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Full Length Research Paper

Assessment of integrated soil and water conservation measures on key soil properties in South Gonder, North-Western Highlands of Ethiopia

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Land degradation caused by erosion was an environmental threat that hampered agricultural production and the causes include: over cultivation, overgrazing, overpopulation and deforestation. Loss of productive land undermined rural livelihoods and national food security. The major factors discouraged farmers adoption of soil conservation measures were labour shortage, land tenure uncertainty, fitness of structures and the farming system. The study assessed effect of soil and water conservation measures on key soil properties in two micro-watersheds of Farta Wereda of South Gonder. Data analyzed using different soft wares. The results revealed that soil chemical and physical properties: soil organic matter, total N, available phosphorous (P), bulk density, infiltration rate and soil texture found a significant difference between conserved and non-conserved. Soil pH and electrical conductivity (EC) did not show significant difference. The non-conserved had the lowest soil organic matter, total N and infiltration rate with highest bulk density, clay content and available P. Soil organic matter content positively correlated with infiltration rate and total N and it negatively correlated with soil bulk density. Cation exchange capacity (CEC) positively correlated with soil pH and available P. The undulating lands were moderately suitable for rain fed agriculture. Hilly and valley lands found suitable for protective forestry and livestock production. Further research shall be conducted for a better understanding for sustainable land use.

Key words: Ethiopia, land evaluation, sustainable development, soil nutrients, watershed management.

INTRODUCTION

The population of the world is dependent on land resource for food and other necessities. More than 97% of the total food for the world's population is derived from land, the remaining being from the aquatic systems (Pimentel, 1993). Agriculture is an essential component of societal well-being and it occupies 40% of the land surface, consumes 70% of global water resources and manages biodiversity at genetic, species and ecosystem levels. At every point of production, agriculture influences and is influenced by ecosystems, biodiversity, climate and the economy, including energy trade. Throughout the world today, depletion of natural resources is among the major problems facing human beings. A survey of soil degradation by the World Resource Institute, United Nations Environment Programmed estimated that 9 million hectare of land are tremendously degraded; with their original biotic functions completely disappeared and 1.2 billion hectares, that is, 10% of the earth's vegetative surface are moderately degraded (WRI et al., 1996). Of which about 1/4th of these degraded land are found in Africa and Asia and the rest 3/4th in North America. Undoubtedly, the acceleration of environmental degradation, soil erosion and climate change has direct effects on agricultural productivity and food security (IPCC, 2007).

On the other hand, degradation, which can be physical, chemical and/or biological and erosion by water and wind, is claiming six million hectares of the global agricultural land per annum (Pimentel, 1993). About 16%

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of the world's agricultural land is affected by soil degradation[1] (UNEP, 2002). Of all the processes leading to land degradation, erosion by water is the most threatening. It accounts for 56% of the total degraded land surface of the world (Oldeman et al., 1990). In Africa alone, it is estimated that 5 - 6 million hectares of productive land are affected by land degradation[2] each year (Stocking and Niamh, 2000). Obviously, erosion is a more serious problem to developing countries including Ethiopia because their dependence on the soil resource is more direct. Erosion reduces rootable depth, removes soil organic matter and nutrients and decreases water-holding capacities.

Population pressure, mismanagement of agricultural lands, deforestation and overgrazing are among the major causes of soil erosion and environmental degradation. The average annual rate of soil loss in Ethiopia is estimated to be 12 tons/hectare/year, and can be even higher on steep slopes with soil loss rates greater than 300 tons/hectare/year or about 250 mm/year where vegetation cover is scant (USAID, 2000). But more emphasize was the greater nutrient loss for crop production (Hurni and Tato, 1992). Hence, land degradation in Ethiopia is becoming a matter of serious concern for its negative implications on the livelihood of the rural population and the environment from which they largely depend. Soil erosion by water in the country is the major cause for the rapid degradation of the highlands (areas above 1500 m a.m.s.l) and undermines agricultural production and frustrates economic development in the country. Furthermore, many research results confirmed that resource degradation particularly soil nutrient depletion is the major cause for decline of agricultural production (Bekele and Holden, 2000; Carucci, 2000).

More than 85% of the country's population live in rural areas and derive their livelihoods from agricultural activities. Therefore, soil and water conservation in Ethiopia is not only related to improvement and conservation of the environment but also it is a key factor for sustainable development of the agriculture sector and the economy of the country at large. Different soil conservation technologies with different approaches have been implemented focusing on the highlands of the country where the problem is more threatening. Soil conservation activities can change the physical conditions of the soil like soil organic matter content, soil structure, water holding capacity, soil bulk density, soil porosity, soil pH and its workability (Teklu, 2005; Gete, 2000). Comparing changes with key soil factors between two watersheds (treated with soil conservation measures and untreated) could contribute for further improvement of the integrated soil and water conservation (SWC) measures currently underway and to draw some recommendations. The purpose of this study is to investigate effects of SWC measures on some key soil properties so as to draw conclusions that contribute in future improvement of SWC measures implementation in improving soil for a better land productivity, erosion control and sustainable use of resources available in the country. Source of data were field survey, soil laboratory analysis and secondary data from relevant offices.

The scope of this study is limited to two micro-watersheds in two peasant associations (PAs) of Farta Wereda. The emphasis was put on the functional use of SWC measures on improving the key soil properties for land productivity. For analysis, management and evaluation of the data collected, GIS and ANOVA soft wares were used.

Objective of the study

Assessing impacts of integrated SWC measures on selected key soil properties in two micro watersheds using on site observation, soil profile descriptions, secondary data and soils lab analysis.

Statement of the problem

Soil erosion is a severe problem in Ethiopia, especially in the highlands where much of the population is living and agriculture is intensive (Gete, 2000). Hurni (1988) estimated that erosion is most severe on cultivated lands with the average of 42 tons/hectare/year. On the other hand, SWC measures mostly implemented on cultivated lands with a few exceptions are physical structures mainly stone or soil bunds. The efforts put towards promotion of technologies so far seem below the threshold which has limited the sustained use of natural resources for a better production. In view of this one may ask questions related to the benefits or outcomes of bio-physical SWC measures implemented. We do not know exactly the amount of benefits returned to the community and to the environment. The hypothesis here is that the biophysical SWC measures are benefiting by reducing soil erosion and changing the soil properties for agricultural productivity. Hence, it is worthwhile to investigate the effects of SWC measures on key soil properties to evaluate the benefit of treating lands with biophysical SWC measures. Therefore, this study attempts to assess and draw conclusions on the effects of biophysical SWC measures on some key soil properties in German technical development (GTZ) project carried out in South Gonder zone of Amhara region, Ethiopia.

[1]Soil degradation is a process which lowers the current and/or the potential capability of the soil to produce goods or services. Six specific processes contribute to soil degradation: water erosion, wind erosion, water logging and excess salts, chemical degradation, physical degradation and biological degradation.

[2]Land degradation is reduction in the capability of land to produce benefits from a particular land use under a specific form of land management or defined as the progressive reduction of the capacity of land to sustain life and provide food security and is a reduction in soil fertility caused by erosion (removal of soil and loss of nutrients)

MATERIALS AND METHODS

The study area

The study was conducted in Farta Wereda of South Gonder zone, Amhara regional state, Ethiopia (Figure 1). A Wereda is the smallest administrative unit in Ethiopia and is composed of a number of Peasant Associations (PA). The study area is located at 660 kms North-West of Addis Ababa, capital city of Ethiopia and lies between the coordinates of 11˚32' to 12˚03' N latitude and 37˚31' to 38˚43' E longitude with an estimated area of 1118 km^2.

The studies of micro-watersheds are located in two Peasant Associations (PAs) of Farta Wereda, namely Tsegur Kidanemihret and Tsegur Eyesus. The names of the micro-watersheds[3] are given by the streams draining them namely Tsegur and Koca. They have an average width of 3 km and a length of more than 6 km with an area of 1800 ha each. The micro-watersheds were selected based on criteria set for this study that is, a watershed with SWC measures for an extended period of time and the other one without introduced SWC measures. The watershed selected has been treated with SWC measures since 2000. The study micro-watersheds are situated between 11˚52' to 11˚54` N latitude and 37˚57' to 38˚00` E longitude with an altitude range between 2400 to 2700 m above sea level. The slope ranges from 5 to 10% at lower part to 35 - 60% on the upper part. The slope orientation is from south-west to North-east with a length of growing period (LGP) is between 90 to 210 days.

The entire area of the study Wereda has a topography characterized by extremely high relief in the upper watershed of Blue Nile River system. The parent rock is eroded shield of volcano consists of alkaline and mainly olivine basalt, basalt and tuff agglomerate. The major soil types in the study area include Cambisols, Regosols and Leptosols with stony phase (Anonymous, 1997). The altitude of the study area varies between 1900 and 4035 m above mean sea level (a.m.s.l) with topography of gentle to undulating (Yitbarek, 2007). The average annual minimum, maximum and mean temperatures are 9.7, 22, 15.5˚C, respectively. The rainfall pattern is uni-modal, stretching from May to September. As indicated in Figure 2, the annual rainfall ranges between 1097 and 1954 mm with a long term average of 1448 mm (Yitbarek, 2007).

The land use pattern according to the Wereda Agriculture Office Annual Report (2006) is 65% cultivated, 10% is grazing, 8% settlement and 16% wasteland. The farming system is a mixed one (growing of crops and rearing of animals). Crop production is mostly rain fed and subsistence oriented. Livestock plays a significant role in the farming system as source of draft power, food and cash (Yitbarek, 2007; Abera, 2003).

Sampling techniques and procedures

One of the problems in land degradation/conservation issue is the determination of extent and rate of the degradation process. What to measure and how to measure is a challenge. Dynamics in land cover/use (specifically de-vegetation), farming practice, soil erosion and soil nutrient depletion are the most commonly used indicators. Following this customary practice, land cover changes and rates of soil erosion by water were used as indicators (Woldeamlak, 2005). The materials used to create the base map and spatial databases needed for the study are field visit and topo maps of Debre Tabor and Amed Ber with scales of 1:50,000. The establishment of the base map and databases involved the following procedures: i) geo-referencing according to the Universal Transverse Mercator (UTM) system using 1:50,000 topographic maps of the area and GPS, and ii) delimiting the study micro-watersheds by first tracing it from 1:50,000 topographic maps and digitizing these separately using GIS techniques. Transects were used to collect information on soils and bio-physical activities. The scale of the study was a detail one. The data collection was done by traveling on foot. The required field data collection formats and scientific instruments were employed in data collection. Observation points were located using coordinates obtained from GPS reading.

Soil samples were taken in selected soil profiles for soil laboratory analysis to get more information about the soil and its horizons. The depth of the soil profile pit depends on its geological formation and usually up to 200 cm is a recommended depth. Core samples were also taken using sampling rings at field level to a depth of 30 cm for the determination of bulk density. The spatial databases created from field observation and soil laboratory analysis results help to characterize each observation points with respect to land unit and actual soil features. A total of 32 augur points and 10 profile pits were investigated. From these 10 profile pits soil samples were collected from 8 of them for further soil laboratory analysis. The samples have been analyzed in the lab for different soil parameters: organic carbon content (Corg), Bulk density, cation exchange capacity (CEC), soil reaction (pH), Total Nitrogen (N), Available phosphorus (P), soil texture and electrical conductivity (EC).

The data obtained from laboratory and field observations were managed and analyzed using different data analysis methodologies like GIS and Soil and terrain data base of FAO-ISRIC (FAO, 1993). Comparison of the data was computed using a simple t-test method where relevant, linear regression equations were established to describe some correlations. Homogeneity of variances for the parameters was also tested using Welch ANOVA testing method.

RESULTS AND DISCUSSION

Results according to methods

Effect of SWC measures on soil physical properties

Soil texture: The textural classes of top soils treated with SWC measures and that of the untreated lands have differences which were confirmed through statistical analysis of the soil laboratory data. The analysis revealed a significant variation of top soil texture in percent sand, silt and clay content due to effect of SWC measures (Table 1). Soils of the non-conserved land had the highest percent clay and silt compared to the soils of the conserved one. The textural classes also have a significant variation. The majority of the sample profiles of the conserved land have a top texture of clay loam and for the untreated is clay. Herweg and Ludi (1999) pointed out that complete removal of topsoil at the loss zone causes the subsoil-dominated by clay material to move down slope and deposited on top of the fertile accumulation.

They also indicated that tillage and water erosion causes colluvium to be deposited in the lower part of fields while soil profiles are truncated in the upper part. Desta et al. (2005) confirmed by their study that annual mass of soil displaced down slope from the truncated area by tillage erosion for 202 study plots was estimated to 39 - 50 kg yr^{-1}. Age of the bund had a significant impact on the

[3] A watershed or water catchments is an area where rainfall, surface runoff drains into one common stream, river or other water body. It can be a spatial unit which covers geographical surface that contributes to a major watershed (GTZ, 2002: Sarah, 2007).

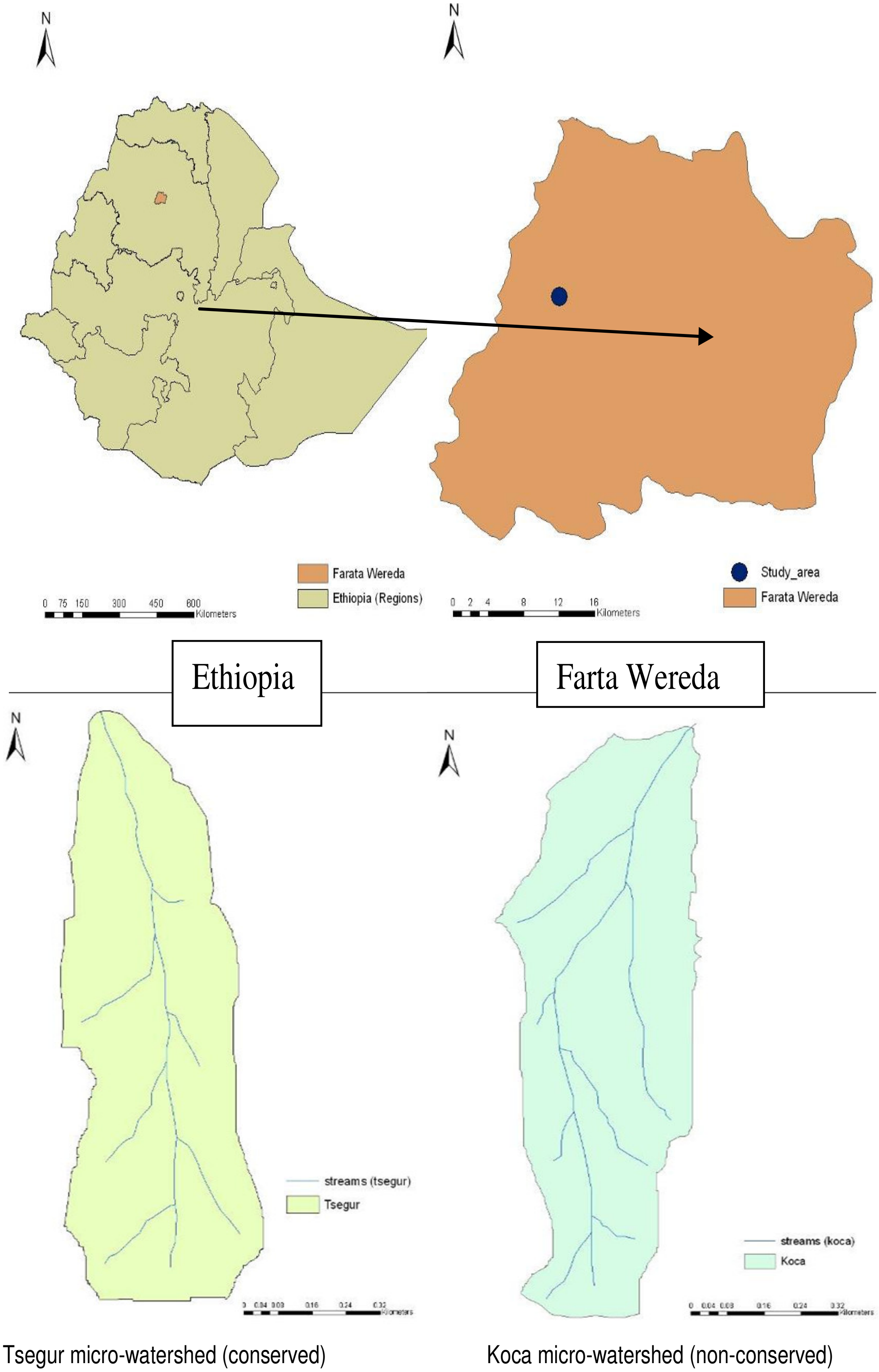

Figure 1. Location map of the micro watersheds in the country and the Wereda.

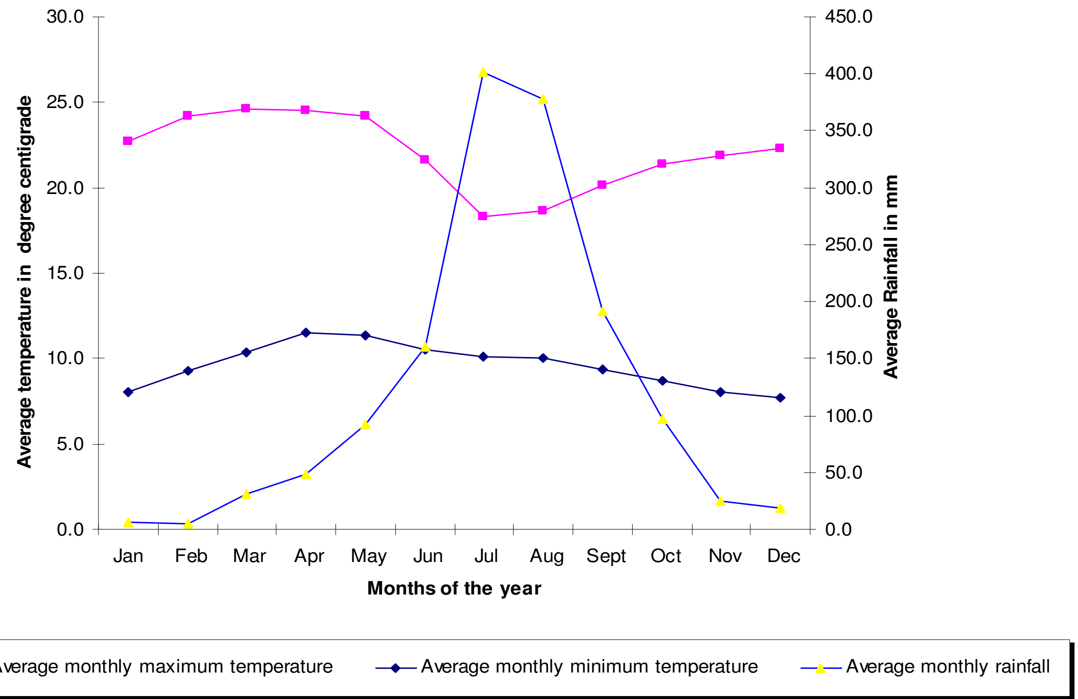

Figure 2. Average yearly minimum and maximum temperature and average yearly rainfall of the study Wereda (1994 - 2003). Source: Debre Tabor Metrological station record, South Gonder.

Table 1. Effect of SWC measures on soil texture.

Site no.	Depth (cm)	Soil texture/hydrometer			Texture class
		Sand (%)	Clay (%)	Silt (%)	
Koca micro-watershed (non-conserved)					
KC-01	0-22	25	42	33	Clay
KC-02	0-20	27	44	29	Clay
KC-03	0-27	33	36	31	Clay loam
KC-04	0-20	25	38	37	Clay loam
Mean value		27.5	40	32.5	
Tsegur micro-watershed (conserved)					
TE-01	0-14	29	44	27	Clay
TE-02	0-10	35	36	29	Clay loam
TE-03	0-16	29	36	35	Clay loam
TE-04	0-17	35	28	37	Clay loam
Mean value		32	36	32	

KC- stands for Koca micro-watershed which is non-conserved and TE- stands for Tsegur micro-watershed which is conserved with soil and water conservation measures.

impact on the lowering of percent clay fraction as it lowers slope gradient and reduced soil erosion and soil organic matter increased with relative soil depth change. In general bunds play a great role in reducing the incurporation of clay-dominated soil from the subsoil to the surface soil, which resulted from removal of topsoil and exposure of the subsoil by erosion. Highest clay content in the non-conserved watershed was due to the exposure of soil by tillage to soil erosion by water ultimately exposes the subsoil, which is naturally high in clay content.

Bulk density (BD): The one way analysis of variance revealed the presence of significant difference in mean value

Table 2. The effect of SWC measures on soil bulk density.

Site no.	Top soil bulk density (g cm^{-3})	Site no.	Top soil bulk density (g cm^{-3})
Koca micro-watershed(non-conserved)		**Tsegur micro-watershed(conserved)**	
KC-1	1.09	TE-1	0.92
KC-2	1.12	TE-2	0.93
KC-3	1.03	TE-3	1.17
KC-4	1.12	TE-4	1.02
Mean value	1.09		1.01

KC- stands for Koca micro-watershed which is non-conserved and TE- stands for Tsegur micro-watershed which is conserved with SWC measures.

value of bulk density for the samples analysed in this study. The non-conserved micro-watershed was found to exhibit significantly the highest mean value of bulk density than the micro-watershed treated with SWC measures. This could be attributed to the presence of significantly higher organic matter as a result of conservation measures. In this study, the relatively lower bulk densities of 0.92 and 0.93 g cm^{-3} were recorded on soils taken from the conserved grassland and cultivated lands with slopes of 6 and 12%, respectively. This implies that more roots of plants, higher organic matter and sediment are accumulated in this zone of the micro-watershed. As the land slope decreases runoff speed also decreases, sediments and organic matter started to settle.

Root abundance, crop stand, crop production and crop residues are better in lower slopes of the micro-watersheds compared to its upper slopes as soil depth upslope is shallow which limits plant growth due to shallow soil depth even with similar conservation measures (Table 2). The topsoil bulk densities of the sampled soils are inline with the ranges described by Rai (1998); Landon (1984) that is, between 0.92 to 1.17 g cm^{-3}. The significant effect of SWC measures on bulk density was observed in the lower slope of the micro-watersheds where bulk density is higher in the non-conserved land than the conserved micro-watershed. The reason for this could be higher accumulation of soil sediments that were eroded from upslope. The upslope part of the two micro-watersheds has almost similar top soil bulk densities.

Infiltration rate (conductivity): Infiltration rate is the soil capacity for letting water to percolate in a given period of time. The measurement is usually done in centimetres per hour. Soils with a SWC measures have a better soil infiltration rates compared to the non-conserved one. In relative terms soils with biological SWC measures have a better infiltration rate than a physical SWC measure due to the roots penetration effect and addition of soil organic matter from plant bodies through decomposition. Infiltration tests conducted confirmed that soil physical structures stabilized with vegetative measures had the highest mean value of infiltration rate compared to the other conservation measures. The non-conserved micro-watershed had lowest mean value of infiltration rate. The soil organic matter content and percent clay soil separates seemed to play a role for the variation of infiltration rates. The relationship of infiltration rate with soil organic matter content and clay percentage of a soil is indicated in Figures 3 and 4. Organic matter was positively correlated with the infiltration rate while clay percentage was negatively correlated. Landon (1984) indicated that physical SWC structures enriched with vegetative measures had better infiltration rate than lands conserved with only physical structures.

Effect of SWC measures on soil chemical properties

Soil organic matter (SOM): Soil organic matter differences between the conserved and non-conserved micro-watersheds were statistically significant ($p \leq 0.05$). The variations in mean value of organic carbon (Corg) can be attributed to the effect of SWC measures implemented. Moreover, the age of bunds stabilized with vegetative measure have a better effect in soil organic matter accumulation (Table 3). This finding agrees with the findings of Million (2003) who studied the effects of indigenous soil and stone bunds on soil productivity. The study revealed that soil organic matter content of three terraced sites with original slopes of 15, 25 and 35% were higher compared with the corresponding non-terraced sites of similar slopes.

Similar conditions were also observed for slope range of 15 to 25% which had 2.3% soil organic matter for the conserved land while 0.85% for the non-conserved ones. According to a study made by Bot and Benites (2005), soil organic matter accumulation is often favoured at foot or lower slopes of hills of non-conserved lands for two reasons: 1) they are wetter than mid and upper slopes, 2) organic matter would be transported to the lowest point of the landscape with runoff and soil erosion. The soil organic matter content has a positive correlation with the fine soil particle content of the soil that is, with the soil textural classes. Soil texture appears to have an important impact on the amount, distribution and chemical properties of soil organic matter (SOM) components. The

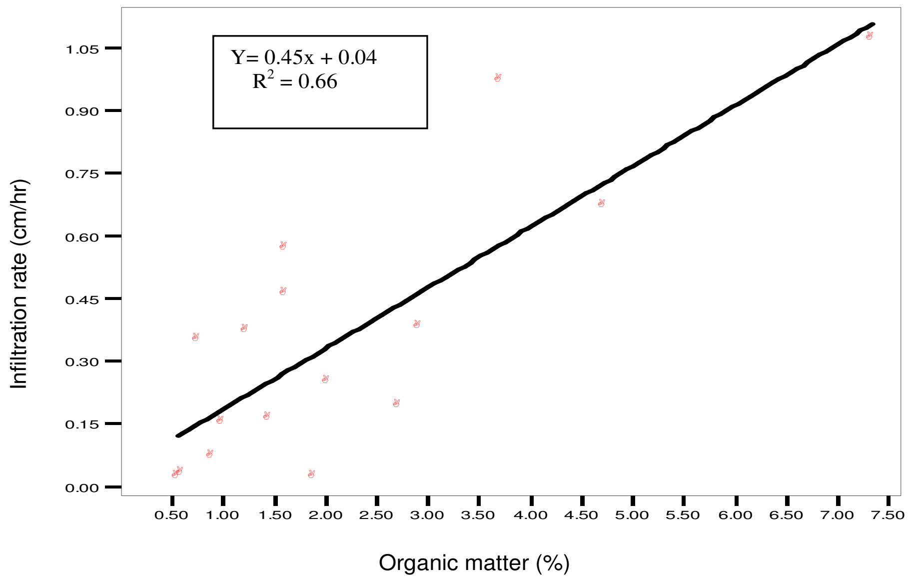

Figure 3. Regression plot for infiltration rate vs. organic matter content (%).

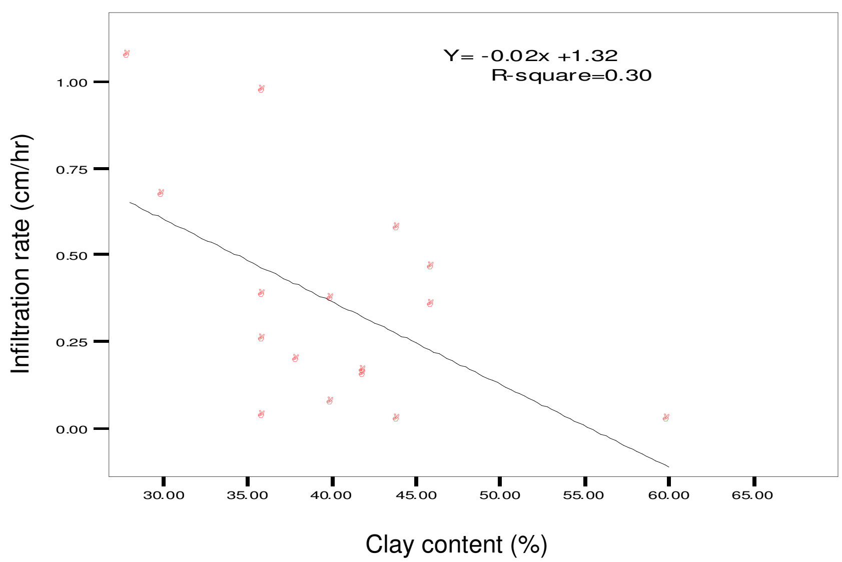

Figure 4. Regression plot for infiltration rate versus clay percentage.

Table 3. Effect of SWC measures on organic matter content.

Site no.	Organic matter (%)	Site no.	Organic matter (%)
Koca micro-watershed (non-conserved)		Tsegur micro-watershed (conserved)	
KC-01	1.45[d]	TE-01	1.6[d]
KC-02	1.89[d]	TE-02	2.03[a]
KC-03	2.91[a]	TE-03	3.71[c]
KC-04	2.71[a]	TE-04	7.34[b]
Mean value	2.24		3.69

The same letter as superscript in the column means they are not statistically different at $p \leq 0.05$. KC- stands for Koca micro-watershed which is non-conserved and TE- stands for Tsegur micro-watershed which is conserved with soil and water conservation measures.

Table 4. Effect of SWC measures on total nitrogen (N) within 25 cm of soil depth.

Site no.	Total N (%)	Site no.	Total N (%)
Koca micro-watershed(non-conserved)		Tsegur micro-watershed(conserved)	
KC-01	0.1	TE-01	0.12
KC-02	0.11	TE-02	0.14
KC-03	0.19	TE-03	0.26
KC-04	0.14	TE-04	0.33
Mean	0.14		0.21

KC- stands for Koca micro-watershed which is non-conserved and TE- stands for Tsegur micro-watershed which is conserved with soil and water conservation measures.

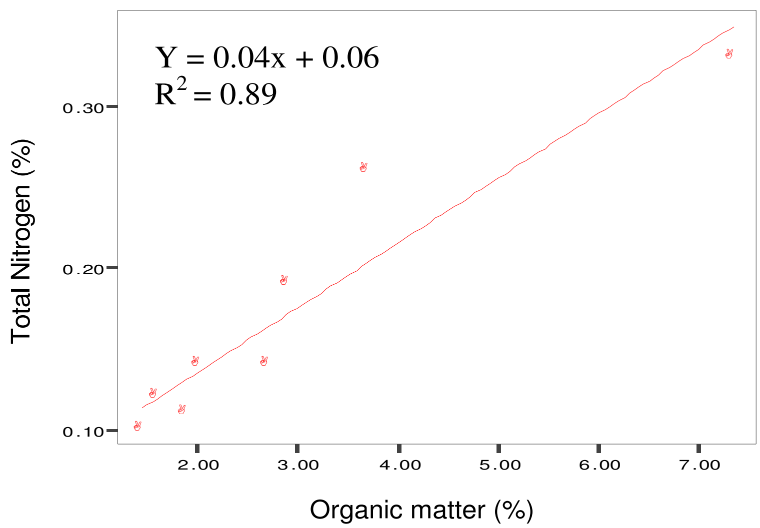

Figure 5. Regression plot for soil organic matter vs. total nitrogen (N).

components. The agricultural significance of soil organic matter in tropical soils is greater than that of any other property with the exception of soil moisture. Its functions are to improve soil structure, and thereby root penetration and erosion resistance; to augment cation exchange capacity; and to act as a store of nutrients, slowly converted to forms available plants.

Total nitrogen (N): The analysis made using statistical methods revealed that the mean total nitrogen difference due to the impact of SWC measures was significant at $p \leq 0.05$. Table 4 presents the mean value of sampled top soil total nitrogen content. However, physical SWC measures stabilized with nitrogen fixing plants have indicated that the total nitrogen (N) is much higher compared with other biological measures. The non-conserved land had the smallest mean value of total nitrogen (N). Million (2003) also found that the mean total nitrogen content of the terraced site with the original slope of 15, 25 and 35% were higher by 26, 34 and 14%, respectively, compared to the average total nitrogen contents of their corresponding non-terraced sloping lands. Moreover, a linear regression analysis made to see correlation of nitrogen with soil organic matter has shown that there is a strong positive relation between them at ($p \leq 0.01$ and $R^2 = 0.89$) (Figure 5).

Soil pH (H_2O): Soil reaction has a direct influence on chemical and biological soil properties and parameters. Low productive soils and sites were associated with low pHs and corresponding low levels of exchangeable bases and organic matter. Soil pH in a soil can be attributed to the type of parent material, extent of soil erosion or the leaching of bases as a result of climatic factors. Soil pH is an indispensable means for characterizing soil from the standpoints of nutrient availability and soil physical conditions like structure, permeability, workability etc. It is also indicative of the status on microbial environment/ community and its net effect on the mineralization of organic residues like humus and/or immobilization of available nutrients and also provides the most rational basis for managing soils for selective agricultural land uses

Table 5. Effect of SWC measures on soil pH.

Site no.	Depth(cm)	pH H_2O(1:2.5)	Site no.	Depth(cm)	pH H_2O(1:2.5)
Koca micro-watershed (non-conserved)			Tsegur micro-watershed (conserved)		
KC-1	0-22	6.38	TE-1	0-14	6.25
KC-1	22-65	6.33	TE-1	14-26	6.15
KC-2	0-20	6.28	TE-1	26-60	6.44
KC-2	20-38	6.05	TE-2	0-10	6.22
KC-3	0-27	5.93	TE-2	26-10	6.2
KC-4	0-20	6.18	TE-2	26-85	6.51
			TE-2	85-125	6.77
			TE-3	0-16	5.92
			TE-3	16-55	6.11
			TE-4	0-17	6.28
			TE-4	17-45	6.36
Mean value		6.19			6.29

KC- stands for Koca micro-watershed which is non-conserved and TE- stands for Tsegur micro-watershed which is conserved with soil and water conservation measures.

such as crop production, pasture cultivation, forestry, etc. Soil pH is also associated with soil fertility status. Soils with high organic matter content have a higher soil pH which favours better exchange of bases and increase availability of nutrients that are needed for the growth of plants in a given soil and ecology. The mean value of pH for the sampled soils in this study shows minor difference between the conserved and non-conserved micro-watersheds.

The laboratory result of sampled soils is in agreement with the findings of other similar studies, for instance Million (2003); Belay (1992) also found that indigenous stone bonding had no significant effect on soil reaction when compared to the control treatment (non-conserved plots). The relatively lower pH mean value for the non-conserved micro-watershed could be attributed to the relatively lower base saturation percentage and lower soil organic matter content. The soil analysis results (Table 5) showed that soil pH for all the soils sampled were slightly acidic to neutral that is, from 5.93 - 6.77.

Low base saturation is another indicator of soil acidity and the removal of basic cations is a major process causing soil acidification in nature (Norton et al., 1999).

As a rule of thumb for every one-half unit drop in soil pH percent base saturation declines by about 15% (Baruah and Barthakur, 1998). The highest pH value associated with the conserved micro-watershed at a lower soil depth could be attributed to the presence of higher exchangeable cations due to the effect of leaching and translocation from the upper soil horizons. Leaching of bases is the major soil nutrient management problem for the soils of humid tropics.

As a result most tropical soils have the problem of nutrient availability for the production of agricultural crops such as potassium, calcium, magnesium and phosphorous. This is one of the problems mentioned by many researchers that make the tropical countries poor and unable to feed themselves in most cases in addition to other problems related to agricultural production and productivity. The regression analysis explored for the variables of soil organic matter and cation exchange capacity (CEC) to see their correlation revealed that soil pH is negatively correlated with the percent organic matter content whereas it is correlated positively to CEC.

Cation exchange capacity (CEC): The cation exchange capacity (CEC) is a measure of the number of adsorption sites per unit weight of soil at a particular pH. CEC is affected quite dramatically by pH changes. Soils with high in organic matter or 2:1 type clays have a high CEC. In contrast, soils dominated by kaolinite and hydrous oxide clays generally have a low CEC. In many weathered tropical soils the maintenance of organic matter is critical in order to maintain the CEC at a satisfactory level (Hesse, 1998; Olaitan et al., 1985). Land productivity in those areas is highly dependent on the availability of soil organic matter. The mean value of CEC in the soil samples collected and analyzed showed that the results obtained were statistically non-significant. The difference between the two micro-watersheds CEC value was very small (Table 6). Lal et al. (1999) discussed that CEC of a soil can be reduced by soil erosion through the loss of soil organic matter even though clay content increases in soils that have Bt horizons because soil organic matter (SOM) has a higher CEC than clay. According to a study conducted by Million (2003) terraced area with original slope of 25 and 35% were found to have mean CEC value of 6 and 49%, respectively, higher than the average CEC of the corresponding non-terraced slope.

A linear regression analysis confirmed the presence of significant positive relationship between CEC and percent

Table 7. Effect of SWC measures on available phosphorous (P).

Site no.	Depth (cm)	Available P ppm (Olsen)	Site no.	Depth (cm)	Available P ppm (Olsen)
Koca micro-watershed (non-conserved)			Tsegur micro-watershed(conserved)		
KC-1	0-22	25.17	TE-1	0-14	24.69
KC-2	0-20	0.5	TE-2	0-10	35.47
KC-3	0-27	22.66	TE-3	0-16	22.31
KC-4	0-20	11.76	TE-4	0-17	15.81
Mean value	15.02				24.57

KC- stands for Koca micro-watershed which is non-conserved and TE- stands for Tsegur micro-watershed which is conserved with soil and water conservation measures.

phosphorous (P) in the studied micro-watersheds were found to be significantly different between the conserved and non-conserved (Table 7). It is evident that the total available phosphorus is much higher in the conserved one. Organic sources of phosphorous are important in these areas for amending the agricultural land for a better land productivity.

The variation could be due to the soil organic matter content difference. Phosphorous availability increases with depth of soil in both micro-watersheds. Vagen (1996) as cited by Vancampenhout (2003) noted that available phosphorous was higher in the accumulation zone than in the soil loss zone in non-conserved land. However, Million (2003) found a contrasting result on terraced sites with original slopes of 25 and 35% compared to the average available phosphorous content of the corresponding non-terraced slopes.

Effect of SWC measures on slope transformation

To observe how the different soil and water conservation measures implemented brought a change on the nature of land slopes, measurements of inter-terrace slope and vertical rise of physical structures were taken. Thus, the result indicated that there is quite a difference in slopes between the conserved and non-conserved micro-watersheds. Bunds stabilized with grasses such as vetiver, elephant grass, etc. and vegetation like populus, acacia, etc. on farmlands and treated gullies have showed the lowest inter-terrace slope than other physical conservation measures such as terraces. This signifies that the integrated implementation of physical structures with biological/vegetative measures especially grasses were found as more effective in slope transformation and stabilization of the micro-ecosystem compared to other soil and stone bund stabilization techniques. Age of soil and water conservation measures implementation with proper maintenance also brought a variation in inter-terrace slope or slopes between bunds, which was realized in the field. During field data collection, observation was made between two different age similar soil and conservation measures on slope of 25% land under cultivation that is, a four years old bund with grass strip and a 9 years old bund stabilized with the same grass species have a very significant difference in their slope stabilization and the gradient between bund lines.

Moreover, the deposition of soil materials and debris on the upper position of a bund (accumulation zone) causes a height increase of the bund year after year, thereby reducing inter-terrace slope between two successive soil and water conservation structures provided that the bunds are maintained properly. A study made by Desta et al. (2005) found that the rate of sediment accumulation by bunds is correlated with the soil loss by tillage because all the soils displaced by tillage remains in the accumulation zone. Sediment accumulation volume was found to increase with slope gradient and bund spacing, but decreased with bung age. This study result revealed that slope; rainfall intensity and topography have a significant effect on soil and water conservation measures in slope transformation especially in steep and highly erosion sensitive areas like the North-Western Highlands of Ethiopia where rainfall is intense and short duration with high runoff volume.

Results and the hypothesis

It was expected that a watershed treated with soil and water conservation measures will be better productive with a better organic matter content, good soil aggregation and high biodiversity than a watershed not treated. Accordingly the results obtained confirmed that a land which is conserved has better soil physical and chemical properties with better vegetation cover and biodiversity compared to the non-conserved. The degree of soil degradation, reduction of soil depth in sloping areas and the silt up of lower slopes with coarser fragments were observed on non-conserved micro-watershed. Among the physical structures the most preferred ones by farmers were soil bunds and grass strips on bunds.

The rationale behind their preference was that soil bunds and grass strips take less space than other structures like stone bunds and also transform into bench terraces over a shorter period of time. The other argument for soil bunds is that they can be damaged easily and need less labour compared to stone bunds and check dams. Generally, effects of SWC works require a long period of time to be appreciable by the farmers. The farmers were asked during focus group discussions to mention any changes in the land condition they may have observed since the watershed management intervention.

The farmers responded that they had witnessed changes in the land cover condition, level of soil erosion and better growth of crops along the SWC structures. The land cover condition improved for two reasons: i) the upper part of the watershed which were uncultivated and degraded were treated, closed and protected from encroachment by livestock, hence natural vegetation were returning and enriched with planted vegetations. ii) Trees planted on the SWC structures (agro forestry) increased the vegetative cover of the land.

Farmers' acceptance and adoption of SWC measures

Accelerated soil erosion is primarily caused by farmers' land use practices. Likewise, the success of any SWC intervention depends on the extent to which the introduced conservation measures are accepted and adopted by the farming community. In other words, acceptance and farm-level adoption of the newly introduced conservation measures by the farmers is the decisive element for the success of a watershed management intervention.

Nevertheless, acceptance of the measures as effective techniques for controlling soil loss and as having potential to improve land productivity cannot warrant its adoption on the farm. While acceptance depends more on the design characteristics of the measures as related specifically to effectiveness, farm level adoption of the measures depends also on several socio-economic and institutional factors. The factors affecting adoption also determine the sustainable utilization of the measures by the farmers (Woldeamlak, 2005). Generally, newly introduced SWC measures can be considered as adopted if the land users (farmers) continue to utilize them as part of their production system after the external assistance is withdrawn. The farmers were asked what their intentions were regarding using the introduced SWC measures in the future. 52% of the respondents expressed their commitment to continue maintaining the established structures after the external support ends. On the other hand, 47% stated that they would not maintain the structures as they were by then. Of the latter group, some argued that they would destroy every other structure so as to reclaim the "lost land" for cultivation; and some others stated that they would destroy some of the structures in order to use the fertile sediments retained behind. In summary, it can be stated that the introduced SWC measures were widely acknowledged and accepted as effective measures against soil erosion and as having the potential to improve land productivity. Nonetheless, their sustainable adoption on the farm level appears to be less likely.

Factors affecting farm-level adoption of the introduced SWC measures

The farm-level adoption of SWC measures depends on several interrelated factors. Effectiveness of the measures in controlling soil loss is only one consideration. As earlier discussed, the majority of the farmers acknowledged the introduced SWC measures to be effective in controlling soil erosion and as having the potential to improve land productivity and most of them did not appear to have intentions or plans to continue maintaining the structures established. The same is true to the farmers from the non-treated watershed to do it by their own initiative seems unacceptable; this also implied that there was a very little chance for the farmer-to-farmer diffusion. Farmers rather frequently reject newly introduced SWC measures even when they are aware that adoption of the measures protects and improves productivity of their lands.

This suggests that the newly introduced SWC measures need to be evaluated not only for their technical efficacy but also for the chances of their sustainable adoption and utilization by the land users. Understanding and recognition of soil erosion as a problem in own farm plots and its causes and impacts on crop yields is the first step towards searching for and adoption of remedial measures. The underlying reason for this is the fact that the process of erosion is gradual, which goes on unnoticed and is recognizable only after reaching some threshold levels. According to Hurni (1986), farmers in northern Ethiopia seem to have realized that their land is being degraded after centuries of farming, when it had already become a severe problem to food production. Once farmers perceive soil erosion as a problem having negative impacts on soil quality and land productivity and expect positive returns from soil erosion control, it is highly likely that they will decide in favour of adopting available conservation measures.

On the other hand, when farmers do not acknowledge soil erosion as a problem, they cannot expect benefits from controlling the erosion process and it is highly likely that they will decide against adopting any conservation measures. The finding also suggested that correct perception of soil erosion as a problem is a necessary but not sufficient condition for the farmers to adopt modern SWC measures. The ability to adopt SWC measures is related to their labor supply and economic status. Tenure security has been shown to be an important factor, besides farmers' awareness and labour availability, affecting farmers' decisions whether to adopt introduced SWC measures.

CONCLUSIONS AND RECOMMENDATIONS

The results of this study revealed that: soil pH and cation exchange capacity (CEC) were not significantly affected by SWC measures. Whereas, soil organic matter (SOM), total nitrogen (N), infiltration rate, bulk density, available phosphorous (P) and soil texture were found to have significant difference between the conserved and non-conserved micro-watersheds. It was observed that the non-conserved micro-watershed soils had the highest clay content and bulk density than the conserved soils due to absence of SWC measures that prevent soil erosion. As the topsoil is eroded the subsoil which is rich in clay content appears as surface soil. The soil infiltration rate is also the lowest in the non-conserved micro-watershed compared to soils of the conserved one. Organic matter content of a soil was found to correlate positively with total nitrogen content and soil infiltration rate. But the correlation of organic matter with soil bulk density was negative. This implies that SWC measures have affected positively the productivity of agriculture in conserved lands. Farmers, on the other hand expressed that physical SWC measures took part of their plot of land and as obstacle for oxen plough. Adoption and continued use of SWC measures strongly indicate that many social, political, economic and technological factors influence the farmer's decisions to use those measures.

Low level of farmers' participation and undermining of indigenous knowledge in the process of planning, designing and implementation as well as government policy on the issue of land holding and tenure security have impacted the implementation and adoption of SWC techniques. If one needs to achieve success in rural development activities such as SWC, farmers` interactive participation should be ensured from the beginning. The problem of fitness of the technologies to the farmers' requirements and the farming system circumstances is partly a reflection of a problem in the approach followed in the planning and implementation of the SWC measures. For instance, the farmers' time-long knowledge and preferences were ignored in dealing with the soil erosion problem.

In a real participatory process, the farmer is the starting point. It starts with analysis of farmers' circumstances, problems, indigenous knowledge and preferred solutions to problems. What is transferred by outsiders to farmers is not a "package of practices to be adopted but a basket of choices from which to select".

Recommendations

The rural households in the two-micro-watersheds are very poor, living on very meager annual incomes. Land degradation, particularly soil erosion by water of cultivated fields, is a threat to their agricultural production. SWC measures are very helpful in increasing land productivity. Thus, all stakeholders need to encourage farmers and the community at large in the facilitation, adoption and implementation of SWC measures at farm-land level. The management of soil nutrients using farm yard manure, crop rotation, weed control, etc. should also be encouraged. Timeliness is a very important factor when important factor when initiating operations of agricultural activities or SWC activities for a direct economic concern to a farmer. However, in addition to combining some of the techniques, planners or conservationists must be fully aware to understand the local land tenure system and then tailor a programmed to fit into that system. Although, indigenous practices may no longer be efficient enough in substantially reducing soil erosion, they are nevertheless, a starting point in which farmers perhaps have more confidence than sophisticated introduced measures. Whatever is proposed, the choice depends on local conditions, but ultimately, farmers choose the measures most appropriate for their situation. Attention should be given to the bio-physical SWC measures. Biological SWC measures have the capacity to make the ecology more stable and economically viable. Moreover, most of the biological conservation practices are linked to the normal agricultural practices and are not too difficult to be learnt by farmers.

The findings of this study revealed that an integrated watershed management approach is by far the most effective way in reducing soil erosion and increasing land productivity. Therefore, integrated watershed management approach initiated by GTZ project shall be further strengthened in the implementation of SWC measures adapted to local socio-economic setup with real participation of all stakeholders. We must face the fact that if agriculture is to flourish, produce enough food and provide employment to rural communities, then it will have to be based on the knowledge and know-how of the communities. The function of the technician is not to cause upheaval but to face the day-to-day realities of farm-life and to help the cultivator to try out new, hopefully progressive ideas by capitalizing his indigenous knowledge and should be planned with him for sustainable farm productivity. Considering alternative measures/technologies such as minimum tillage and putting greater emphasis on biological measures will help in reducing labour requirements without compromising erosion control effectiveness. The fitness of technologies to farmers' requirements and the farming system was one of the barriers for adoption of SWC measures. The lasting solutions to the problem of resource degradation and rural poverty should include easing population pressure on the resources, technological improvements in agriculture and development of other sectors of the economy. Moreover, more research on socio-bio-physical SWC approach is required to get a comprehensive idea on effects of SWC measures on key soil properties, socio-economic development, environmental impacts, cropping and tillage systems, etc. to have a better understanding in an integrated way.

REFERENCES

Abera B (2003). Factors influencing the adoption of soil conservation practices in north-western Ethiopia. M.Sc. Thesis, Institute of Rural development, University of Göttingen, Germany. p.72.

Anonymous (1997). Intermediate evaluation of the GTZ-IFSP supported development activities in South Gonder, presented by technical team, Debre Tabor, Ethiopia. p.9.
Baruah T, Barthakur H (1998). A text book of soil analysis. Vikas publishing House Pvt. Ltd., New Delhi, India. p.334.
Belay T (1992). Erosion: Its effect on properties and productivity of Eutric Nitosols in Gununo area, Southern Ethiopia, and some techniques of its control. African Studies Series A9. Berne, Switzerland. p.9
Bot A, Benites J (2005). The importance of soil organic matter, key to drought resistant soil and sustained food and production. FAO Soils Bulletin 80, Rome, Italy. p.78.
Carucci V (2000). Guidelines on water harvesting and soil conservation for moisture deficit areas in Ethiopia: The productive use of water and soil, Manual for trainers, first Draft, Ministry of Agriculture, Addis Ababa. p.383.
Desta G, Nyssen J, Poesen J, Decker J, Haile M, Govers G, Moeyersons J (2005). Effectiveness of stone bunds in controlling soil erosion on cropland in the Tigray Highlands, Northern Ethiopia. Soil Use Manage. 21: 287-297.
FAO (1993). Guidelines for land use planning. Inter-departmental working group on land use planning. FAO, Rome. p.96.
Farta Wereda Agricultural Office (2006). Report on agricultural activities in the wereda (in Amharic), Planning and training service, Debre Tabor, Ethiopia. p.80.
Gete Z (2000). Landscape dynamics and soil erosion process modeling in the north-western Ethiopian highlands. African Studies Series A16. Berne: Geographica Bernensia.
Hesse P (1998). A text book of soil chemical analysis. Satish Kumar Jain for CBS Publishers and Distributers, Nazia Printers, New Delhi, India. p.520.
Herweg K, Ludi E (1999). The performance of selected soil and water conservation measures – A case studies from Ethiopia and Eritrea. Catena., 36: 99-114.
Holden T, Bekele S (2000). Incentives for sustainable land management in peasant agriculture in the Ethiopian highlands. Science Publishers Inc., Norway. p.78.
Hurni H (1986). Guidelines for Development Agents on Soil Conservation in Ethiopia, Ministry of Agriculture, Addis Ababa, Ethiopia. p.77.
Hurni H (1988). Degradation and conservation of the resources in Ethiopian highlands. Mountain Res. Dev. Stud.. 8(2/3): 123-30.
Hurni H, Tato K (1992). Erosion, Conservation and Small Scale Farming. ISCO/Geographica Bernensia, Berne, Switzerland. p.89.
IPCC (2007): Summary for Policymakers. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, http://www.ipcc.ch/about/about.htm, pp: 7-22.
Lal R, Mokma D, Lowery B (1999). Relation between Soil Quality and Erosion. In: R. Lal (Eds.). Soil Quality and Erosion. Soil and water conservation society of America, Ankeny, pp: 237-258.
Landon R (1984). Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics, Longman Scientific and Technical Publishers, London, p.450.
Million A (2003). Characterization of Indigenous stone bunding (Kab) and its effect on crop yield and soil productivity at Mesobit-Gedba, North Showa zone of Amhara Region. Master of Science thesis, Alemaya University, Ethiopia. pp.45-54.
Norton D, Shiainberg I, Cihacek L, Edwards J (1999). Erosion and soil chemical properties. In R. Lal (eds.) Soil quality and Erosion, Soil and water conservation society of America, Ankey, pp: 39-56.
Olaitan S, Lombin G, Onazi O (1985). Introduction to Tropical Soil Science. 2nd edition, Macmillan Intermediate Agriculture Series. Macmillan Publishers Ltd. Hong Kong. p.126.
Oldeman L, Hakkeling R, Sombroek W (1990). World map of the status of human-induced soil degradation. Wageningen: International Soil Reference and Information Centre (ISRIC).
Pimentel D (1993). Overview. In World soil erosion and conservation, edited by D. Pimentel, 1-5. Cambridge: Cambridge University Press.
Rai M (1998). Principles of Soil Science, 3rd edition, Macmillan India Ltd, New Delhi, India. p.305.
Stocking M, Niamh M (2000). Land degradation Guidelines for Field Assessment. Overseas Development Group, University of East Anglia, Norwich, UK. .p.121.
Teklu J (2005). Land preparation methods and soil quality of a vertisol area in the central highlands of Ethiopia. PhD Thesis, Hohenheimer Bodenkundliche. Heft 76, University of Hohenheim, Stuttgart. p.133.
UNEP (2002). Protecting the Environment from Land Degradation. UNEP`s action in the Framework of the Global Environmental Facility, Nairobi, Kenya.
USAID (2000). Amhara National Regional State Food Security Research Assessment Report. USAID Collaborative Research Support Program Team, Addis Ababa, Ethiopia. p.143.
Vagen T (1996). Phospherous status in soils from terraced and un-terraced land on highly eroded slopes in Tigray, Ethiopia. M.Sc. thesis, Agricultural University of Norway. p.75.
Vancampenhout K (2003). Consequence of stone bund implementation in the Highlands of Northern Ethiopia. M.Sc. thesis, Katholieke University Leuven, Belgium. p.86.
Woldeamlak B (2005). Land degradation and farmers` acceptance and adoption of conservation technologies in the Digil watershed, North-western Highlands of Ethiopia. Trop. Res. Manag. paper. p.50.
World Resource Institute (WRI), United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP) and the World Bank (1996). World Resources.
Yitbarek T (2007). Economic valuation of gully rehabilitation, a case study at Farta wereda, South Gonder. M.Sc. thesis. Addis Ababa University, Ethiopia. p.87.