a lack of precaution, in the watershed shallow, medium and deep gullies have been formed. The gullies observed in the watershed are classified into three categories as follows.

Table 12. Classification of gullies

No.	Gully type	Description		
		Width (m)	Depth (m)	Side slope
1	Shallow	< 1	0-1.5	2:1
2	Medium	1-2	1.5-2.0	3:1
3	Deep	> 2	> 2	3:1

Technical Consideration

The entire watershed area experiences episodes of intensive rainfall which, coupled with steep gradient slopes, cause highly erosive runoff. It is this high-velocity runoff that is responsible for the high rate of sediment transportation, i.e. 126 387 t/year. Thus, there is a need to regulate this soil loss by all possible means so as to rehabilitate the degraded watersheds.

Long-term measures undertaken include:

- Re-vegetation of denuded hill slopes with trees and vetiver strips or belts;
- Introduction of an agro-forestry programme that is comparable with crop, livestock and forestry development with micro vetiver or soil basins;
- Crop and livestock production development; and
- Homestead vacation enhancement.

Short-term soil and water conservation measures are given due attention.

- Cut-off drains are constructed to intercept the runoff.
- Stone and soil bunds are encouraged.
- Gully control by both vegetative and structural measures is being implemented.

Additionally vetiver bioengineering was integrated in the watershed management program. The main interventions were as follows:

- Inter-bund management
- Bund stabilization
- Buffer zone establishment
- River bank re-vegetation

Vetiver Bioengineering in the Watershed Management

Inter-bund management

One of the popular conservation measures identified and promoted for land treatment of humid areas in Ethiopia is soil bund construction. The recommended bund specification is a vertical interval of 1 m for slopes up to 15% and 2.5 times of the soil depth for lands with a slope gradient of less than 15% to suit different crops.

Bunds have a part to play in the farming systems of Ethiopia and most of the farmers are aware of the benefits of soil bunds as an effective measure to control runoff. But they are reluctant to construct bunds because they find it somewhat impractical to follow technical recommendations strictly. Bunds need frequent maintenance. Their effectiveness depends a great deal upon the inputs of technical personnel and on the way they are constructed and maintained. Thus one can conclude that bunds are no use in isolation and vetiver hedge rows must be integrated.

That is, farmers are advised to construct three or two master bunds at wider vertical intervals than technically recommended. In between, vetiver strips are established as inter-bund management**.** These strips will intercept some of the runoff, which could have been beyond the capacity of the adjacent bunds, and spread out the water by taking away its erosive power. Thus, the runoff discharge is properly managed and controlled. The new approach will minimize the labour and time required for bund construction by decreasing the number of bunds that were supposed to be constructed in a unit area, while greening the denuded areas.

Bund stabilization/maintenance

Developing terraced lands into bench terraces depends a great deal upon the way they are maintained. The labour required to maintain the terraces is quite considerable and farmers are reluctant to carry out this task. The observations made in the watershed have brought out the potential of vetiver in maintaining soil bunds. Here vetiver is used either to increase the height of successful bunds that have trapped enough silt or to maintain bunds that were broken out due to many factors, such as missing contour settings during establishment, uneven height, etc.

Contour strip/vetiver rows

In view of the ineffectiveness of protecting wide areas of land with soil bunds and of the difficulty to construct continuous bunds, let alone the high cost of construction, alternative methods of erosion control are being investigated. Vetiver has been identified as a suitable perennial plant for soil and moisture conservation purposes. Based on this perception, large areas of land have been treated with vetiver hedgerows.

Buffer zone

These are vetiver hedges of two or more rows spaced 0.5 to 1 m between rows and 0.15 cm between plants, usually established at the bottom of steep slopes. These intercept the runoff that could have flown further down the slope and also decreases and spreads the erosive power of the runoff.

Riverbank buffering by re-vegetation

To halt riverbank erosion one of the proposed interventions is re-vegetation of about 5 to 10 m width of the riverbank. With this intervention in addition to other trees and indigenous shrubs, vetiver has been established along riverbanks as a means to stabilize them.

Conclusion

At the present landscapes of the Zegzeg watershed, seven principal slope elements have been identified from the ridge crests of about 260 m to the riverbeds at about 1300 m. Recognizing them in the field gives the observer an immediate impression of whether soil erosion problems are severe or moderate. Soil erosion occurs on all land units (except unit VII, which has no soil cover).

Conversely, the seven land units have very different erosion hazards and each unit has its own range of limitations for the selection of conservation measures or land management options. But one of the strengths of vetiver hedges is that they are suitable or at least applicable to all the land units, without limitations and as an effective measure. Therefore vetiver is being used for wider purposes and the effects of vetiver bioengineering have been quite encouraging to date. Some thick vegetation hedgerows have been established and during field assessments and performance evaluation, vetiver hedges were observed to catch soil materials moving down slope in the process of erosion. Additionally, on denuded areas adjacent to the hedgerows the spontaneous growth of native grasses, which are greening the area, is encouraging.

Despite these important functions and other obvious advantages of vetiver in the watershed management programme of Zegzeg, there are limitations in using vetiver alone. It was found difficult to reclaim gullies deeper than one metre and unstable along sloped lands. Thus, the experience showed that vetiver bioengineering alone is not always adequate in watershed management and some small-scale physical engineering techniques have to be applied as well.

In general the major strength of vetiver is its effectiveness in checking soil transportation on hilly lands and mountain-foot slopes, because any soil that is being swept down is caught by the hedge, whose establishment is cost effective.

It is hoped that vetiver will significantly contribute to the rehabilitation of the degraded watershed of Zegzeg. Moreover since thatching material is in high demand, farmers will continue to establish vetiver hedgerows on a wider scope in the future.

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