Soil Conservation in Tigray, Ethiopia

By Kjell Esser, Tor-Gunnar Vågen,
Yibabe Tilahun and Mitiku Haile

Noragric Report No. 5

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1. INTRODUCTION

Land degradation is a major cause of poverty in rural areas of developing countries. In many areas, farming populations have experienced a decline in real income due to demographic, economic, social, and environmental changes. Land degradation is a result of several factors of both physical and socio-economic nature. The immediate consequence of land degradation is reduced crop yield followed by economic decline and social stress. The integrated process of land degradation and increased poverty has been referred to as the "downhill spiral of unsustainability" leading to the "poverty trap" (Greenland *et al.*, 1994).

Soil erosion is one facet of land degradation that affects the physical and chemical properties of soils. The physical parameters are primarily organic matter content, structure, texture, bulk density, infiltration rate, rooting depth, and water-holding capacity. Changes in chemical parameters are largely a function of changes in physical composition. The consequences of topsoil erosion on soil productivity depends on the depth and quality of the topsoil relative to the subsoil. In areas where the topsoil is acid and the organic matter content is initially low, surface erosion may, in fact, increase crop yields due to the exposure of a more favourable subsoil.

Tigray is the northern region of Ethiopia (Fig. 1). It consists of several agro-climatic zones, determined mainly by altitude, rainfall and temperature. The eastern parts of the region, including the Danakil depression, are extremely dry. The highlands of central Tigray vary in altitude from about 1 300 m to over 3 000 m in the highland areas of Adwa. Most parts of Degua Tembien and parts of Abergelle have rolling to hilly high plateaus. Most of the areas between 1 500 and 2 300 m have an annual rainfall of less than 900 mm. Rainfall in the area is unpredictable, and it is quite common to observe both water logging and drought during one cropping season. The population density in the region is relatively high, and small units of land are extensively cultivated by subsistence farmers.

The severity of soil erosion in the Tigray region and in Ethiopia in general, is the result of the mountainous and hilly topography, torrential rainfall, and low degree of vegetational cover. According to Hamilton (1977), deforestation started already 2 000 years ago. In many parts of Tigray, soil erosion has made cultivation of old farmland impossible. Farmers have been forced to constantly cultivate new and more marginal areas.

The objective of this presentation is to review soil erosion and conservation research as well as conservation efforts made in Tigray. We have included both traditional measures and activities promoted by non-government organizations (NGO's) and government projects. Main emphasis is placed on stone terracing and stone bunds since these are the most widely used soil conservation measures in the region. Relatively limited research has been made in Tigray. We have therefore included some important findings from other parts of the Ethiopian highlands for comparison.

2. SOIL EROSION IN TIGRAY

Depending on rates of soil formation and soil loss tolerance, soil erosion may not necessarily destabilize an ecosystem irreversibly. Hurni (1984a) found that the use of a soil degradation ratio, defined as the actual soil loss divided by a theoretically acceptable level of soil loss, is a practical method to evaluate the destabilizing potential of soil erosion in agricultural eco-systems. The cereal/livestock based ox-plough agriculture in Tigray has been described as less stable than agroforestry systems in more humid southern and south-western regions of Ethiopia (Getahun, 1984). This is mainly due to differences in climatic, vegetational, and demographic conditions between the regions. Tigray is characterized by torrential rains and frequent droughts, steep slopes, sparse vegetation and a relatively high population density. In addition, crop residues are commonly used as fodder for livestock, and manure is burned for heating and cooking, thus removing virtually all organic litter from the soils.

Approximate annual soil losses in runoff from cultivated fields can be estimated using the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) adapted to Ethiopian conditions (Gebreselasie, 1996). The adapted USLE equation has been able to predict an average of 40 % of the variation in soil loss at four sites over eight years. The discrepancy varies largely between -100 and 100 % (Fig. 2).

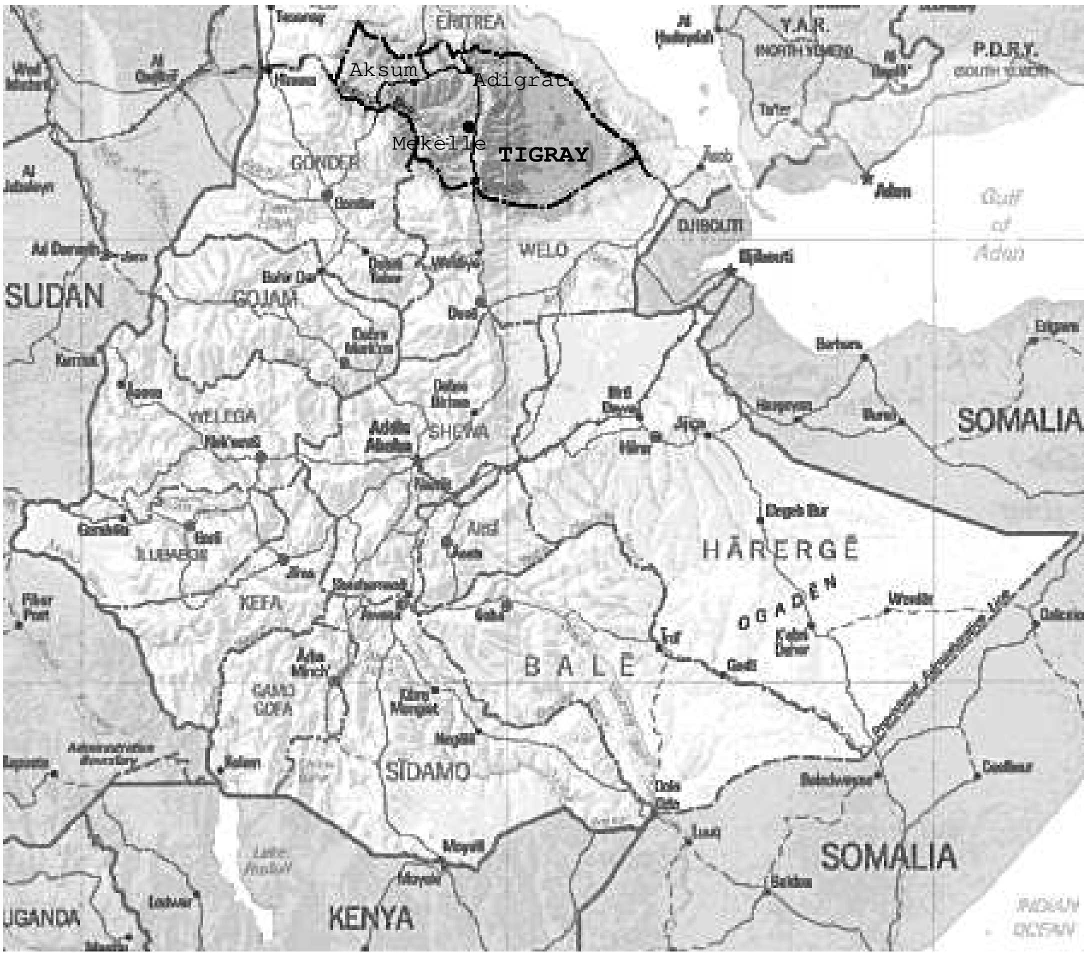


Fig. 1. Map of Ethiopia with the Tigray region outlined.

Soil erosion is severe in all of Tigray and poses a major threat to continued agricultural production in the area. Virtually all topsoil, and in some places parts of the subsoil, has been removed from sloping land leaving stones or bare rock at the surface. In order to feed the increasing population, steeper and more marginal lands are brought into cultivation.

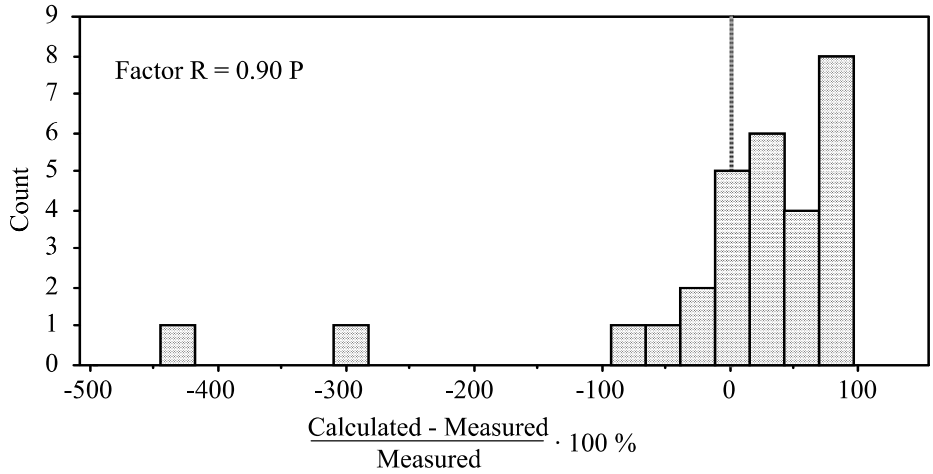


Fig. 2. Distribution of relative difference between calculated (using adapted USLE) and measured soil erosion at four observation sites over eight years (R-factor is set at 0.90 P; based on Gebreselasie, 1996).

According to the Land Use Planning and Regulatory Department (LUPRD) of the Ministry of Agriculture (MOA), 24 % of the Ethiopian Highland is presently "seriously" erosed and 25 % "significantly" eroded (Thomas, 1984). The LUPRD recently estimated that an additional 13 % of the land will be unsuitable for agricultural production if current rates of erosion persist for the next 25 years. The Quiha watershed area in Tigray had an estimated average soil loss of 33 000 kg/ha during the 1975 rainy season, while soil loss from the Maydollo watershed was estimated at an average of 17 000 kg/ha (Hunting, 1976). The latter is considered representative for the central plateau area (1 500 - 2 000 m elevation). Comparing this soil loss rate with the rate of soil formation estimated by Hurni (1990), soil material is lost from cultivated land at a rate 27 times higher than the soil formation rate.

A land suitability classification was made for Tigray based on the soil's susceptibility to erosion (Hunting, 1976). The slope of the land, soil depth and altitude were used as criteria when dividing the land into different suitability classes (Table 1 and 2). A map was then developed based on the land suitability classification. The C1, C2, C3, and C4 classes represent cultivated areas with few, moderate, intensive and very intensive conservation measures, respectively. Class code P represents areas with controlled grazing, F1 represents areas with exploitable forest and controlled browsing, and F2 represents protected forest.

Table 1. Altitude zones, suitability classes and main crops grown (Hunting, 1976).

Altitude zone	Land suitability class suffix	Main crops cultivated
< 1500	1	Maize, sorghum, teff, bean
1 500 - 2 000	2	All cereals, lentil, bean, chickpea
2 000 - 2 500	3	Finger millet, wheat, barley, bean, teff, pulse crops, linseed, neug, safflower
2 500 - 3 000	4	Teff, wheat, barley, bean, pea, lentil, vetch
> 3 000	5	Teff, barley

Vegetation cover is important for the protection of the soil surface from the beating action of raindrops (rain splash) and erosion by surface runoff. Studies in West Africa have shown annual erosion under natural forest cover lower than 500 kg/ha even on slopes up to 65 %, while rates were up to 1 000 times higher from bare soil on equivalent slopes (Roose, 1986). Data from Ethiopia also indicate the importance of land cover on soil loss (Table 3).

Table 2. Land suitability classes, average slopes and area cultivated in the central plateau area (Hunting, 1976).

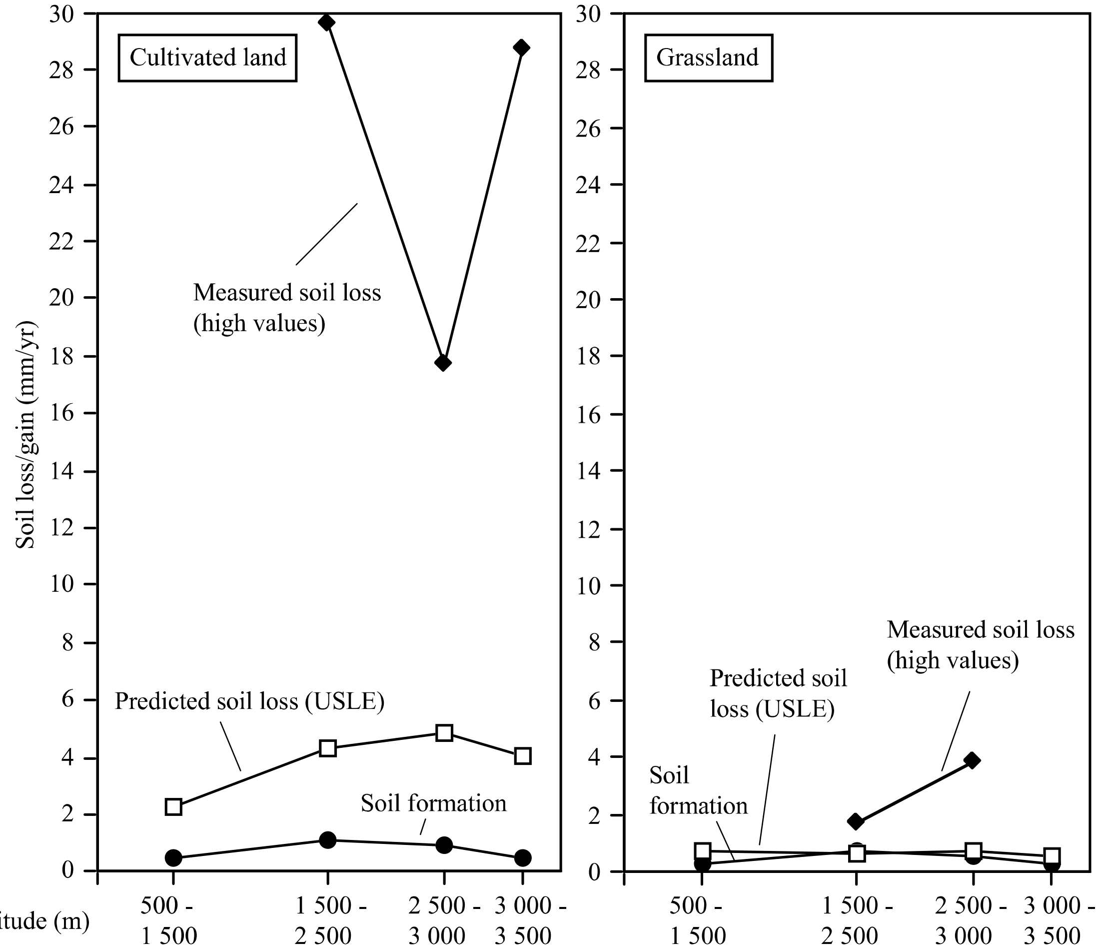
Land class	Average slope (%)	Total area (km^2)	Cultivated area (km^2)	Proportion of cultiv. area (%)
Level of measures				
Few (C1)	2	558	436	9.4
Moderate (C2)	4	1 351	1 132	24.4
Intensive (C3)	8	1 308	1 056	22.7
Very intensive (C4)	16	753	156	3.4
Sub-total		3 970	2 780	59.9
Controlled grazing (P)	20	1 761	824	17.8
Exploitable forest (F1)	20	553	270	5.8
Protected forest (F2)	25	3 496	768	16.5
Sub-total		5 810	1 862	40.1
Total		9 780	4 642	100.0

Table 3. Estimated rates of soil loss in Ethiopia for different land use and vegetation classes (Hurni, 1987).

Land cover type (from LUPRD)	Area	Estimated soil loss	
	(%)	(10^3 kg/ha·yr)	(10^9 kg/yr)
Cropland	13.1	42	672
Perennial crops	1.7	8	17
Grazing and browsing land	51.0	5	312
Currently unproductive	3.8	70	325
Currently uncultivable	18.7	5	114
Forests	3.6	1	4
Wood and bushland	8.1	5	49
Total	100.0	136	1 493

Under semi-arid conditions, there is normally sparse ground cover at the onset of rains, leading to relatively severe rates of runoff and soil loss. Erosion generally varies considerably according to land-use and agro-climatic zone. There is a much higher soil loss in cultivated areas compared to grassland. Measured soil erosion, predicted erosion, and estimated soil formation for four agro-ecological zones and two land-use classes are presented in Fig. 2. Soil erosion rates were measured in test plots and predicted values were obtained using a simplified version of the USLE (Hurni, 1990). Soil formation rates were estimated based on assumptions of soil regeneration as a function of geology and soils, slope gradient, climate and land use.

In many parts of Ethiopia, including Tigray, the shortage of firewood leads to the utilization of straw and leaves for fuel. Animal manure is also commonly dried and burned. Very little organic residues are therefore returned to the soil apart from the roots of annual crops. As a consequence, soils become low in organic matter after some time of continuous cultivation. Depletion of organic matter and destruction of soil aggregates lead to increased rates of soil losses in cultivated areas. The brown and black soils of the northern regions of Ethiopia are known to be productive even at relatively advanced stages of degradation. The fertility of the subsoil is related to the predominantly volcanic soil parent material and the associated higher concentrations of some plant nutrients as well as a relatively fine texture. In comparison, the fertility of the reddish soils in the western parts of the country are more easily influenced by erosion (Hurni, 1990).



	Cultivated land				Grassland			
Mean annual temperature (ÞC)	25	18	12	7.5	25	18	12	7.5
Mean annual rainfall (mm)	200	900	1 600	1 300	200	900	1 600	1 300

Fig. 2. Soil erosion and soil formation in Ethiopia in relation to altitudinal belt and land use (average values for measured soil loss are not available; adapted from Hurni, 1990).

Surface stones have been shown to protect the soil surface from erosion. In Kenya, very stony soils had significantly less soil loss compared to soils with 50 % or less stones on both cultivated land and grazing land (Barber, 1984). Studies in the Kori Sheleko watershed in Ethiopia showed a soil loss of 56 000 kg/ha from a non-stony soil on a 16 % slope as opposed to a soil loss of 2 000 kg/ha from very stony soils on slopes of 37 % (Hurni, 1982 in Barber, 1984). In the USLE adapted for Ethiopian conditions, stone content has been included under the management factors (P) (Hurni, 1985).

3. SOIL CONSERVATION IN TIGRAY

3.1. Background and perspectives

Land degradation attracted increasing awareness during the 1980s. A paradigm shift took place from projects dealing mainly with physical and chemical aspects of degradation towards integration of a broader range of disciplines. The pre-1980 period was largely dominated by a "technical-fix approach", where a physical problem was identified and a physical solution prescribed (Stocking, 1992). Since then, research has attempted to integrate different aspects of land degradation and rehabilitation. The terms used to identify problems and solutions have varied through "conservation", "desertification", "drought control", "agroforestry", "sustainable agriculture", "on-farm adaptive research" and so forth (Stocking, 1992). Emphasis is now on production possibilities, on social, legal, and institutional constraints, and on specific technical issues. An important development in research is the improved collaboration between scientists, administrators, and farmers recognizing the need for a joint effort to solve the various problems of soil erosion.

The aim of soil conservation is to facilitate optimum level of production from a given area of land while keeping soil loss below a critical value. The soil loss tolerance value is defined as the rate of erosion at which soil fertility can be maintained over at least 25 years (de Graaff, 1993). The effect of a conservation measure in reducing soil loss generally varies with soil type, topography, climate and intensity of the measure, e.g., the distance between terraces or density of vegetation cover. Mitchell (1986) gives equations that can be used to calculate the required terrace spacing when the natural conditions and the required protection factor are known.

3.2. Cross-slope barriers

The term “cross-slope barriers” embraces the whole range of terraces, ditches, drains and banks used to manage run-off or soil loss on sloping lands (Hudson, 1992). Bench terraces have been used for generations on all continents. A number of factors determine the type of terrace that is most suitable for a given area, such as purpose of terracing, steepness of slope, soil depth, and farming practices. The objective of terracing in dryland farming is to reduce erosion and increase water infiltration. Since most of the cultivation is done by oxen in Tigray, the width of the terraces must be sufficient to allow easy turning at each end. In cases where cultivation is done by hand, the width of the terrace is of less importance. Construction of terraces requires a great deal of labour input, which is a major constraint to their application. In some areas terraces with outward slopes are built, or the labour input is spread over time by progressively moving towards level terraces over several years. Due to the severity of soil erosion in Tigray, steep slopes and high stone content of the soils in the region, construction of stone terraces is often the only realistic option. Alternatively, grass strips can be created along the contour lines to reduce erosion on any slope. Grass strip contouring is used by many farmers in Tigray. According to Hudson (1992) the grass strip should be vigorous, easily propagated, provide good quantity of palatable fodder and not invasive into the crop area in order to be effective. In some cases, however, livestock must be kept away from the grass strips in order for the grass to grow to proper height. Grass which is unsuitable for fodder can be used, such as vetiver grass (*Vetivera zizanioides*). Vetiver is quite commonly used for this purpose since it can be grown almost universally (Morgan and Rickson, 1995). A number of other species can be used for vegetation strips depending on the preferences of farmers. A disadvantage of vegetation strips, as well as stone bunds, is that they can harbour burrowing animals that can damage food crops.

3.3. Soil conservation programmes

An afforestation and bench terracing programme was started in Tigray in 1971 under the auspices of a USAID food-for-work programme. This was later complemented by a UN/FAO world food program project (Hunting, 1976). From 1974, the World Food Programme (WFP) was the sole supporter of the project under the administration of the State Forest Development Agency. Implementation of terracing and reforestation was undertaken by the Extension and Project Implementation Department (EPID). The initial stage of implementation had technical failures like incorrect spacing and alignment of terraces, poorly organized nurseries and wrong choices of species (Hunting, 1976). Soil conservation programs were implemented by the contemporary new regime in 1976, with the assistance of donors, following the drought in Wello and Tigray. The soil and water conservation accomplishments made between 1983 and 1988 are summarized in Table 4. People mainly participated in these programs to receive food for survival. There was a general lack of commitment and awareness among farmers concerning the soil conservation efforts. From 1988 to 1990, the Tigray Peoples Liberation Front (TPLF) and the Relief Society of Tigray (REST) took over the soil and water conservation programs in the previously government held areas. The objectives of the soil and water conservation led by TPLF and REST were; (1) to promote food security, (2) to prevent environmental degradation and desertification by physical rehabilitation measures, and (3) to secure water supply for irrigation, livestock and domestic use. The program also emphasized the importance of community involvement at all levels including problem identification, planning, implementation, and evaluation. Demonstration centres were established in order to train farmers in soil and water conservation techniques. Food aid was used as a source of motivation for soil and water conservation activities. The area of land that was terraced between 1988 and 1995 in Tigray amounted to approximately 418 500 ha (Table 5), while 800 000 ha of land were terraced in the country as a whole during 15 years of soil conservation (Kejela, 1993).

Table 4. Physical structures for soil and water conservation completed from 1983 to 1988 (SAERT, 1994).

Structures	Length (km)
Hillside terrace	94 000
Bund construction	18 000
Bund maintenance	11 000
Road construction	290
Check dam construction	280

Table 5. Extent of soil and water conservation work organized by REST and TPLF.

Year	Area of land terraced (ha)	Source
Before 1988	2 000	Relief Society of Tigray, 1993 (donor forum)
1989	not available	
1990	56 000	TTAC, 1991
1991	not available	
1992	104 000	Bisrat News Magazine, 1995;1 (Reg. Govt. Tigray)
1993	96 100	ibid.
1994	86 100	ibid.
1995	74 300	ibid.
Total	418 500	

Stone terracing is demanding in terms of labour. The costs are usually not repaid by short-term increase in crop yields. On highly eroded, steep hillsides, there has already been a great loss of organic matter and plant nutrients. Some form of initial "restoration investment" is therefore needed. It is problematic to determine the benefits of soil conservation, even by easily measurable factors like productivity. A gradual decline in production can be expected if no conservation measures are implemented. Similarly, a slow productivity increase can be expected from conservation efforts. In many cases, however, the benefit of conservation may merely be the absence of a yield decrease. Modifying land management represents a risk for the farmers, and they will usually not do so unless it has an immediate economic benefit. Farmers will generally be willing to make such modifications only if soil erosion is perceived to pose a direct threat to farm productivity, or if changing their land management leads to an immediate economic gain (Barbier and Bishop, 1995). A minority of farmers have the resources to build terraces on their own. Support to farmers through food-for-work has therefore been necessary. Stone terraces require maintenance to avoid breaks in the stone bund structures. Lack of such maintenance is a problem due to labour shortage. Cuts through stone terraces may lead to severe, localized erosion with downstream gully formation.

3.4. Land use

Land preparation and planting

Oxen are used for ploughing, but many of the farmers do not have oxen of their own and need to rent from other farmers. Some farmers also consider leasing their land to other farmers as an option if they are short of oxen. It becomes difficult, therefore, for those who have no oxen to finish their land preparation in time. Almost no farmers consider preparing their land by hand even if this could have been a possible option when no ox is available. Hand hoe cultivation is not a common cultural practice in Tigray.

Most of the farmers use their own seeds for planting, but seeds are also bought from the local market and received from the local government in times when harvests are low. Some farmers use improved seeds. Planting times vary with the onset of rains and availability of oxen, but are generally set according to the traditional planting times that have been handed over from generation to generation (Wondimagegn, 1994). The method of planting used is exclusively broadcasting.

Cropping systems

Wheat and barley are the major crops in the highland areas of Tigray. In the lowlands, sorghum and maize are most commonly grown. Due to the unpredictable rains and frequent droughts, maize is grown to a lesser extent than before. The production of sorghum has also been reduced due to the late start of the rains and due to *Striga* (a parasitic weed). Teff is grown in all of the altitudinal zones, but is most common in the lowlands. Some of the minor crops grown in the area are millet, faba bean, chickpea, pea, grass pea, sesame, niger seed, lentil and *flax lathyrus*. The relative importance of these crops varies for different areas. Mixed cropping is commonly practiced in order to minimize risk. Most farmers do not consider more effective utilization of resources and cropping season since their primary aim is to minimize risk.

Agroforestry is practiced to some extent, although relatively rarely. In *keyih tekli*, a type of irrigated home gardening comprising citrus trees, coffee and banana is practiced (Wondimagegn, 1994). It is not a multi-layer system, however, as home gardens normally are. In the same area, scattered trees on crop land are also found, but the trees are widely spaced and probably have little effect in maintaining soil fertility.

3.5. Traditional soil conservation

Indigenous soil and water conservation techniques can be divided into "ethno-engineering", agroforestry and agronomic practices. Quite frequently, a combination of these practices exists. The term "ethno-engineering" covers indigenous practices such as terracing, harnessing of runoff, and development of small drainage systems (Jodha, 1990). The potential of these indigenous soil and water conservation practices have very often been ignored or underestimated by researchers, soil conservationists and government staff (IFAD, 1992).

The objectives of traditional practices give us an understanding of farmers' way of thinking (Hudson, 1992). The aim of farmers does not necessarily correspond with the aim of the scientist. Some practices are simply good farming practices that happen to reduce soil erosion. At other times, conservation practices are applied where there is no recognition of erosion as a reducer of yields, but they are used for other purposes (Hallsworth, 1987).

Physical conservation practices

Bench terraces are widely applied in the tropics in indigenous conservation systems. Terracing may have developed in western Asia and then spread southwards to Africa, westward to the Americas, and eastward to Southeast Asia, largely by known sea routes (Hallsworth, 1987). More likely, it may have evolved independently in several areas as farmers were forced to cultivate steep lands for several reasons, e.g., to escape hostile tribes on the plains, to avoid malaria at lower and warmer altitudes, and due to increasing population density (Hudson, 1992). The construction of terraces is not new to Ethiopia (Hurni, 1984b). The Konsos of southern Ethiopia are well known for their traditional soil and water conservation practices. Their farming is based on an elaborate system of terraces, a variety of other soil and water management practices and the integration of livestock and forestry with the rest of their agriculture (FAO, 1990). Stone bunds are generally quite common in the dry zones of the tropics, since they are relatively easy to construct during the dry season. Sloping terraces are present in several parts of Ethiopia. Hunting (1976) reported that most of the terraces seen in Tigray are only half formed so that the walls only rise about one third of the vertical interval between benches, and thus are largely ineffective in controlling soil erosion. Other physical conservation structures traditionally built by farmers in Tigray include check dams and cut-off drains.

Agronomic conservation practices

In a field study among 52 farmers in the Hagere Selam uplands of Tigray, 48 of them were practicing crop rotation (Vagen, 1996; Tilahun, 1996). Many of the farmers used crop rotation as a means to conserve soil fertility by planting legumes one year and non-legumes the following cropping season, e.g., bean or lentil, then barley or wheat. Farmers also incorporate legumes in their crop rotations approximately every four years. Other traditional soil conservation practices are contour ploughing, grass strips and tree planting. The traditional way of ploughing graded contours is used by nearly all farmers. Due to the population increase, traditional fallow periods have become very short and rare, if existent at all. Manure is used by some farmers, but due to the shortage of fuel wood, it is most commonly dried and used for cooking and heating purposes.

4. BENEFITS OF SOIL CONSERVATION

4.1. Soil fertility

Very few studies have been conducted to assess the effects of soil conservation on soil fertility in Tigray. Weigel (1986b) determined some physical and chemical characteristics of soils from the soil loss zone directly below contour bunds and the soil accumulation zone above the contour bunds in the Maybar/Wello area. The concentration of plant available phosphorus was higher in the soil accumulation zone than in the soil loss zone down to 50 cm depth (Table 7).

Table 7. Characteristics of soil samples taken from accumulation and loss zones of a sloping terrace (adopted from Weigel, 1986b).

	Topsoil (0 - 25 cm)		Subsoil (25 - 50 cm)	
Soil characteristics	Accumulation zone	Loss zone	Accumulation zone	Loss zone
Organic matter (%)	4.16	3.44	4.13	2.72
Total nitrogen (%)	0.17	0.15	0.20	0.14
Extractable P (mg/kg)	11.89	8.19	8.02	5.69
Exchangeable K (cmol/kg)	0.86	1.12	0.46	0.89
Clay content (%)	42	49	48	56

Vagen (1996) studied soils in a topo-sequence of terraced (down- and mid-slope) and non-terraced land (up-slope) in the Hagere Selam uplands in Degua Tembien, Tigray. Surface soils from terrace benches and the soil loss zone of terraces had the highest clay contents, while soils from non-terraced land were more sandy. Cation exchange capacity and base saturation were high for all soil groups due to the influence of mafic volcanic rocks in the area. Organic carbon and total nitrogen contents were very low for all soil groups, but slightly higher in soils from non-terraced land. The experimental design did not, unfortunately, permit a separation of the impacts of slope position, soil erosion and deposition, and agricultural history on soil fertility. Non-terraced areas, which were located only on the concave upper part of the slopes, had been cleared much later than the terraced areas, leaving less time for depletion of organic matter and consequently nitrogen. Soils from terrace benches had higher concentrations of available P than soils from the soil loss zone of terraces and from non-terraced land (Table 8). There were some variations, however, between plots with bean and wheat with respect to differences in concentrations of available P between soil groups (Table 8). Phosphorus is normally strongly bonded to soil particles and are therefore easily transported down slope during erosion, giving higher concentrations of available P in the soil accumulation zone of terraces. The terraces were only 4 years old or younger. More time will probably lead to greater differences in available P between soil groups due to prolonged erosion, particularly between non-terraced land and soil accumulation zones on terraces.

Table 8. Extractable phosphorus in the soil from different parts of terraces under bean and wheat cultivation (Vagen, 1996).

Location	Extractable phosphorus		
	Bean	Wheat	Average
	-------------------- mg/kg --------------------		
Bench of terrace	12.07 (b)	16.07 (a)	14.07 (a)
Soil loss zone of terrace	10.31 (b)	10.39 (b)	10.35 (b)
Non-terraced (up-slope)	11.16 (b)	10.22 (b)	10.69 (ab)

Different letters within columns indicate significantly different observations at 95 % confidence.

4.2. Crop yield

The benefits of terracing on crop yields vary with the degree of degradation before terraces are built. The beneficial effect may be limited to a prevention of further erosion or a slow but persistent increase in soil fertility. In either case, the relative increase in crop production may not be obvious to farmers.

Yohannes (1989) compared barley crop and biomass yields above the bund (soil accumulation area) and below the bund (soil loss area) of *fanya juu* terraces in the Andit Tid area of northern Shoa during three cropping seasons from 1986 to 1987. The average barley yield was 1650 kg ha^{-1} above the bund, which was 43 % higher than below the bund.

Prevention of runoff through tied ridging led to marked increases in sorghum and maize yields in the Harerghe highlands (Table 9). Maize showed highest yield increase due to its sensitivity to moisture stress. Sorghum, on the other hand, is more drought-tolerant and did not show the same response as maize.

Table 9. Average yield increases due to tied ridging in the Harerghe highlands in 1981 and 1982 (Barber, 1984).

Year	Maize	Sorghum
	------------ % -------------	
1981	36.4	16.8
1982	20.7	18.4

Gebre Egziabher (1988) found that soil bunds are effective in controlling soil erosion in a study from the Gununo twin watershed, Sidamo Research Unit of SCRP. Yields of maize were found to be higher in the soil accumulation zone (above bunds) than in the soil loss zone (below bunds). This is consistent with findings by Weigel (1986a).

Tilahun (1996) estimated yields of wheat and faba bean grown on soil accumulation and soil erosion segments of terraces and on un-terraced (upslope) areas in Degua Tembien (same plots as used by Vagen (1996)). Yields were highest at the accumulation zone of terraces (Table 10). Yields of wheat correlated positively with both silt contents and available P concentrations (Vagen, 1996). The positive correlation between yield and silt content in plots with wheat probably reflects the influence of silt on the moisture holding characteristics of the otherwise sandy soils. Available P seems to explain parts of the variability in yields between the soil groups, but is mainly a group effect since the available P contents and yields are higher on the terrace benches (Table 8 and Table 10).

Table 10. Mean grain and straw yields of wheat and bean from the different soil groups (Tilahun, 1996).

Soil group	Wheat		Faba bean	
	grain	straw	grain	straw
	------- kg/ha -------			
Accum. zone of terrace	1 601 (a)	2 825 (a)	806 (b)	1 203 (b)
Erosion zone of terrace	851 (b)	1 454 (b)	549 (b)	749 (b)
Non-terraced land (upslope)	664 (b)	1 169 (b)	537 (b)	643 (b)

Different letters within columns indicate significantly different observations at 95 % confidence.

5. FARMERS' PERCEPTIONS

Although an understanding of the physical erosion phenomena is important for the formulation of erosion control strategies, it is also vital to understand social relations influencing management choices. Traditional land resource utilization in many areas has followed an exploitative sequence consisting of clearing cultivation erosion abandonment (Kuru, 1986). This unsustainable farming practice is linked to a lack of choice due to poverty rather than linked to neglect. Interviews with farmers in Tigray verify that they are, in fact, concerned about the degradation of their land (Hunting, 1976). However, there is apparently a widespread apathy due to the fact that they are living barely on a subsistence level. They do not have the economic or labour capacity to implement necessary conservation measures. In some cases farmers are aware that some of their actions are actually damaging the land, but the immediate benefits of these actions seem more important than long-term degradation.

A study of Ethiopian farmers' attitudes to land degradation and conservation by Admassie and Gebre (1985) indicated that farmers were aware of the problems of land degradation. Erosion was identified as the main cause for land degradation, followed by drought, deforestation, rainfall, and improper farming practices. According to the farmers, the effects of land degradation were famine, drought, reduced yield, and poverty. Soil and water conservation activities undertaken by farmers prior to the food-for-work projects were mainly construction of drainage canals and ditches as well as soil and stone bunds. Farmers also practised fallowing, mulching and crop rotation. Among the food-for-work activities, soil bunds, hillside terraces, reforestation, and stone bunds were considered by farmers to be the most effective for soil and water conservation. In the Gunono area of Wolaita, 80 % of the farmers were of the opinion that soil bunds increase yields, 7 % responded that there is no change, 6 % did not know, and 7 % did not construct bunds or terraces at all (Gebre Egziabher, 1988).

Farmers in the Hagere Selam uplands, Tigray, conducted a land capability classification in 1989 (Tilahun, 1996). The land was classified as areas suitable for cultivation, grazing land, or closure. The cultivable areas were further classified into degraded, medium and fertile land. Available land was then allocated to all farmers in the farmers' association (*tabia*) according to the land quality. Farmers receiving fields on degraded land were allocated 2 500 m^2 while the share of medium and fertile land was 1 650 m^2 and 1 250 m^2, respectively. This practice demonstrates the understanding among farmers of the consequences of soil erosion and land degradation.

Fifty farmers interviewed in Hagere Selam showed that they and their families had participated in soil and water conservation implemented by campaign programs (Tilahun, 1996). The individual time spent annually on such work ranged from 14 to 540 days with an average of 133 person-days per family. The conservation work done through the campaign was mainly building of stone terraces and micro-dam construction. Only 26 % of the farmers constructed soil conservation structures on their own, mainly down-sloping stone terraces. Some farmers also made check dams in order to control gullies. Most farmers were positive to building conservation structures, and 80 % said that soil and water conservation investments were profitable. Sixty eight percent of the farmers were of the opinion that conservation practices led to increased yields in normal years. They were mostly in favour of building stone terraces on their own, but lacked the necessary labour. The farmers classified their land into different classes according to degree of erosion (Fig. 4). Most plots were evaluated as having less soil erosion after the conservation structures were built (Fig. 5). The farmers were also asked what they perceived as the most important causes and effects of soil erosion. Deforestation and over-cultivation were rated as the most important causes (Fig. 6). Reduced productivity was by far the most frequently reported effect of erosion (Fig. 7). According to the farmers, the most serious disadvantages of stone terraces include; (1) harbouring rodents, (2) causing water logging, (3) making land preparation difficult, and (4) aggravating soil erosion on steep slopes due to the removal of stones from the soil surface when constructing terraces.

In many cases the technical standard of terraces built through food-for-work projects is poor. There is also commonly a lack of involvement from the farmers and consequently little sense of ownership resulting in poor maintenance. This can be seen many places in Ethiopia, including Tigray. Food-for-work projects conducted by REST are largely exceptions to this. REST has been able to involve farmers and create attachment to the conservation work. This may be a result of the war situation and REST's constant involvement during difficult times. The food-for-work programs implemented by REST are based on the wishes and needs of farmers. The main reason for the present lack of maintenance of terraces in Tigray is commonly shortage of labour rather than lack of enthusiasm by farmers.

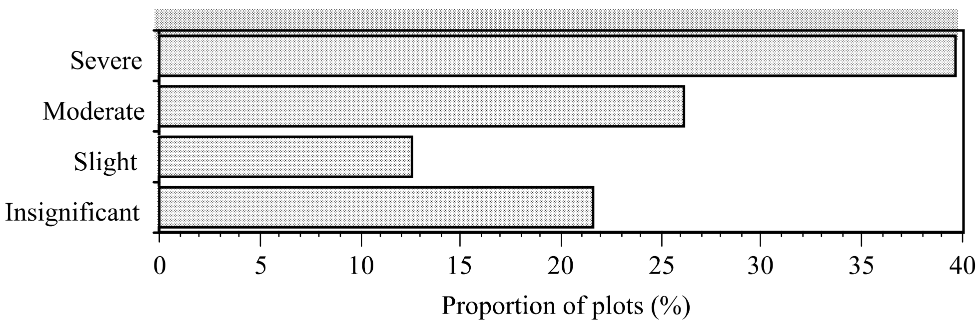


Fig. 4. Level of erosion before conservation according to farmers (Tilahun, 1996).

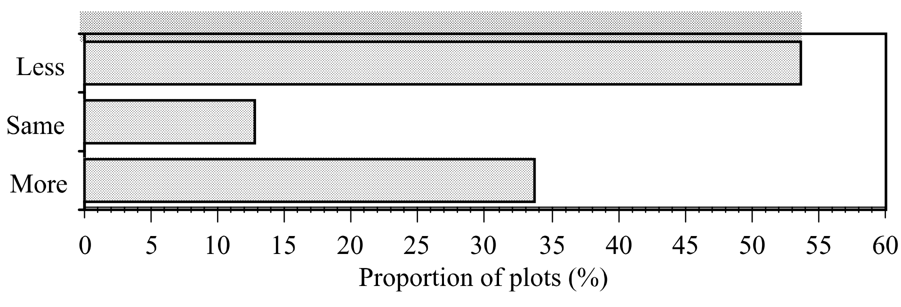


Fig. 5. Change in level of erosion after conservation efforts according to farmers (Tilahun, 1996).

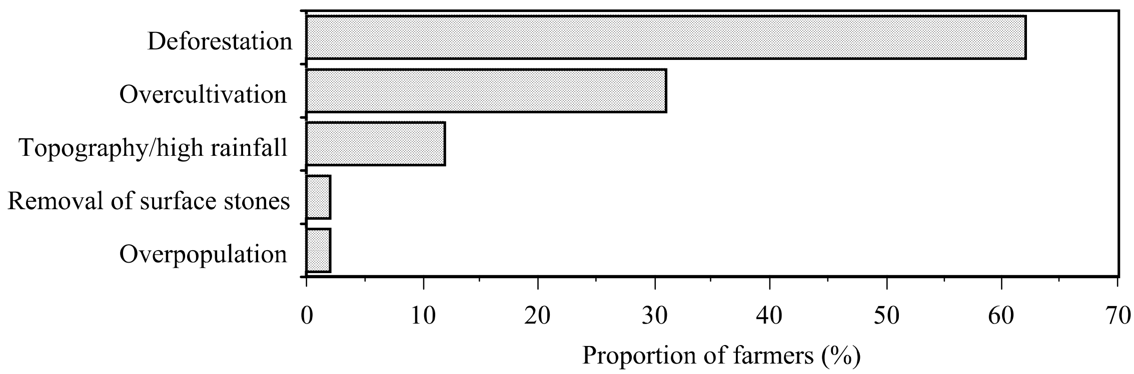


Fig. 6. Major causes of erosion according to farmers (Tilahun, 1996).

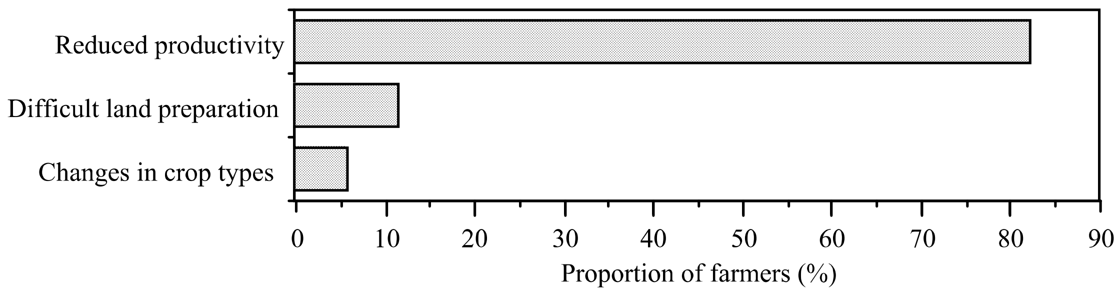


Fig. 7. Major effects of erosion according to farmers (Tilahun, 1996).

6. Conclusions

The severity of soil erosion in Tigray makes investment in soil conservation necessary for continued agricultural production in the region. Various agronomic and physical soil conservation measures have, to some extent, been used traditionally by farmers in Ethiopia. In Tigray, down-sloping terraces are most commonly created by the construction of stone bunds. Farmers also construct check-dams and cut-off drains. In addition, farmers use various agronomic conservation practices, including contour ploughing and vegetation strips. The traditional practices are efficient in controlling soil loss in some cases, but should be modified and developed further. One example is the down-sloping stone terrace which does not control erosion sufficiently on steep slopes. Construction of level bench stone terraces was implemented through USAID and government food-for-work projects in the 1970's. Most of the terraces built in the region have, however, been constructed after 1988 organized by REST and TPLF as food-for-work programs. Terraces are most commonly constructed of stones since the soils are generally shallow and their stone content is generally high. Stone terraces can be constructed during the dry season when labour is available. Other soil and water conservation measures implemented through food-for-work activities include tree planting and dam construction. Food-for-work projects are often regarded by the local people merely as a way to obtain food for survival. This leads to a lack of commitment and awareness by the farmers involved concerning soil conservation. In some cases, the negative effects of indifference may be devastating due to poor organization and incorrect construction of terraces.

Soil conservation research in developing countries has changed during the past decade, from a "technical-fix approach" to an approach where several aspects of land degradation and restoration are brought into focus. It is important that farmers participate in the planning and implementation phases to a greater extent than before. The food-for-work projects organized by REST in Tigray take the participation largely into account. Community involvement is emphasized in the approach taken by REST. Farmers in the region are now quite committed to soil and water conservation—not only as a means of getting food aid, but also to reduce land degradation.

The impacts of soil conservation on soil fertility and crop yields have been studied to a very limited extent in Tigray. It is therefore not possible to quantify the benefits of soil conservation on food production. Research results from other parts of Ethiopia show that the construction of stone terraces and soil bunds leads to increased soil fertility and crop yields in the zone immediately above the bunds compared to the soil-loss-zone below bunds. Much of the down-slope fertility gain on sloping terraces is linked to a related loss in fertility up-slope. The building of stone terraces in Hagere Selam, Tigray, led to increased yields of wheat on four-year old terraces. Farmers also seem to be aware of the long-term effects of soil conservation measures on crop yields, but may not be in a position to act on their own to protect their soil.

When recommending changes in farming practices, a new approach to the farmer is needed in many cases. Since reducing soil erosion is likely to be a less important objective for the farmer than securing immediate food needs, recommended changes should be shown to provide tangible results. Construction of mechanical conservation structures should be followed up by other inputs, such as fertilizer, improved seeds, and other farming factors. If no additional improvement is offered, the promised yield increase from conservation measures is likely to be small.

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