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Soil and Water Resources and Degradation Factors Affecting their Productivity in the Ethiopian Highland Agro-ecosystems

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Abstract

Ethiopia has not been able to maintain its economic, political and social development because of internal and external pressures for many years. The natural resource is the worst hit by the slow progress in economic development and this has made matters worse. To get out of the stagnation the present government has adopted a policy called Agricultural Development Led Industrialization taking agriculture as the stepping stone to industrialization.

The soil and water resources of Ethiopia although, still rich, is going through fast degradation processes. Topography, soil types and agro-ecological parameters are playing significant role in the degradation processes influenced by man.

The fast growing population of Ethiopia is playing significant role in hastening land degradation. The population of Ethiopia has tripled in the last 50 years. The increasing population abused land by deforestation and overgrazing for more cropland and grazing area. Recurrent droughts have aggravated the situation leading to repeated cycles of famine in recent years.

Three major types of land degradations are affecting productivity. These are biological, chemical and physical degradations of soils. As a result soil organic matter has declined, soil nutrients depleted, and soil depth decreased leading to the decline in yield of crops and forages. Yields are also declining due to the effect of soil acidity, salinity and drainage problems as well as the inherently low available soil phosphorus.

However, the most serious problem of Ethiopia's land resources is soil erosion. Every year the country is losing billions of birr in the form of soil, nutrient, water and agro-biodiversity losses and awareness creation.

Efforts have been made and are still being made to avert the degradation but with very little progress. A lot is yet to be done in the area of policy issues and economic development.

1. Introduction

The country has maintained its political independence by resisting foreign invasions and economic dominance, but internal conflicts, wars due to border disputes and failure by successive governments in handling economic and political affairs did not give chance to develop the economy. Hence, mainly the rural population became the victim of natural disaster such as drought. The country remained poor and totally depended on the natural resources (land and vegetation) for its livelihood. Because of over exploitation, mismanagement and natural disaster the natural resources (vegetation, soil and water) suffered most, in some areas beyond recovery. The objective of this paper is to review the soil and water resource base, the degradation that is taking place now and summary of the coping strategies.

Agricultural development strategy

In the economic development policy of the government of the Federal Democratic Republic of Ethiopia, the development of the agriculture sector has been taken as the steppingstone to the development of the industrial sector in what is known as "Agricultural Development Led Industrialization". To attain this goal, meeting the following objectives is essential. (i) Insure production of food in quality and quantity; (ii) increase and diversify the production of raw materials for the industries; (iii) increase and diversify the production of export commodities, (iv) improve the living standard of the rural people as they are the main work force for agricultural outputs and (v) conserve, develop and utilize the natural resources in friendly ways

However, increasing production of local or improved varieties of crops, forages and livestock will depend on the quality of land. To meet an improved and sustainable use of the natural resource (soil and water) now and in the future it is imperative to conserve, develop and utilize land in friendly ways.

Geographic diversity having high rugged mountains, flat-topped plateaus, deep gorges, incised river valleys, and rolling plains is a specific feature of Ethiopia. Most of the country consists of high plateau and mountain ranges with precipitous edges dissected by numerous streams, which are the tributaries of many rivers. The physical conditions in altitude have resulted in a great diversity of climate, soil and vegetation.

2. The Natural Resources Base

The diversity in climate, soil and vegetation has encouraged the development of 18 major types of soil associations, which in a way are assets, if properly developed and exploited. Such development has also influenced the type of land use practiced and the settlement of population in different parts of the country where dependable crop growing period and fertile soils were sustainable.

2.1 The Major Soil Resources

The conditions that favored soil development in Ethiopia:

Of the 18 major soil associations existing in Ethiopia only few are important from agricultural development point of view. These are Nitosols, Cambisols, Vertisols and Fluvisols and their proportion is given in Table 1. The soils that are important as arable land have a total area of about 40 million hectare.

The Nitosols dominantly occur from sub-moist to humid agro-ecological zones mainly in the western and southern parts of the country. These soils are highly weathered, acidic, high P-fixing and well drained. However, Nitosols are vulnerable to erosion and leaching.

Table 1. Major Soils of Ethiopia and their Area Coverage in Percentage

Soil type	Square km	Of the total Land area (%)	Of arable land area (%a0
Litholos	210 585	17.1	-
Nitosols	150 089	12.2	23
Cambisols	144 438	11.6	19
Regosols	135 613	10.9	-
Vertisols	123585	10.0	18
fjuvisols	102 461	8.3	-

Source :LUPRD 1986

Source: - LUPRD 1986

Cambisols: These soils occur in the steep slopes and spread all over the country, but mainly they border the large areas of Nitosols in the western highlands and Lithosols in the Harerge highlands and a large patch in the northeast. It shows wide variability as compared to the other major cultivated soils in the country.

Vertisols: These are the soils commonly found in the central highlands namely Shewa, Gojjam and Wello. However, Vertisols also occur in southern, eastern and western parts of Ethiopia specifically in Sidama, Wolaita, Arsi, Bale, Hadiya, and Guragie zones in the south, and in Jima, and Gambella in the Southwest and Harerge in the east. In most cases Vertisols are found in topography having flat or gentle slopes. The main constraints of these soils are waterlogging during the wet season and cracking during the dry season thus creating cultivation difficult for the traditionally oxen-drawn plowing or tractor operation. The good advantage of Vertisols is its relatively better fertility compared to the other major soils.

Some foreign experts always suggest to use Verisols for rice production. However, during the cropping season the Ethiopian highlands are cool with minimum temperatures as low as 10 ^{0}C or lower and too cool for rice production. Rice production is however, already introduced to Foggera plain North of Lake Tanna and Gambella in the west having Vertisols and warm temperature.

Fluvisols: Fluvisols are very fertile soils developed from recent alluvium. These soils occur on flat ground at the bottom valleys along the sides of streams. Condition of this soil is highly variable depending upon where it occurs. It may be calcaric or non-calcaric and often has drainage problem but can be improved through the construction of cumber bed. Fluvisols are very productive if used during off-season by using irrigation or in the small rainy season.

2.2 Water Resources

The Ethiopian plateau is the source of the Abay, Tekeze, Mereb, Baro, Akobo and Omo rivers that flow to the west and southwest. The Baro/Akobo basin is potentially the largest possible irrigable area although none of it has yet been developed probably because of the large investment requirement and the distance from the central market for commercial agriculture. Awash River is the only river that is extensively used for commercial plantations of industrial and horticultural crops in the Rift Valley. From the total irrigated agriculture of about 161,125 hectares, over 43 % are found in the Awash River basin. This is also the river providing 440 giga watt hour (GWH) which is 20% of the current energy requirement of the country from hydroelectric power source. The remaining potential for irrigated agriculture using Awash River is estimated at 136 220 hectares (Aberra Mekonen and Deksios Tarekegne, 2001). The potential for developing irrigated agriculture nationally is given in Table 2.

Table 2. Potential for Irrigated Agriculture in Ethiopia

Basin	Hectare
Abay	711 000
Awash	206 400
Baro Akobo	483 000
Genale Dawa	326 000
Mereb	38 000
Omo Gibe	348 100
Rift Valley	46 500
Tekeze	302 000
Wabi Shabele	122 000
Total	2 583 000

Source: Aberra Mekonen and Deksios Tarekegne, 2001

Small-scale irrigation:

By definition a small-scale irrigated agriculture has a unit area of not more than 200 ha. Recurrent droughts in the last two decades have led to increased interest in the development of small-scale irrigation. Some of the Regional States have established Irrigation Development Authority whose responsibility is to study the feasibility and develop irrigation structures at small-scale level. There are two categories of small-scale irrigated agriculture in the country, the traditional and the properly designed or the modern type. All over the country there are an estimated 130 340 and 48 074 ha under the traditional and the properly designed modern methods, respectively. The bulk of them are in Oromia, Amhara and South Nations, Nationalities and Peoples Regional States (Tedesse Bekele 2001).

2.2.1 Threats to Water Resources

It is true the country is endowed with water resources. However, there are some constraints that limit the use of water resources for irrigation. The physiography of the country where most of the population concentrated is undulating and not suitable for furrow irrigation, the simplest method of irrigation with greatest loss of water.

In the past 40 to 50 years, due to increasing population pressure in the high lands, fast deforestation took place that has exposed the land to severe water erosion. Hence, the valley bottoms, which could have been put to irrigation, are filled with sediments, making the construction of irrigation structures difficult. There are several examples of failed irrigation projects and structures as a result of filling up of canals or micro-dams by sediments that made maintenance expensive (e.g. Borkana micro-dam in south Wello).

Another impact of deforestation in the development of irrigation is in irregularity in the supply of water to the canal. About forty or fifty years ago many of the Ethiopian streams in the highlands were perennial where the springs at the mountain foots and hills provided continuos supply of water to the streams. At present however, the springs and streams are dry as a result of deforestation at upstream and the supply of irrigation water is at stake.

The Awash River has been infested by water hyacinth that may eventually threaten the use of water for irrigation. Except in the southwestern region of the country where vegetation cover is relatively better many tributaries of the major rivers are dirty and may not fit to continuous pumping or sprinkler irrigation as it may obstruct the structure.

The constraints of the major rivers are that many of them are in deep gorges making the construction of irrigation structure expensive. Otherwise water from most of the Ethiopian rivers are safe to use for irrigation.

2.3 Vegetation

In this section the importance of vegetation is seen in the context of soil erosion control, soil moisture conservation, and its role in the conservation of agro-ecological balance of an area. In the early 1950s it has been estimated that high forests covered 16% of the country, 3.8% in the early 1980s and only 2.7% or less since 1989 (EFAP 1994, IUCN 1990). At present this figure has further dropped down as a result of the increasing population depending totally on forest resources for fuel wood, construction materials and other uses (EARO, 2000). Consequently, land has been exposed to severe soil erosion. Water infiltration has been significantly reduced as a result of the accelerated flow of the runoff down the slope.

2.4 Topography/ Relief

Ethiopia has great geographic diversity with high and rugged mountains, flat topped plateaus, deep gorges, incised river valleys and rolling plains. The physical conditions and variations in altitudes have resulted in a great diversity of climate, soil and vegetation.

The Ethiopian relief includes a range of altitudes stretching from below sea level to nearly 4600 meters above sea level. Within these extremes, about 50% of the land surface is above the 1500 m contour line. The major characteristics of Ethiopia's relief and landscape are also illustrated by cross section characters over much of Ethiopia and the limited extent of flat surfaces that are represented in Ethiopia.

The difference in altitude and therefore of climate conditions have provided the scene for a wide variety of cropping patterns in agriculture. The extreme difference in altitude has also created the conditions for high potential in the production of hydro-electric power.

2.5 Agro-ecological elements influencing the Natural Resources

The present agro-ecological zone classification and characterization system followed, in Ethiopia, primarily focuses on potential biomass productivity and secondly on species composition and distribution of the plant community of an area or zone. Biomass productivity is a function of climate, soils, and management of which moisture and temperature are the important ements of climate. Moisture availability for plant growth was assessed by giving attention to the concept of the length of growing period (LPG), which considers the mean monthly rainfall and mean monthly evapo-transpiration relationships. The length of growing period is an uninterrupted time during the year when precipitation is greater than one half the values of evapotrnspiration. For agricultural planning purpose dependable growing period that can be expected in four out of five years with sufficient moisture for optional plant growth was considered.

The second important parameter required to classify the major agro-ecological zones in combination with moisture availability is the thermal class zones. Three major temperature regimes were adopted and the matrix of six LGP with three thermal zones gave the 18 major agroecological zones.

The influence of topography on the natural resources has been explained earlier. The commonly observed physiography used in this study is mountains, plateaus, gorges, valleys, lakes and rift valleys and lowland plains. The combinations of these physiographic features with the major agro-ecological zones produce the sub-agro-ecologica zones of an area. Further subdivision of the sub-agro-ecological zones takes into consideration the farming/land use system and the soil types.

Within the last two generations the agro-ecology of Ethiopia has been modified. Some of the indicators of the changes are observations by the elderly citizens who could compare the amount and pattern of precipitation at present day with those when they were young. Hence in Ethiopia, the occurrence of drought is more frequent today than fifty years ago. For example, there were 15-drought incidences observed as a result of the failure of the short rain or its late onset. The main rainy season may start late or stop early. Some study however, indicate that the moving average of the total amount of rainfall is not very significantly low (EARO/ICRA 1999). The late onset or early stopping of the rain once in 4 or 5 years may not have significant impact on the economic life of the rural people. Crises may occur when the biomass produced during the same season is low and consumed by livestock and people leaving the land bare.

2.6 Agents contributing to degradation

Human population: Rising population, soil erosion, undulating topography, and deforestation have contributed to the rapidly declining soil fertility. The population of Ethiopia was estimated at 20.0, 23.6, 29.4, 37.7, 50.1 and 61.8 million in 1950, 1960, 1970, 1980, 1990 and 2000 respectively. The estimated rate of growth for selected periods from 1935 to 1989 is given in Table 3 (EPA 1997).

Table 3. Rate of growth of population for selected periods

Period	Growth rate	Period	Growth rate
1935-1939	1.30	1960-1964	2.20
1940-1944	1.50	1965-1969	2.30
1945-1949	1.80	1970-1974	2.60
1950-1954	2.00	1975-1979	2.80
1955-1959	2.10	1980-1989	2.95

Asmerom Kidane, 1987 (As quoted by EPA by 1997).

The current rate of growth of population is estimated at 3.4%. The increase in human population in the highland, to some extent, has also caused increase in the population of livestock where 88% of the human population is concentrated (EFAP 1994, CSA 1999, EPA 1997). The rising human and livestock populations together have exerted pressure on the natural resources. In need of fuel and construction wood the rural population depended fully on cutting trees (Table 4). This table indicates how fast population has increased in the last 65 years and depended on the natural resources compared to the nearly stagnant economic growth.

In 1992 the total fuel wood requirement was estimated at a total of 45 million m^3 of which the rural and urban need was 41.6 and 3.4 million m^3, respectively. It is forecasted that the demand will double by 2015 in the countryside and increase by 150% in urban areas. The estimated annual woody biomass yield after the requirement for construction and industrial use deducted is 12.5 million m^3 that is totally used as fuel wood. It is observed that there is a deficit of about 32.5 million m^3 ((EFAP 1994). It is believed that some improvement will be made by reafforestation. However, most of the deficit will be covered by mining the forest resources and by the increased use of dung and agricultural residues. This process has been taking place for the last forty years. The farmers witness the effect of deforestation that has contributed to the decline in soil fertility. The farmers also needed grazing areas and forage and pasture for livestock. This has caused exposure of the land to severe erosion.

Table 4. Estimate of household energy requirement by source (1992)

Source of Energy	Urban		Rural	
	1992	2014	1992	2014
	(% of the total energy)			
Wood, Charcoal	62	42	66	68
Dung	16	8	20	13
Crop residues	11	5	14	7
Electricity	3	5	-	5
Kerosene, gas	8	20	-	2
Coal	-	10	-	5
Total	100	100	100	100

EFAP 1994

Table 5. Major types of vegetation and land covered at Adaa Bargaa District

Vegetation type	Area (ha)	
	1995	1996
High forest	2000	1717
Woodland	3500	3217
Reverie	670	387
Shrub and bash	3000	2613
Savanna	1000	717
Others	500	319

EARO/ICRA 1999/No. 3

3. Land Degradation

Land degradation, defined as a temporary or permanent decline in the productive capacity of the land, or its potential for environmental management, has been a significant factor of the low yield of crops and livestock in this country.

Parallel to this, potential climate climax vegetation is the vegetation that would develop in the absence of human interference and reflects the existence of an area determined by environmental conditions only.

Hence, land degradation is an effect of altered agro-ecological elements on an area for a longer period of time reacting with the hand of man or other animals on the already disturbed eco-system. The work of these forces on land may bring about biological, chemical or physical degradation or combinations of them.

A sustainable agro-ecosystem can only result when the effect of conservation practices equals or exceeds the effects of soil degradation processes. Climate is a major factor determining the sustainability of an agro-ecosystem. The effects adverse climate must have occurred so many times in the past several centuries that had induced a form of soil degradation but in those days the recovery was faster because of the low density of human population. In the past two generations of this country, we have observed frequent famine cycles as a result of the late onset or the early stopping of the rain, shortening the length of growing period of crops. The effect of some of the droughts was not so severe but the socio-economic status of the peasant farmers was so low and forced them to tradeoff between the short-term benefits and the long-term negative consequences.

3.1 Biological Degradation

Biological degradation refers to a process that leads to a decline in the humus content of soil through mineralization. It includes the reduction in the organic matter content, declines in the amount of carbon from biomass and decreases in the activity and diversity of soil fauna. In the small cereal producing areas of Ethiopia, during the harvest time, the straw is carried away from the farm plot to the residential quarter or heaped at a central point within the farm before threshing. After threshing the straw is transported near the living quarter and is piled there for livestock feeding or roof thatching or sold to the nearby town dwellers for various uses. The straw is cut about 5 to 10 cm from the ground on which the cattle graze after the harvest season. In the maize and sorghum growing regions of Ethiopia, the stalk is left on the site or it is carried away for fuel, livestock feeding, fencing, and for construction in some case. Hence, crop residue return to the soil is very minimal.

Under normal situation organic residues are decomposed by the activities of soil microorganisms and the essential mineral nutrients are released to the plants upon mineralization. However, in the conventional method of preparing land for crop planting it is plowed several times before planting. Such operation exposes the soil to air several times inducing oxidation of the carbon and reducing the organic matter content of the soil much faster.

Today, in many parts of the country, the farmers plow their lands without rest or fallow because the size of the land is so small, they can't sacrifice any cropping season. Hence, the continuous cultivation practiced reduced the soil organic matter through oxidation and by leaching. The destruction of organic matter in the soil also reduces the activity of soil microorganisms and their population. Soils having their organic matter maintained showed significant improvement in the infiltration and retention of water after rain or irrigation (Derpsch et al, 1988 and Philips et al, 1985).

3.2 Chemical Soil Degradation

Soil Nutrient Depletion: Chemical soil degradation processes can lead to a rapid decline in soil quality. The highland agro-ecosystem of Ethiopia is characterized by intensive agriculture. There is over 63% increase in population in the last 20 years and the size of holding per household has shrunk and will likely continue to shrink unless there is a break through in economic development that will draw most of the labor force from the farm. The topsoil is exposed to severe erosion. Hence, production fields are becoming marginal to every farmer with respect to soil fertility. The farmers are also forced to move onto the valley slopes of 50 per cent gradient or above, despite an extension advice to cultivate only lands with slopes below 35 per cent (LURD/MoA 1997; Thomas Tolcha 1991). The farmers are also forced to cultivate the same land year after year without rest that aggravated chemical soil degradation. Among the cropped land cereals occupy about 90%. Hence, there is little option left to the subsistence farmer to improve soil fertility through crop rotation although resource rich farmers do practice some rotations and apply manure. Farmers with relatively small farmlands do not adopt soil conservation practices easily since they think it takes away part of their croplands. This has an impact on soil fertility management and soil conservation, which will then cause land degradation as a result of unsustainable intensification of the land. The continuous cultivation has also aggravated soil erosion because the land where most of agricultural activities take place is steep in many areas and the soil is carried away. The method of land preparation has favored erosion where together with the soil lost essential nutrients have been washed off Kefeni 1992. Severely degraded land has gone out of production particularly in steep slopes due to soil fertility and organic matter decline. In north Shewa some studies suggest reducing soil depth as a result of erosion (Yohanis Gebremichael 1989) and production of some crops may cease after about 40 to 50 years unless proper erosion control measures are taken from now onwards (Holden & Shiferaw B., unpublished).

Soil acidity:

In Ethiopia, soil acidity is a problem that has not been addressed in depth. Examples of some acidic soils are given in Table 6. It is observed that most of these soils are found in the highlands receiving high rainfall. Yields of the major cereal crops, particularly that of barley is as low as 0.5 Mg ha $^{-1}$ partly as a result of soil acidity Improving the soil pH by the application of lime and nitrogen and phosphorus has increased yield by threefold (Desta Beyene, 1987).

Salinization:

Soils of the Rift Valley and northern and northeastern parts of the country are high in pH. In these areas precipitation is low while evapo-transpiration is considerably high. In Lake Ziway basin salt incrustation is observed where irrigation is practiced by pumping water from the lake (Fisseha 1999). Several hundred hectares of land is also badly affected by salt in the Awash Valley mainly due to drainage problem or flooding. However, repeated monitoring of the quality of Awash River for irrigation showed an Ecw value for upstream and downstream sites ranging from 0.25 – 0.52 dS/m and below the FAO water quality limit for irrigation (Girma Tadesse et al, 1999).

Table 6. Status of soil acidity and phosphorus concentration in different types of soils from different regions

Locations	Soil types	Soil pH	Phosphorus level (ppm)
Bako	Chromic Vertisol	4.2	19 (Olsen)
	Pellic Vertisol	5.8	10 "
	Humic Vertisol	4.6	4 "
Metahara	Mollic Andosol	5.4	- "
N. Eastern escarpment	Humic/Mollic Andosol	5.2	8 "
Anno (East Wellega)	Humic Acrisol	4.7	1 "
Aleta Wondo	Nitosol	5.35	4.39 (Bray II)
Dale (Yirgalem)	Nitosol	5.49	4.87 "
Chorra (Illubabor)	Nitosol	5.42	7.04 "
Metu (Illubabor)	Nitosol	5.24	9.36 "
Gimbi	Nitosol	5.07	5.82 "
Harru	Nitosol	5.07	5.17 "
Anfillo	Nitosol	5.36	18.42 "
Kosa (Limu	Luvic Phaeozem	5.8	1.5 "
	Eutric Nitosol	5.4	1.25 "
Gumer (Limu)	Eutric Nitosol	5.2	2.8 "
	Luvic Phaeozem	5.2	2.7 "
Suntu (Limu)	Nitosol	5.2	0.2 "

Fixation of P: Phosphorus is the most limiting nutrient in the Ethiopian soils. Many studies carried out on Ethiopian soils indicate that total-P and available-P are low and P-sorption capacity is relatively high. The low available P in the soil is reflected in the low content of active P forms (Piccolo & Huluka 1986; Tekalign et al 1988; Paulos Dubale 1996). P-sorption capacity varies widely among the Ethiopian soils. Sahlemedhin and Ahmed (1983) found P-sorption ranging from 150 to 1500 mg P kg^{-1} in the soils they tested. Tekalign and Haque (1987) found very high sorption in a volcanic ash soil while Fluvisols and Regosols had very low sorption values. Sorption of P was significantly correlated with exchangeable and extractable forms of Fe and Al as well as pH and organic matter but it was not correlated to the clay content of the soils.

3.3 Physical Land Degradation

Overpopulation, deforestation, and large density of animals that trample the soil are contributing to faster degradation of the soil resources. The inherent nature of the soils like the low bulk density of Andosols makes the soils highly vulnerable to water and wind erosion. Physical degradation may occur as a result of movement of the soil away from its place, compaction, reduction in aeration and reduced permeability and sealing of the soil. Such degradation is accelerated largely by poor soil management practices or by the removal of soil covers by the land users or by overgrazing. Soil erosion is by far the largest process causing land degradation, in Ethiopia.

3.3.1 Soil Erosion:

The unique topography, type of soil, deforestation, intensive rainfall and low level of land management and the type of land use practiced all have resulted in heavy runoff that induced soil erosion particularly in the northern and central highlands. Soil erosion is taking place all over the country but because of the effect of overpopulation on land that is already fragile (steep and mountainous), and mismanagement of the land itself the northern and central highlands are the worst affected. Estimation made on the amount of soil that leaves the plot and deposited elsewhere or that leaves the country is very variable. This is expected because the Ethiopian relief, agro-ecology, type of soil associations, land use type, etc, are all very variable from one location to another. Kappel (1996) explained the source of variation in estimation as the complexity of land degradation that is taking place, the difficulty of measurement and the uncertainty of the extrapolation. However, the estimations made by EHRS and SCRP are 100 tons/ha with 1.8% loss of productive cropland (Constaable, M and D Belshaw, 1989) and 42 tons/ha with 2% loss on productive cropland per annum by SCRP (Hurni, 1988). NCSS and the World Bank also estimated the soil loss at 45 tons/ha with 0.21% loss on productive cropland by National Conservation Strategy Secretariat (NCSS) (Sutcliffe, 1993) and 20 tons/ha with 0.12% loss of productive cropland by the World Bank (Bojo & Cassells, 1995), respectively..

Effect of topography: Some parameters that influence soil erosion are given in Tables 7. Description on the topography of the Ethiopian highlands is also given in Section 2.4. From Table 7 it is observed that significant proportion of the land is covered by steep slopes and by hills and mountains.

Soil type: It is also observed that the highlands are occupied by soils having high vulnerability to erosion such as Andosols, Eutric and Dystric Nitosols, Planosols, Acrisols, Regosols, Cambisols, etc., (Table 8) (Braun, 1997). As a result of high rainfall erosivity, steep terrain and poor land management Vigro and Munro (1978) observed a soil loss in the range of 17 to 33 t ha^{-1} yr^{-1}. Yohannes (1989) estimated the rate of soil loss in North Shewa around Andit Tid to be 152.5, 42.5, 14.7 t ha^{-1} yr^{-1} for un-conserved land, for land conserved with traditional techniques and land conserved by use of graded *fanya juu*, respectively. The nutrient loss from land conserved by the traditional techniques (42 tons/ha) has been estimated at about 64 kg N, 138 kg P_2O_5 and 1179 kg organic matter (Kefeni 1992). The high altitudes indicated in Table 7, above 1500 m, are also characterized by high amount of rain that also has high intensity.

Table 7. Distribution of land under different slope and soil erodibility categories

Slope			Altitude			Soil erodibility		
Slope (%)	Area (km^2)	Area (%)	Altitude (m)	Km^2	Area (%)	Class	Area (km^2)	Area (%)
0-2	34 645	8	1200-1500	92 030	21	High	185 357	41
2-16	234 693	52	1500-1800	116 387	26	Intermediate	175 193	39
16-30	71 787	16	1800-2100	104 532	23	Low	77 972	17
>30	109 906	24	2100-2400	72 035	16	nda	13 139	3
			2400-2700	37 311	8			
			>2700	24 635	6			

Source: Braun et al 1997

Nda = no data available

Water Erosion: In the highlands of Ethiopia erosion caused by water is severe. It is the main course of erosion in the highlands. The rain is concentrated into three to four month period at the summer time. More than 72% of the highlands receive more than 600 mm of rain between May and September (Braun et al 1997).

Land use and Poor land management: There is no defined land use system followed in Ethiopia. Every farmer plans on his own way. For the last many years this has led over exploitation of the forestland and grazing areas. This has resulted in deforestation and overgrazing. It is an area where the government and the public should agree to adopt a policy if further degradation is to be avoided. Some crops need four or five plowings before planting. After planting these crops also need water outlets from the field which is always made at 50 or 60 degree slope and favors erosion. Crop rotation could reduce erosion but because of land shortage farmers are reluctant to use crop rotation.

Table 8. Soil loss and soil depth by soil type

Soil type	Soil loss t/ha	Average soil depth (cm)
Andosols	77.9	55
Regolosols	143.1	45
Cambisols	218.1	35
Badlands	171.0	20

Yohannes (1989)

Defirestation: Mulugeta and Yilma (1999) studied the relation between household food security and environmental stability around Antsokia in North Shewa. About 50% of Antsokia was covered by forest in the 1930s and was reduced to less than 4% in 1994. Trees have been removed from the upland plateaus, medium and lower elevations and caused severe water and wind erosions. The outcome was a mass movement of topsoil down the slope during the main rainy season leading to flooding and sedimentation at the valley bottom. The hills also failed to retain soil and water leading to the drying up of the springs at the foothills. Overgrazing has further contributed to the land degradation exposing the soil to wind erosion during the dry season. Hence, erosion can bring a total change of the agro-biodiversity to a village, e.g. diversity in people’s culture, and intact knowledge from the preceding generations, soil organisms, crop and livestock genetic diversity, and wild life. When such diversity is interrupted by drought its is beyond the control of the Ethiopian poor farmer. In the case of Antsokia, the World Vision Ethiopia Project, an international NGO, intervened and brought life back to normal after 10 years of development activities in the village.

3.3.2 Poor Drainage

Vertisols, Fluvisols and other soils having vertic properties make more than 28.6 million hectares all over the country. More than half of this is found in the highlands where the density of population is high. The major constraint of these groups of soils is the poor drainage during the main rainy season. In fields with low gradient of slopes flooding is a problem while gully formation can quickly develop in steep slopes if the water discharge out of the farm is not properly managed. These soils are also difficult to work with either by oxen drawn implements or by tractor drawn machinery.

Th pH of these soils may depend on the source of the parent material. Nitrogen and phosphorus are always the limiting nutrients, organic matter content is usually low falling below 1.0%. Hence, in general the main constraints of these soils are seasonal water-logging, moisture shortage in the low land areas, lack of improved inputs, workability, etc.

3.3.3 Effect of termite mounds

The infestation of termites is widespread in the rift valley particularly around the lakes region, in Borena, west Wellega and Gambella hampering land productivity and making mechanized farming difficult. Termites also consume dead organic debris much faster and in West Wellega the infestation is so severe that it has started eating barks of green plants, crops and pasture. Fisseha (1999) found that Cambisols and Fluvisols in the Rift Valley are particularly subject to the fast degradation. In many other parts of the country these also the soils vulnerable to termite infestations.

Research Recommendations:

Although EARO is reorganizing itself to address soil and water related production constraints of the future, there are some milestones under each theme that are being used to improve productivity of soils.

Soil Fertility and Plant Nutrient Management:

Mineral fertilizer recommendations for all major crops under specific agro-ecological and soil conditions are available for domains around each research center. However, to refine these recommendations soil test, based fertilizer calibration studies have been initiated and the work has been started in some zones in collaboration with the Regional Bureaus of Agriculture, the Ministry of Agriculture, Sassakawa Global 2000 and CIMMYT. The Ethiopian Agricultural Research Organization (EARO) strongly recommends the Extension Departments of both the Regional Bureaus of Agriculture and the Ministry of Agriculture to advise the farmers to adopt the integrated approach of nutrient management. The components of these recommendations are crop rotation particularly with legume crops, crop residue management, green and farmyard manure applications. The technology of biologically fixed nitrogen fertilization is also on the way. An example of a new package adopted by the farmers using improved seeds and recommended level of nitrogen and phosphorus fertilizers has increased yield of major cereals two to three folds as given in Tables 9& 10.

Table 9. Yield of major cereals by adopting packages of extension management and training plots (ton/ha)

Crops	Year					
	1996			1997		
	EMTP	Conventional	% increase	EMPT	Conventional	% increase
Maize	5.4	1.8	300	4.3	1.5	287
Teff	1.5	0.6	250	1.4	0.8	175
Wheat	2.8	1.1	255	2.9	1.1	264
Sorghum	4.5	1.3	346	3.6	1.0	360

EMTP: Extension Management Training Plots

Source: Ministry of Agriculture, 1999

Table 10. Yield achievement by farmers through the adoption of the extension-managed and training plots by Regions (ton/ha) (1994) (tons/ha).

Regions	Traditional Management				EMTP			
	Maize	Wheat	Teff	Sorghum	Maize	Wheat	Teff	Sorghum
Tigray	1.0	0.7	0.4	0.9	3.0	2.0	1.0	2.5
Amhara	1.5	0.7	0.6	1.4	5.0	3.5	1.5	3.0
Oromia	1.6	1.1	0.6	1.1	4.5	3.4	1.35	3.1
SNNPR	1.6	1.2	0.6	-	4.1	2.7	1.3	-

EMTP: Extension Management and Training Plots.

Soil and Water Conservation:

The significance of soil erosion and water runoff as one of the important factors causing land degradation has been discussed earlier. The severity of the problem is quite serious in the northern parts of the country where the damage has led to the displacement of people from their villages and for some of those still living there the land is not productive. Soil erosion coupled with deforestation and inappropriate land cultivation methods followed, the land has been exposed to severe erosion in many parts of the country. The situation has forced the government and non-governmental organizations to give attention to conserve soil and water *in situ* by adopting methods universally accepted and also tested in Ethiopia. Hence, millions of kilometer lengths of stone bunding and earth banks have been constructed in the northern highland regions through food-for-work assistance. However, this technology still has not been integrated yet into the routine land management practices of the farmers. The reasons for failure may require further studies and discussions.

Other technologies that the farmers are applying in different parts of the country are contour bunding, hedgerow planting of agro-forestry trees, and vetiver and elephant grasses planting. Afforestion of degraded lands is also a major intervention taken in many parts of the country to halt soil erosion.

In some parts of Ethiopia it is said that the technological packages of soil conservation, particularly terracing is cumbersome and costly and hence is not appreciated by the farmers. However, Ethiopia also has classic examples of indigenous soil conservation practices in Konso and Kindo in southern Ethiopia. Both stone bunding and earth banking terraces are common practices in these areas and these districts, having steep slopes, have not faced critical soil erosion problems for many years. However, reasons given that the farmers are not adopting the soil conservation measures may be related to (i) policy problems such as land tenure and land use issues, (ii) lack of participation by the end users at some stage on soil conservation technology development process, (iii) diversity in the social and demographic, topographic, agro-ecological and watershed setups of the different regions and (iv) the lack of legislation pertaining to the natural resources management. An additional point that may contribute to the low adoption in soil and water conservation measures is poverty of the rural people. Many of the farmers are subsistent producers and even do not have enough to eat let alone earn cash to invest on land. The average size of their land is so small that they decline to put any part of their land to conservation. Since the land is not productive they have no cash to pay additional labor they hire for this purpose. Erosion control measures should always adopt an integrated system such as terracing with earth banking or contour bunding or terracing with tree planting. It is also a long-term investment and the farmers should be advised that it is their long-term investment.

Irrigation and Drainage

Most of the experience EARO has in irrigation is in the commercial plantation areas of Awash Valley. Since the major crop produced in the valley is cotton crop water requirement for this crop has been studied in detail. Practical recommendations were made on sowing dates, irrigation systems for cotton, sesame and groundnut. The influence of pre-irrigation treatment at seedling stage and various planting irrigation regimes on the yields of maize, groundnut, kenaf, sweet pepper, banana, beans, onion, citrus and sesame were also studied and appropriate recommendations given.

A pilot drainage scheme was installed on saline waterlogged land at Amibara in Awash and the appropriate sub-surface drainage spacing and most efficient envelope materials were determined and results were extended to the users.

The nature and extent of soil salinity problems in the middle Awash Valley were investigated and has been characterized as saline, saline-sodic, and non-saline.

The quality of Awash River quality for irrigation is found moderately safe and ranging from 0.32 to 0.6ds/m and the sodicity hazard for the river was slight to moderate. Among the middle rift valley lakes, Lake Ziway is found safe for irrigation.

Management of Vertisols:

Vertisols make up about more than 10 million hectares and are being cultivated in much larger area than the total areas irrigated in the lowlands. Since Vertisols makeup a significant proportion of cultivated soils comprehensive studies have been conducted in the highland Ethiopia to drain out Vertisols by a method called broad-bed maker (BBM) technology which is becoming popular among many farmers. The gain in yield in the Vertisols areas by adopting the broad bed furrow system increases crop yields two to three folds.

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