University of Florida

Soil and Water Science Department

Erosion Impacts on Soil and Environmental Quality:

Vertisols in the Highlands Region of Ethiopia

By: Louis Philor

Advisor: Samira H. Daroub

April, 2011

Table of Content

Abstract

The loss of soil on the land surface by wind and water erosion has been identified as a major constraint in generating enough food to feed the world's escalating population (Pimentel, 2006). Soil erosion has been a major threat to soil quality since the beginning of agriculture. Slash and burn and tillage before or after planting have led to soil erosion. These practices have been widely unpopular among farmers today. Nevertheless, due to their quick positive effect on yield, pest control, and nutrients availability, some part of the world still rely on theses unsustainable practices to respond to the immediate needs of their people (Donahue, 1972). For example, Ethiopia is one of the fastest growing populations of the world. Providing food, water, shelter and other goods and services have put major impacts on soil resources. As a result, land use has seen tremendous changes in the past 50 years. The population of Ethiopia has suffered three major famines since 1970. The second famine of 1984/1985 claimed over one million lives. Dubale said that soils in Ethiopia are inherently fertile, but has been continuously degrading which could not sustain its growing population (Dubale, 2001). Most of the Ethiopian arable soils are in the Highlands area where more than 90% of the population lives. According to the UN report, Ethiopia's reliance on foreign aid is increasingly growing to meet the daily nutritional needs of its population.

Also, soil degradation has forced people to cultivate soils that were previously under forest cover. As more agricultural land is abandoned, more forested land is brought under agricultural production. At present there is more cultivated land in the Highlands region of Ethiopia in comparison to what it had 10 years agon. The natural process of soil regeneration in the Highlands areas is 10 times slower than the loss of soils through to different forms (Hurny, 1988). Food and Agriculture Organization (FAO) reports that close to one billion people are chronically malnourished in the world today. The Hunger World Map[1] shows hunger has severely affected more than 35% of the Ethiopian population. Ethiopia is one of the most under-nourished countries of the world. FAO documents a steady but meager increase in food production that cannot keep pace with population increase in recent years[2]. Using better and enhanced agricultural practices to reduce soil erosion while simultaneously increasing the yield, vertisols can play an important role in crop production in the Highlands of Ethiopia.

Introduction

Many experts agree that in order to feed the world's escalating population, major effort to combat soil erosion must be undertaken in agriculture soils of the world. Soil erosion has decreased in many parts of the developed countries by means of good agricultural practices and soil conservation methods. As a result, these countries produce more food today than 50 years

[1] http://www.fao.org/fileadmin/templates/es/Hunger_Portal/Hunger_Map_2010b.pdf
[2] http://faostat.fao.org/DesktopDefault.aspx?PageID=377&lang=en#ancor

ago. In fact, many of the world's developed counties increased their food per capita in the last fifty years (Roetter and Keullen, 2008). For example, according to NRCS, cropland erosion was reduced from 3.06 billion tons of soils in 1982 to 1.72 billion tons in 2007 in the United States[3]. Although other factors such as the use of chemicals can be associated with the increase in food production, better soil and water conservation is also paramount. Nevertheless, the total cropland today is considerably lower compared to 1982 in the USA. Nearly 10 million ha of cropland worldwide is abandoned every year because of problems associated with soil erosion alone (Pimentel, 2006).

Ethiopia

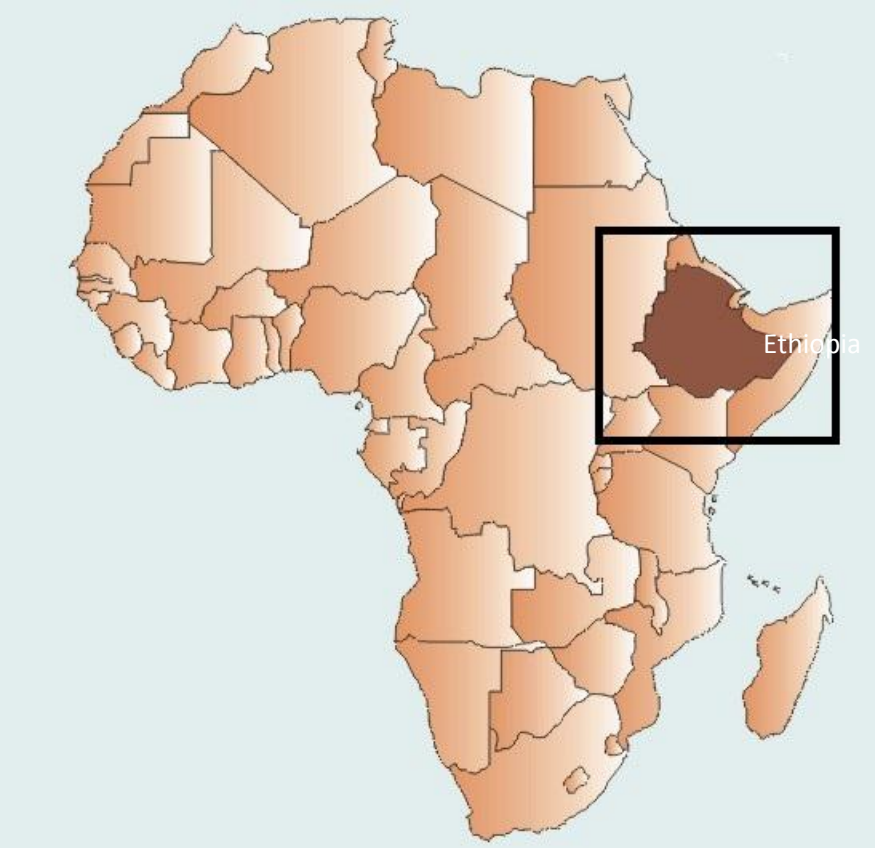


Figure 1. Map of Africa showing Ethiopia

Source: http://www.uneca.org/aisi/nici/country_profiles/ethiopia/ethiocond.htm

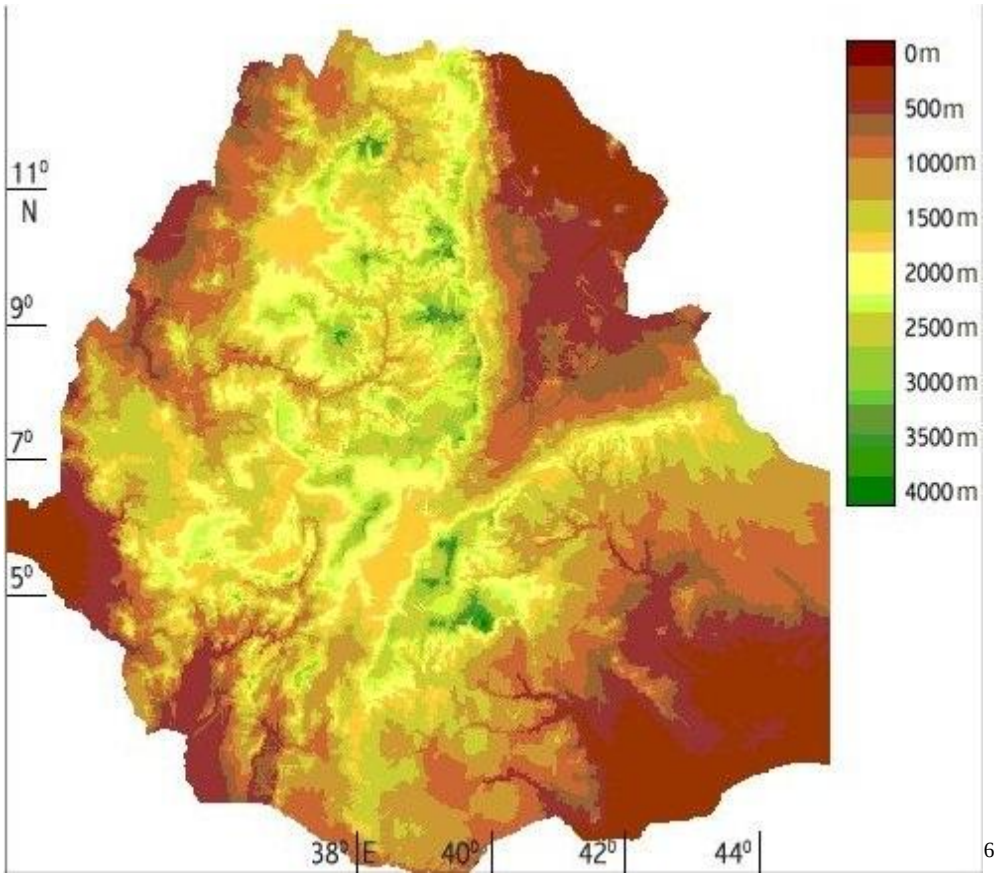
With 110, million hectares of land Ethiopia is considered as one of the largest countries in Africa[4]. In the 2007 census showed Ethiopian population to reach 75 million and almost 85 million in 2010[5].It is the second largest population in the African continent. Ethiopia has experienced a 63% population increase in the last 20 years (Dubale, 2001). Its climate, soils, and topography are very diverse. This creates a lot of opportunity and challenges to generate adequate and safe food to feed a fast growing population, maintain environmental quality by enhancing soils, air and water quality, and promote human and animal health. Some areas receive an average of 2,700 mm of rain per year whereas other areas see less than 100 mm per year. It has mountains higher than 4,000 meters above sea level and lowland areas 110 meters

[3] http://www.nrcs.usda.gov/technical/NRI/2007/2007_NRI_Soil_Erosion.pdf
[4] http://faostat.fao.org/DesktopDefault.aspx?PageID=377&lang=en#ancor
[5] http://esa.un.org/unpp/

below sea level (Edwards, 2010). Only 1% of Ethiopia is below sea level (Donahue, 1972). Donahue (1972) noted four major soils orders: Aridisols, entisols, ultisols, and vertisols. Also because of topography and climate diversity there are a plethora of plant genetic diversities in Ethiopia.

Highlands

The Highlands area is the area located above 1,500 meters above sea level (ASL) (Saleem, 1997). The majority of the population lives in the Highlands region. The Highlands region accounts for 43% of Ethiopian land or 537,000 square kilometers (Hurny, 1988). The Highllands region is responsible for 95% of cultivated land (Bekele, 1999). This area accounts for 90% of the Ethiopian economy. As a result, it is home for almost 90% of the population and 75% of livestock (Hawando, 1997).



[6]

Figure 2. Map of Ethiopia altitude showing Highlands region: Area above 1500 m ASL

[6] http://www.ethiopianwolf.org/afroalpine/AltitudinalMap.shtml

Vertisols

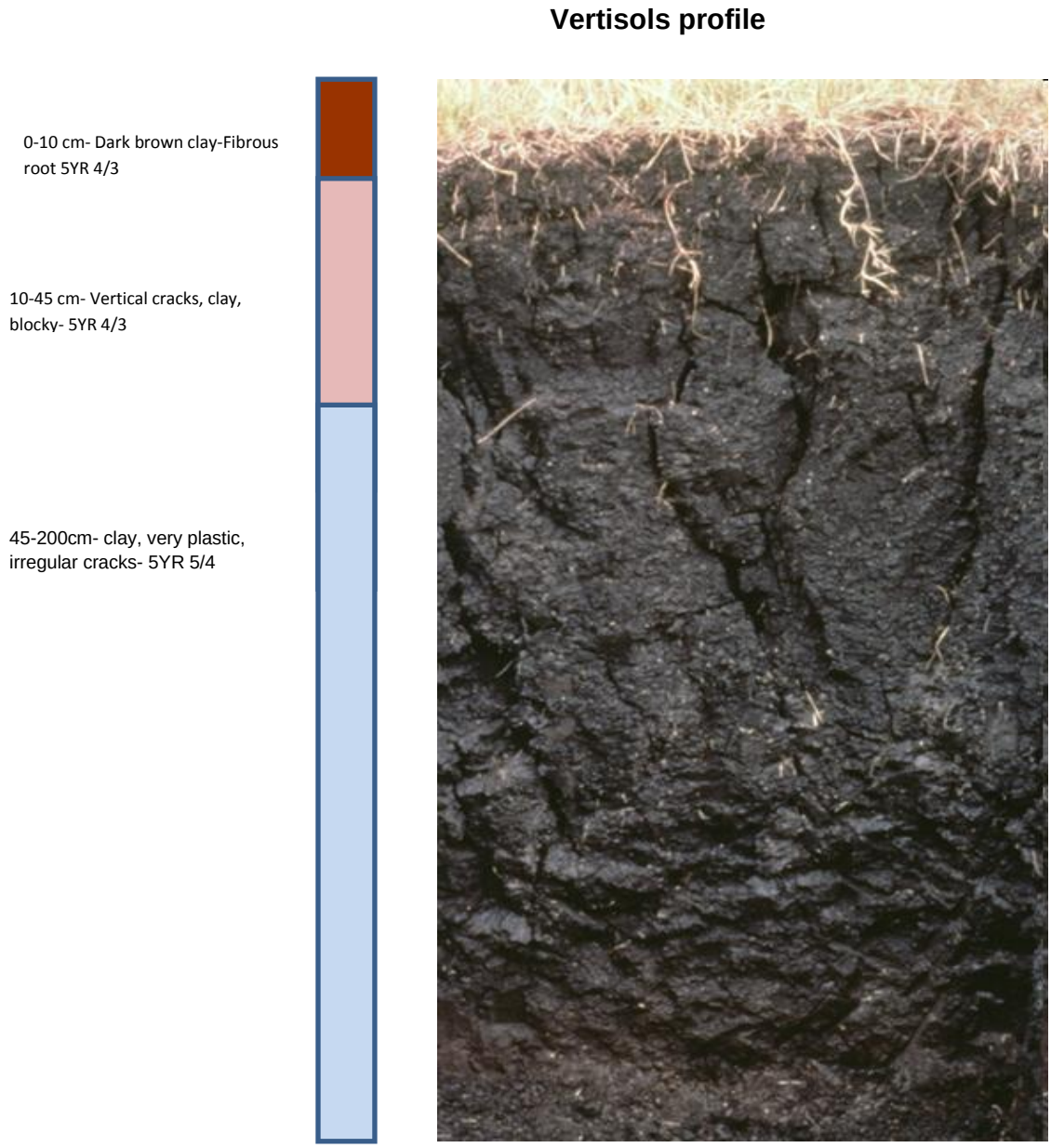
The diversity of Ethiopian soils is very pronounced. Vertisols cover over almost 13 million ha in Ethiopia, of which 63% or 7.6 million are in the Highlands region (Jutzy et al, 1988). Only 1.93 million ha are cultivated in the Highlands region (Jutzy et al, 1988). Vertisols are naturally fertile, but present difficult challenges for farmers for crop production because of susceptibility of soil erosion and other physical constraints. Manual and mechanical seed bed preparations are impeded by the plasticity of vertisols when wet and hardness when dry (Syers, 2001). This study will analyze how sustainable management and increase use of vertisols in the Highlands region can contribute to boost grain production in Ethiopia and improve environmental quality.

Food and Agriculture Organization (FAO) defines vertisols (from Latin vertere= to turn) as soils that have vertic horizons within 100 cm from the soil surface. They are marked by cracks that open and closed depending on the moisture regime[7]. Vertisols are very heavy in clay averaging 30 to 95% (Donahue, 1972). They encompass very high water holding capacity. Water infiltration can be low especially when the soils are wet due to swelling of the clay particles. Plants that have shallow root system may suffer.

Ethiopia has been hit by major famines and drought periods in recent history. In fact, the 1984/1985 famine claimed almost 1 million lives. Documented soil degradation is considered as the major cause of these famines. By contrast, FAO[8] confirms that there is more cropland in Ethiopia today than 50 years ago. The highlands area where more than 95 percent of food in Ethiopia is grown has been losing its soils at an alarming rate (Jijo, 2005). Hawando estimated that up 300 ton of soil/ha/year is lost in Ethiopia depending of slope and land use. As a result, food production is reduced. Highlands of Ethiopia have inherently fertile soils, good rainfall, and low evapo-transpiration compared to lowland areas (Hawando, 1997).

[7] ftp://ftp-fc.sc.egov.usda.gov/NSSC/Soil_Orders/vertisols.pdf

[8] http://faostat.fao.org/DesktopDefault.aspx?PageID=377&lang=en#ancor



[9]

Figure 3. Vertisols profile general characteristics.

The Ethiopian population has increase by nearly 63% in the last 20 years (Dubale, 2001). Food per capita has steadily decreased in the past fifteen years[10]. Grain production has remained stagnant despite an increase in agriculture land area and fertilizer and pesticide import. Ethiopia has lost its ability to feed its people[11].

[9] http://alic.arid.arizona.edu/jordansoils/_pdf/jordan_vertisols.pdf

[10] http://faostat.fao.org/DesktopDefault.aspx?PageID=377&lang=en#ancor

[11] http://faostat.fao.org/DesktopDefault.aspx?PageID=377&lang=en#ancor

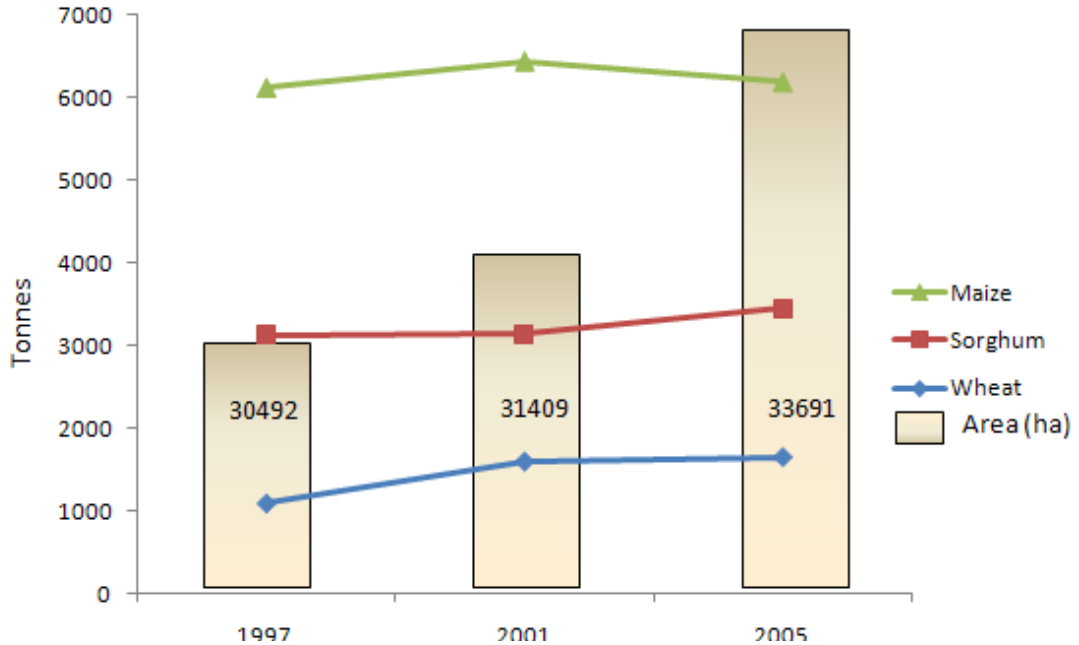


Figure 4. Ethiopia: Trends in cropped area and grain production [12]

Types of erosion

Erosion is the displacement of soil particles by wind or water. Soil erosion by water increases when water at the soil surface exceeds water infiltration (Hillel, 1998). Soil can be moved out of place by splashing or by the effect of raindrops on the soil surface. Also, sheet erosion comes about when soil particles are dislodged by raindrops on the soil surface. Sheet erosion most of the time develops into rill erosion. Small and slow channels form. Once, these channels are developed, gully erosion occurs. Soils that have good structure resist erosion when they are not disturbed. Good cohesiveness between soil particles and soil cemented by organic matter may resist water and wind erosion (Hillel, 1998).Because of high smectite clay content vertisols are prone to erosion. In fact, when clay particles are swollen, infiltration becomes negligible, so surface runoff increases (Pimentel, 2006).

Soil cover

Pimentel et al (1987) report that land degradation reduces food production by 15 to 30%. Also, Taddese (2001) argued that unsustainable increase of population is the main cause of soil erosion in the highlands areas. With a reduction of food production coupled with an escalating population increase in the highlands of Ethiopia, massive efforts are focusing on land cover. Forest loss has been a major threat to food security in Ethiopia by the way it affects soil erosion.

[12] http://faostat.fao.org/DesktopDefault.aspx?PageID=377&lang=en#ancor

In fact, Ethiopia has had three major famines from 1970 to now. Originally more than 60% of the country and 90% of the highlands areas were forested. Today only 2.2% of Ethiopia and 5.6 of the Highlands region are covered with forest (Berry, 2005). One of the major constants is the clearing of forest for fuel and crop production. Necessity to cultivate highly sloped area is another soil degradation problem. Because of high rainfall and productive land, the Highlands region accommodates more than 85% of the Ethiopian population, 75% of the livestock population (Jijo, 2005). More and more stress is being applied to marginal land to generate more food and habitat for escalating population. Farmers practice soil burning because of quick nutrients availability and manageability of the soils. Donahue (1972) reported that vertisols with 30% sand can become 78% sandy after one burn. Also, more phosphorus and carbon became readily available for plan growth (Donahue, 1972). Unfortunately, converting forest to agriculture also increase the erosive potential of the soil. Soil loss of 10 tons per hectare per year exceeds soil formation per ten folds (Pimentel, 1987). Highlands region in Ethiopia soil loss by erosion is high due to land use and unsustainable practices. When soils become barren, they are inclined to raindrop and wind erosion when of the biological materials are removed from the soil surface.

Soil Type

Ethiopian soils are still very productive as reported by Dubale (Dubale, 2001). Major soil orders in Ethiopia are aridisols, entisols, vertisols and ultisols (Donahue, 1972). Veritisols cover 15-20% of the highlands areas. 1.93 million ha are under cultivation in the Highlands region. Ethiopian vertisols are dominated by vermiculite (smectite) clay. At least 30% clay is observed throughout the soil profile (Jutzy, 1988). Smectite clay is known for swelling and shrinking. Soils can be very permeable during the dry season. However, when the soil is wet, water infiltration is negligible. As a result, potential for surface run-off increase during the rainy season. Also, sheet and gully erosion are observed more in vertisols. Vertisols occurs in slope 0 to 8% in Highlands Ethiopia (Hurny, 1988). The hydraulic and physical characteristic of Ethiopian vertisols makes them unappealing for crop preparation. In fact, insufficient moisture as well as waterlogging pose major challenges for farmers (Jutzy et al, 1988). Although vertisols are ‘inherently’ fertile, they are under-exploited due partly to difficulty to develop effective land management strategies (Syers, 2001). Vertisols have good soil structure or cohesiveness between soil particles making them less vulnerable to wind erosion.

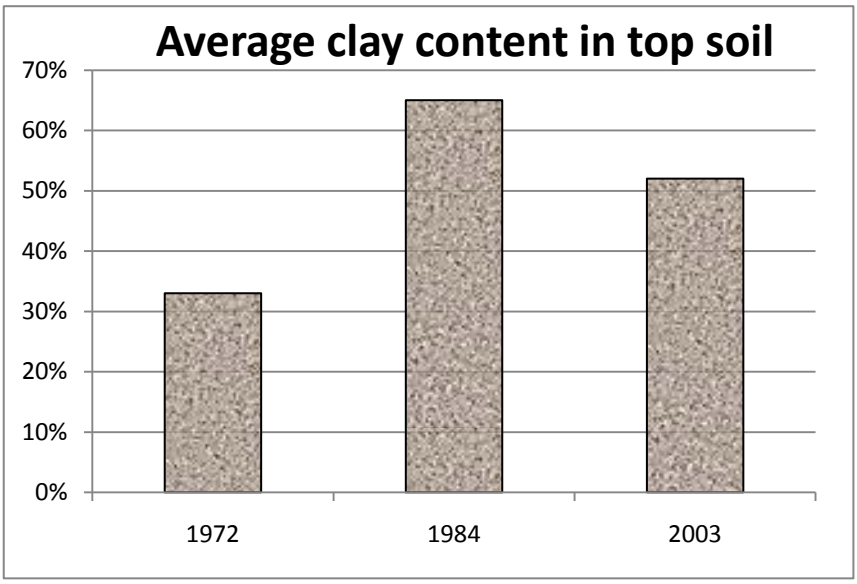


Fig. 5. Average clay content in top soil.

Soil erosion has caused loss topsoil. As a result crop roots are exposed to soil with high clay content, pH, and CEC and lower organic matter, phosphorous, and nitrogen. In 1972, with relatively good land cover, vertisols top soil had an average of about 33% clay (Donahue, 1972). Today, it averages 52% clay. Vertisols were studied by Kidanu (2004) in the Highlands region. Highlands region vertisols average chemical and physical characteristics are shown in Table 1. When soils lose the topsoil, crop roots struggle to obtain required water and nutrients in soils with high clay content, low nitrogen and phosphorous availability. As a result, crop productivity decreases.

Table 1. Physical and chemical properties of a typical Highlands region vertisols

Soil Depth (cm)	Percent Clay (%)	pH	P (Olsen)	TN (%)	OM (%)	CEC (Meq/100g of soil)
0-15	52	6.5	7.0	0.12	3.0	55
15-30	62	6.5	6.3	0.10	2.8	67
30-100	64	7.2	6.0	0.9	1.8	68
100-200	44	7.9	5.0	0.6	1.6	50

Kidanu (2004)

Topography

Ethiopia is very mountainous. An estimated 50% of all mountains in Africa are in the Ethiopian highlands (Mengistu, 2003). Mengistu reports at least 371,000 km² of land is over 2000 m above sea level. Highland areas are considered as land situated 1,500 m above sea level. Vertisols rarely occur on slope higher than 8%. In fact, it is reported that 70% soils on slope 0 to 8% in the highlands areas are vertisols (Jutzi et al, 1988). Because vertisols in the Highlands are on relatively flat land, most of the erosion occurs during period of heavy rain/monsoon (Pimentel, 2006).

Climate

Ethiopia is a land of impressive biodiversity. Its climate is one the parameters responsible for that diversity. The rainfall in Ethiopia ranges from under 100 mm per year to close to 3,000 mm per year (Hawando. 2000). The rainfall is high in the highlands areas. On the other hand, lowland areas that are 110 m below sea level receive little rainfall. The annual temperature varies from 0°C in the Mountain Ras Dejen to over 40°C in Danakil Depression (110 m below sea level) (Blaich, 2005). Climate diversity creates challenges to control factors that affect soil erosion. Nevertheless, this situation also creates great opportunity for sustainable agriculture production with wide range of crop species varieties production. Vertisols in the Highlands region occurs in areas that receive between 642 to 1117 mm of rain per year according to the United Nations (Hawando. 2000). Hawando (2000) reports that mean rainfall is 900 mm per year. Most of the rain is received in three to four months during the summer months (Dubale, 2001). Water infiltration on vertisols is limited once the soil is wet. This condition exacerbates soil erosion.

Soil Quality

Soil quality is the ability of the soil to "function, within natural or managed ecosystems boundaries, to sustain plant and animal productivity or enhance air and water quality, and support human health and habitation[13]." For example, today in the highlands of Ethiopia where 85% of the people and 75% of livestock population, 75% of sheep and 90% of the equine population live, there is pressing need to generate enough food and habitats (Jijo, 2005). The population is growing at a pace of 3% per year (Blaich et al, 2005). Accommodation for these large human and animal populations on marginal land with steep slope is not an easy task. It is also worth mentioning that most of the 85% of the Ethiopian population depends directly on agriculture. Also, all rivers in Ethiopia originate from the highlands areas (Abebe, 2005). This area is the source of many important tributaries to the Nile River, including the Blue Nile (Dubale, 2001). Therefore, soil erosion can affect water quantity and quality.

[13] http://soils.usda.gov/technical/handbook/contents/part624.html

Cattle alter the landscape and affect soil quality through grazing. Animal grazing changes the land cover by decreasing soil organic matter and soil aggregate, promoting surface crusting and inhibiting water infiltration (Mwendera, et al, 1997). Reduced organic matter (OM) in soil can affect a lot of other soil quality indicators. For example, it reduces the amount of water in soil. As a result biodiversity can suffer. Also, soil water chemistry is not the same. In the case of vertisols, the cracks stay open. On the other hand, Donahue (1972) noticed a change in many soil properties following burning. For example, burning changes texture of highland vertisols. A soil changes from 34% sand to 78% sand after burning (Donahue, 1972). Also, according to Donahue (1972) available phosphorus and pH greatly increase in the short-term. Nevertheless, burning of soil destroys organisms and other soil quality indispensable for crop production in the long-run. Burning and removal of crop residue, deforestation, overgrazing, high human habitation, and crop production on steep terrains are among the major problem causing land degradation and subsequent loss of soil quality.

Soil Depth

Soil depth is very critical for plant growth and health. Soil biota needs enough soil to grow and provide the important nutrients for plant growth. Topsoil loss in the Highlands region can be as high as 300 tons per ha per year. As a result, soil depth has been reduced to less than 40 cm in many areas of the Highlands. Some areas have soil depth ranges from 10 cm to 35cm (Hurni, 1988). If this trend continues, there will not be sufficient soil available to sustain plant life. Also, plants and crops will be grown in soils with higher sodium content, CEC and reduced nutrients such nitrogen and phosphorous. Pimentel estimates that soil erosion can reduce crop production up to 30% (Pimentel, 2003).

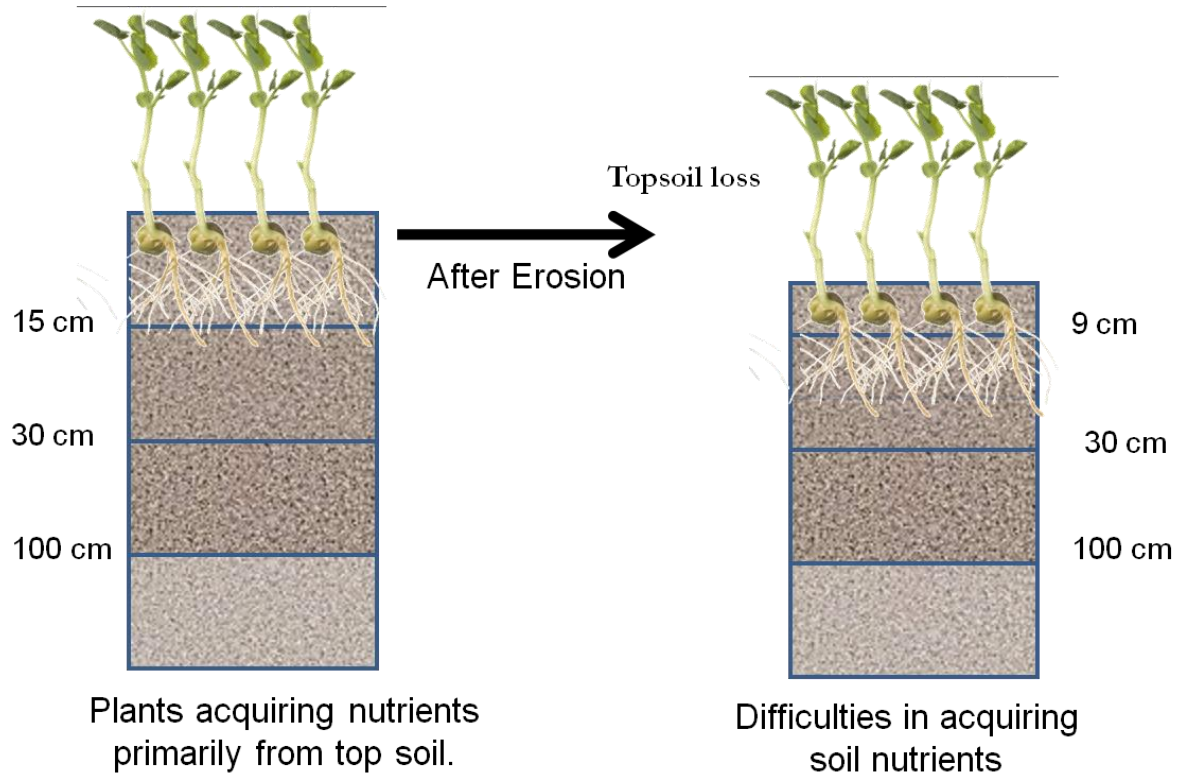


Figure 6. Reduction in surface soil depth due to erosion

Physical Properties

Generally vertisols have good structure. Also, their clay content can be as high as 95% in subsurface horizon (Donahue 1972). Removal of the top soil causes soils with high clay content to be exposed. First, all Ethiopian rivers come from the highland area. Low evapo-transpiration and other natural condition such as geology present perfect environment for river head. A lot of major tributaries to the Nile River emanate from the highlands region. Therefore, water infiltration to different aquifer systems is paramount to the entire region. Soils that are removed from the highlands region can pose major threats to dams, natural ecosystems, and biodiversity in the lowland areas. In fact, land clearing is widely practiced in land management of vertisols in the highland region. Fire (burning of soil called guie) can transform heavily clayey soil into sand. Fire can transform vertisols to up to 78% sand (Donahue, 1972). As a result, the top soil becomes exposed and susceptible to all types of erosion including wind.

Biological Properties

Despite inherent fertility of the vertisols in the Highlands areas of Ethiopia soil biodiversity has been reduced due to soil degradation and agricultural practices in the region. First, losing up to 300 tons of topsoil per ha per year has resulted in unsustainable loss of soil organic matter and decrease in soil fauna activities (Hawando, 1997). Residues from harvested crops usually decompose to release or replenish soil organic matter. However, in Ethiopia theses residues are used for other purposes. For example, with a high livestock, wild and domesticated animal population, crop residues are taken to other lands for animal feed (Dubale, 2001). Also, the straw from cereal field is used for construction, fuel and fencing (Dubale, 2001). In many cases, crop residues are in high demand in some local market for different uses. As a result, the land is left barren after harvest living it vulnerable to wind and water erosion.

Because of plot sizes farmers usually over-cultivate their lands. In Ethiopia farmers plow the land up and down the slope (Hawando, 1997). As a result, the land is exposed to water and wind erosion. Also, plowing exposes the top soil and part of the soil profile to air that stimulates oxidation of the soil carbon and decreases soil organic matter (Dubale, 2001). Decrease in soil quality presents an insurmountable challenge for the poor peasant in the highlands area because they have limited resources to improve soil quality (Jijo, 2005). Some inherent physical and chemical characteristic of the topsoil may be irreversibly loss through erosion.

Chemical Properties

Highlands's vertisols can be good agriculture land with proper management. They are considered low acid to alkaline soils and show a wide range of pH (Jutzy et al, 1988). All of the Ethiopian vertisols pH increase with soil depth (Jutzy et al, 1988). Their sodium content increases with depth. Most of highlands vertisols are formed from volcanic parent materials (Jutzy et al, 1988). They are low in nitrogen and phosphorous. Also, concentrations of both nitrogen and phosphorous decrease with depth. About 7.8 billion metric tons of soil per year is accompanied by loss of million tons of N and P in soils that already lack of such nutrients.

Soil salinity and sodicity have caused the fall of many great civilizations. The area in Iraq known as the 'cradle of civilization' is now a barren desert (Essington, 2004). Salt accumulates in soil through irrigation water. Poor irrigation water quality exacerbates soil salinity and sodicity. Vertisols are naturally high in exchangeable sodium percentage (ESP) thorough the soil profile. Unlike nitrogen and phosphorous ESP increases with depth (Syers, 2001). The Highlands vertisols are low in ESP compared to other places in Ethiopia, India, or Australia. Some vertisols in Australia have ESP higher than 30% (Syers, 2001). As erosion removes topsoil that is relatively low in ESP, plant roots are exposed to higher soil salt content. This condition impedes crop production in vertisols.

Water Quality

Ethiopia has a plethora of diversities: Soils, climate, topography, plant species, etc. according to Dubale; it also contains 'high and rugged mountains with flat plateaus, deep gorges, rolling plans, and incised rivers valleys' (Dubale, 2001). Unsustainable deforestation and increase in human and livestock population in the highlands areas have caused major land degradation in Ethiopia. As a result, water resources have suffered major setbacks. All river systems in Ethiopia come from the Highlands area. As reported by many experts, about 2.2% of the original forest is left in the Ethiopian highlands. Consequently, the land has been exposed to major wind and water erosion. Dubale reports that some of the springs that used to flow year around are dry today. As soil erosion removes 3% of the top soil annually, unfavorable topsoil is exposed. In the case of vertisols soils with higher smectite clay and CEC are showing at the soil surface. First, Because of poor hydraulic conductivity of these clays when they are wet, water infiltration becomes negligible. As a result, sheet and gully erosion possibly increase. In addition, water flow to the ground immensely deceases (Dubale, 2001). All in all, obtaining water for irrigation is getting harder everyday for these poor farmers. For example, major rivers such as the Blue Nile or the Awash Rivers are in deep Gorges and not available to poor farmers with limited resources (Dubale, 2001). Siltation in smaller rivers has been a nightmare for farmers that try to obtain irrigation water by pumping.

The removal of soil causes other environmental problem namely siltation of dams, micro-dams and irrigation canals. Although FAO[14] reported a decline in chemical use in the small family-owned farms in the highlands due to plot sizes and increase in fertilizer and pesticide prices, fertilizer and pesticides import have substantially been raised over the last ten years. In fact, most land in the highlands is individually owned and cultivated in small scale (Jutzy, 1988). Those farmers for the most part are poor and cannot afford chemicals. Nevertheless, the concentration of chemical can be seen especially in small rivers marked by increase in vegetative growth. Dubale (2001) said that the Awash River that irrigates 43% of the irrigated land in Ethiopia is covered with water Hyacinths in the drought season making pumping and other types of irrigation extremely difficult. Some other river systems, such as the Baro-Akobo Basin, have the potential to irrigate more land, but have not been exploited fully (Dubale, 2001). Other small rivers are dirty from domestic and municipal waste and cannot be used as sustainable source of water for irrigation.

[14] http://faostat.fao.org/site/575/default.aspx#ancor

Discussion

Hawando (1997) estimated that erosion causes 7.8 billion tons of soil loss in Ethiopia per year. In addition, area under agriculture as well as chemical fertilizers and pesticides application have been steadily increasing. Nevertheless, grain production has not been able to meet the growing daily food requirements of the Ethiopian escalating population. The loss of organic matter in the top soil and nutrients unavailability has adversely affected the yield in the Highland region of Ethiopia. FAO reported that the total land under cultivation in Ethiopia today is greater than what it used to be five years ago, however this has not translated into corresponding increase in grain yield. Given this situation, several agencies are currently helping Ethiopian farmers to utilize better farming techniques.

Soil degradation through different types of erosion is a threat to food security in the Highlands region. Also, erosion causes crop roots to be exposed and results into yield loss. The Highlands region vertisols are low in phosphorous and nitrogen. The concentration of both of these nutrients tends to get lower down the soil profile as shown in Table 1. On the other hand, clay content and CEC increases with depth in the vertisols profile. This makes it difficult for the roots to acquire water and other nutrients; consequently, food production declines. In addition, as topsoil is lost, soil with high clay content is exposed and water infiltration is curtailed. This negatively affects replenishment of the different aquifers in the region. All rivers in Ethiopia come from the Highlands region. Soil erosion, therefore, affects both water quantity and quality.

Vertisols present many challenges to the farmers in the highlands region of Ethiopia. Most farmers utilize oxen to plow the land. When dry, Vertisols are rigid and present great difficulty in plowing using oxen. Being sticky and plastic when wet, these soils need heavy farm equipment for seedbed preparation (Jutzy, 1988). Farmers plant seeds in furrow and broadband to encourage evaporation in the root zone (Jutzy, 1988).

To circumvent this problem, experts have suggested cultivation of crops with limited water requirement. Jitzy (1988) says that crops like wheat, lentil, chickpeas, and vetch can grow to maturity with residual moisture (Jitzy, 1988). Therefore, these crops can be planted after the rainy season. Also, in dry season; soil can be irrigated after planting. No additional irrigation would be needed in periods of low water availability.

Small scale farms can get one or two additional grain harvests per year. Soils could be protected by an additional cover of wheat during the winter. This additional crop can help reduce potential for soil erosion.

Recommendations

- Pimentel (2006) suggested that about 99.7% of all human food comes from the land. As global population continues to increase, the available land resources experience increasingly higher pressure to meet the growing food demands. The Highlands region in

Ethiopia has seen a 63% population increase in the last twenty years (Dubale, 2001). A lot of cropped land is located on steep terrains in the Highlands region. The Vertisols in the Highlands region, currently underutilized, can be brought under cultivation to increase the food supply in Ethiopia. First, these soils occur on relatively flat terrain and represent a great crop production resource (Jutzy, 1988). Also, because of their inherent fertility, more vertisols should be cultivated in the Highlands region. Their position in the Highlands region and soilstructure make them less prone to water and, particularly wind erosion.

- Land cover poses a major problem for farmers. A country with limited resources, crop residues are used for energy, animal feed, construction, etc. The soil usually stays without cover after the harvest. Plant residue decomposition in soil is critical in replenishing organic matter and enhancing nutrient availability in soil. It contributes enormously in soil regeneration and formation. Crop residues should be left on soil surface to prevent erosion and enhance biomass decomposition on soil to improve soil quality and ensure food quantity.

- The vertisols in the Highlands region have conducive physical and chemical characteristics for rain water harvesting and storage. Water can be retained in vertisols because they have low permeability when the soil is wet. Also, at high altitude the evapo-transpiration is low compared to lowland region. Although, temperature varies in the Highlands region, nocturnal temperature can get very low in the vertisols plateaux. Excess water can be stored in the form of 'artificial lakes' or small tanks during the rainy season. This water can be used for irrigation during the drought months and could serve as a valuable resource.

- Despite their fertility, crop yield in highland vertisols is far below the potential. Proper management of soil moisture can enhance crop yield in vertisols.

- Drought resistant crop should be utilized during months when water is scarce.

- Because of genetic diversity, Ethiopia has a unique opportunity to use different type of crop types depending on climate or season. For example, tef can tolerate waterlogging. Therefore, it should be planted during the rainy season.

- Erosion removes the topsoil resulting in soil with higher salt content or exchangeable sodium percentage (ESP) where crops are grown. Since Ethiopia is rich in plant genetic diversity, salt tolerant crops may be selected to grow in these areas.

- Reforestation of steep terrains to increase soil cover and change land use to combat erosion.

Bibliography

Abebe, S. (2005). Land-Use and land-Cover Change in Headstream of Abbay Watershed, Blue Nile Bassin, Ethiopia. Addis Ababa University.

Astatke, A. and Saleem, M. (1998). Effect of Different Cropping Options on Plant-Available Water of Surface-Drained Vertisols in the Ethiopian Highlands. Agriculture and Water management 36, pp 111-120.

Berry, L. (2005). Land Degradation in Ethiopia: Its Extend and Impact. GM and WB

Blaich, R., Stahr, K., Sauerborn, J. & Römheld (2005). Land Preparation Methods and Soil Quality of a Vertisol Area in theCentral Highlands of Ethiopia. UNIVERSITÄT HOHENHEIM (310); D-70593 Stuttgart.

Donahue, R. (1972). Ethiopia: Taxonomy, Cartography and Ecology of Soils. African Studies Center

Dubale, P. (2001). Soil and Water Resources and Degradation Factors Affecting Productivity in Ethiopian Highland Agro-Ecosystems. Northeast African Studies Vol. 8, No. 1 (New Series), pp. 27-52

Edwards, S., Egziabher T., and Araya, H (2010). Successes and Challenges in Ecological Agriculture: Experience from Tigray, Ethiopia. Food and Agriculture Organization of the United Nations

Essington, M. (2004). Soil and Water Chemistry: An Integrative Approach. CRC Press. Boca Raton.

Hawando, T. (1997). Desertification in Ethiopian Highlands. RALA Report No. 200. Norwegian Church AID, Addis Ababa, Ethiopia. 162 pp.

Hillel, D. (1998). Environmental Soil Physics. Academic Press. San Diego.

Hurni, H. (1988). Climate, Soil, and Water: Degradation and Concervation of the Resources in the Ethiopian Highlands. Mountain Research and Development Vol.8, pp 123-130

Jijo, T. (2005). Land Preparation Methods and Soil Quality of a Vertisol Area in the Central Highlands of Ethiopia. Universität Hohenheim (310); D-70593 Stuttgart.

Jutzy, S. (1988). Deep Black Clay Soils (Vertisols): Management Options for the Ethiopian Highlands. Mountain Research and Development, Volume 8, pp 153-156.

Jutzi, S., Haque, I., McIntire, J., and Stares (1988). Management of Vertisols in Sub-Saharan Africa. International Livestock Centre for Africa.

Kidanu, S. (2004). Using Eucalyptus for Soil & Water Conservationon the highland Vertisols of Ethiopia. Tropical Resourse Management Paper No. 51.

Mengistu, M. (2003). Ethiopia. Addis Ababa University. alemayehumengistu@yahoo.com

Mwendera, J., Saleem. M., and Dibabe, A. The effect of livestock grazing on surface runoff and soil erosion from sloping pasture lands in the Ethiopian highlands. Australian Journal of Experimental Agriculture, 1997, **37**, 421–30

Pimentel, D., (2006). Soil Erosion: A Food and Environmental Threat. Environment, Development and Sustainability 8: 119–137

Pimentel, D., Allen, J., Beers, A., Guinand, L., Linder R., McLaughlin, P., Meer, B., Musonda, D., Perdue, D., Poisson, S., Siebert, S., Stoner, K., Salazar, R., and Hawkins, A (1987). World Agriculture andSoil Erosion: Erosion threatens world food production. BioScience, Vol. 37, No. 4 , pp. 277-283.

Roetteri, R., and Van Keulen, H. (2008). Food Security. Science for Agriculture and Rural Development in Low-income Countries, 27–56.

Shiferaw, B. and Holden, S. (1999). Soil Erosion and Smallholders' Conservation Decisions in the Highlands of Ethiopia. World Development Vol. 27, No. 4, pp. 739±752.

Syers, J., de Vries, F., and Myamudeza, P. (2001). The Sustainable Management of Vertisols. CABI Publishing. New York, NY.

Taddese, G (2001). Land Degradation: A Challenge to Ethiopia. Environmental Management Vol. 27, No. 6, pp. 815–824